

INDIAN CARTOGRAPHER

Volume 31, 2011

FOCAL THEME

CARTOGRAPHY for DISASTER MANAGEMENT

XXXI INCA INTERNATIONAL CONFERENCE

15-17 OCTOBER, 2011

Organised by

**DEPARTMENT OF GEOGRAPHY (CAS, UGC)
PANAJB UNIVERSITY, CHANDIGARH**



JOURNAL OF THE INDIAN NATIONAL CARTOGRAPHIC ASSOCIATION

INDIAN CARTOGRAPHER

Vol. 31, 2011

Focal Theme
Cartography for Disaster Management

XXXI INCA International Congress
15-17 October, 2011

Department of Geography (CAS-UGC)
Panjab University, Chandigarh



Journal of the Indian National Cartographic Association

Indian Cartographer

Vol.31, 2011

Published by

Dr. Krishna Mohan
Organizing Secretary,
XXXI INCA International Congress
Department of Geography (CAS-UGC)
Panjab University, Chandigarh-160014

Editor

Professor (Mrs.) Dhian Kaur

Editorial Board

Professor K.D.Sharma
Professor Smita Bhutani
Dr. Karanjot Kaur
Dr. Ravinder Kaur
Dr. Ashu Pasricha

The views expressed by the authors are their own and INCA does not necessarily endorse them in part or whole

Copyright © 2011
Indian National Cartographic Association

ISSN: 0972-8392

Regd. Office: Room No.234, 2nd Floor, APGDC Block
Survey of India, Uppal, Hyderabad-500 039 (A.P)
Voice No.044-27202217 Email:secretarygeneralinca@gmail.com
Website:<http://www.incaindia.org>

CONTENTS

From Editor's Desk.....	xvii
Indian National Cartographic Association (Mapping the Success Story)	xviii
-INCA on Path to Glory.....	xix
-INCA Flag Bearers.....	xx
-INCA Conference Themes.....	xxi

XXXI INCA International Conference, Chandigarh

-National Advisory Committee.....	xxii
-INCA National Executive Council, 2010-2011.....	xxiii
-Local Organizing Committee.....	xxiv
-Local Sub-Committees.....	xxv
-Carrying the Flag to Greater Glory	xxvi
-Themes and Sub-Themes	xxvii
-INCA International Congress, 2011- Lying the Report	xxviii

INAUGURAL SESSION

Presidential Address	2
Inaugural Address	4
Chair's Remarks	9
Prize Winners of INCA Quiz Contest	11
Chairpersons of Sessions	12

MEMORIAL LECTURES

Todal Mal Memorial Lecture	14
<i>David G. Dickason</i>	
Professor S.P. Chatterjee Memorial Lecture	
(Oral Presentation)	
<i>Josef Strobl</i>	

GUEST LECTURES

The 2011 Census of India and GIS Technology	28
<i>Aji Pal Singh</i>	
Mapping the Idea of A Disaster	
(Oral Presentation)	
<i>Anu Kapur</i>	
High Resolution Terrain Mapping of Himalayan Region	32
<i>Ashwagosh Ganju</i>	
Modern Cartography and the Role of the International Cartographic Association (ICA)	41
<i>Georg Gartner</i>	
Generation of Database and Implementation of Web Enabled Water	46
Resources Information System in India	
<i>Jaswant Raj Sharma</i>	
(Only Manuscript received)	
BACK TO HANDSHAKE: A Plea to Restore Harmony between	52
Geography and GIS/Cartography	
<i>Jawahar Lal Jain</i>	

McMahon Line: Its Background and Mismanagement during the 1962 War <i>Kamal Ramprit Dikshit</i> (Only Manuscript received)	59
Geologic Hazards: Earthquakes and Landslides <i>Ravinder Kumar</i>	73
Role of Hydrographic Department in Disaster Management <i>Saroj Kumar Jha</i>	83
Land Use-Land Cover Dynamics in Indian River Basin (Oral Presentation) <i>Shiv Prasad Aggrawal</i>	
Dynamic Cartography for Effective Disaster Management (Oral Presentation) <i>Shahnawaz</i>	
Earth Observations Data and Geomatics Applications for Disaster Management in India <i>Vinay Kumar Dadhwal</i> (Only Manuscript received)	86
Floods Hazard and Control Measures in Hungary <i>Wilhelm Zoltan</i>	96

TECHNICAL SESSIONS

SECTION I: CONCEPTUAL ISSUES IN CARTOGRAPHY

Design of Maps for Disaster Management: Some Conceptual Cartographic Issues <i>Vineeta John</i>	106
Conceptualizing Cartographic Techniques for Disaster Management <i>Baisakhi Sarkar</i>	117
Requirement of Orissa State Spatial Data Infrastructure for Managing Disasters in Orissa <i>P.K. Das</i>	122
Planimetric Accuracy Evaluation of ETM Ortho-Images for Indian Landmass <i>K.S.S. Sekhar, Bankim Shah, B.Kartikeyan</i>	127
Disaster Mapping and Management - A Participatory Approach <i>B.K. Ramaprasad</i>	133
Cartographic Applications and the Disaster Management <i>Dharam Singh</i>	139
Evaluation of Indian National DEM from Cartosat-1 Data <i>S. Muralikrishnan, Abhijit Pillai, B.Narender, V.Raghu Venkataraman, V.K. Dadhwal</i>	144

SECTION II: MAPPING DISASTERS

Sikkim 2011 Earthquake: Lessons to Learn <i>Smita Bhutani, Tarun Vats</i>	150
Flood Proneness and Agriculture Development in Kannur District, Kerala: A Study based on GIS Technology <i>M. Sulfikkar, Nadheer Bin Haneef, O. B. Sukumar and Ahalya Sukumar</i>	157
Forest Fire: A Boon or Bane? <i>Asim Kumar Goswami</i>	160

SECTION III: MAPPING VULNERABILITY

Hazard Mitigation: A Socio-Political Problem <i>Rajbala, Dinkar Srivastava, P. S. Dhote</i>	166
Geomorphic Assessment and Mapping of Gullied Landscapes in the Eastern Margin of Thar Desert using GIS & Remote Sensing <i>P.C. Moharana</i>	176
Degradation of Pasture/Grazing Lands and its Impact on Livelihood of Rural Communities in Rajasthan <i>Balak Ram, J.S. Chauhan</i>	182
Identification of Ground Water Potential Zone in and around Dehra Doon using Index Overlay Method <i>D. K. Mandal</i>	190
Slum Mapping and Remote Sensing and GIS Technology <i>Debjani Mitra, H.R. Betal</i>	197
Assessment of Vulnerability and its Impact on Livelihood Caused due to Shifting Channel of River Ganges in Malda District (West Bengal) using Geo-informatics <i>Chhanda Dey, Jatisankar Bandyopadhyay</i>	201
Mapping of Soil Moisture in Kollam District Using NDVI and Tasseled Cap Analysis <i>P. Deepthi, B. Sukumar, Ahalya Sukumar, S. Sandhya</i>	208
Mapping Vulnerability of Slum Areas in Chandigarh City <i>Ravinder Kaur</i>	213
Mapping of Land Use Changes and Land Degradation in Nagaur District of Arid Rajasthan <i>Balak Ram, J.S. Chauhan</i>	220

SECTION IV: DISASTER MANAGEMENT

GIS Mapping of Urban Growth, Spatial Transformation and Characteristics of Slum Wards in Kolkata: A Comparison between KMC and KUA <i>Anuradha Banerjee, Mala Mukherjee</i>	228
Hazard Mapping and Disaster Management in Andaman & Nicobar Islands <i>S.C. Chaturvedi</i>	235

Land use/cover Changes and its Impact in Kollam District, KERALA: A Study Using GIS and Remote Sensing <i>S. Sandhya, P. Deepthi, B. Sukumar, Ahalya Sukumar</i>	245
Demographic Changes and Agricultural Land use in Kerala <i>N. Saniya, G. S. Lekshmi, V. Dani, E. Saravanan</i>	249
Spatio-Temporal Analysis of Crop Land Use in Palakkad District, Kerala <i>G.S. Lekshmi, N.Saniya, V. Dani V, E. Saravanan</i>	253
Analysis of Agricultural Land use of a Drought Prone Area using Geomatics: A Case Study of Radhapuram Block, Tirunelveli District, Tamil Nadu <i>V. Dani, R.S.Sujarose, N. Saniya, G.S.Lekshmi, E. Saravanan</i>	256
Planning for Residential Land use of Raipur city: A GIS based Analysis <i>Z.T. Khan, S.K. Mustak</i>	261
Management of Groundwater using Geoinformatics with Reference to Dwarkeswar Watershed in Puruliya District <i>Kartic Bera, Jatisankar Bandyopadhyay</i>	265
Land use/cover in Rohtak City: A Comparison between Planned and unplanned Residential Areas using Geoinformatics (A Case Study of Sector 1, HUDA and Ramgopal Colony) <i>Parmod Bhardwaj, Sneh Nehra, Babita Bhardwaj</i>	271
An Integrated Approach to Predict Urban Growth in Hyderabad City using Sleuth Model, Remote Sensing and GIS Techniques <i>S. Indhira Gandhi, V. Madha Suresh, M. Stalin</i>	276
Detection of Land use/cover Changes using Remote Sensing and GIS: A Case Study of Bulandshahr District, Uttar Pradesh <i>Mohd. Shahnawaz Khan, Mohd. Mazhar Ali Khan</i>	284
Drought Insurance as a Disaster Management Strategy in Iran <i>Kiyanoush Ghalavand, Ashu Pasricha</i>	290
The Role of Insurance in Disaster Management <i>Kiyanoush Ghalavand, Ashu Pasricha</i>	299
Landscape Appreciation of Neyyar River Basin, Thiruvananthapuram, Kerala <i>M. Chandrasekar.M, R. Anilkumar</i>	308

SECTION V: GEO-SPATIAL TECHNOLOGIES AND DISASTER MANAGEMENT

Mapping Vulnerability Along Kalka-Shimla Highway Using Fuzzy Logic Technique in GIS Environment <i>Gaurav Sapra, Preetika S. Sapra</i>	313
Landslide Vulnerability Mapping Applying GIS-based Fuzzy Logic Relations: A Case Study of Upper Tons River Valley in Garhwal Himalaya <i>Radha Raman, Milap Punia Ranjeet Kaur</i>	318

Geospatial Technologies for Developing a Rain Water Harvesting Model to Solve Water Problem in Twin Villages of Neb Sarai and Maidan Garhi, NCT of Delhi <i>Satya Raj</i>	327
Development and Conservation of Archaeological Heritage Sites Using Geomatics <i>Raj Gaurav, D. Gowtham Sai</i>	333
High Resolution X-band SAR Data for Snow Studies in Manali Area of Western Himalayas <i>Praveen K Thakur, S.P. Aggarwal, Snehmani, P. K. Garg, R. D. Garg</i>	338
Glacier Monitoring and Debris Cover Mapping using Remote Sensing and GIS Techniques with Reference to Gangotri Glacier <i>Snehmani, Satwant Kaur, A. Ganju1, M.R. Bhutiyani1, A.K. Nigam</i>	346
Modelling Glacier Sensitivity of Gangotri Glacier, Indian Himalayas <i>Snehmani, Mahima Chatranta, A. Ganju1, M.R. Bhutiyani, A.K. Nigam</i>	351
Estimation of Snow Depth in NW Himalayas Using Field Observations and Digital Elevation Model <i>H S Jassar, Snehmani, Balwan Singh, S. K. Dewali, and A. Ganju</i>	356
Application of Open Source GIS in Coastal Disaster Management: A Case Study of Porbandar District, Gujarat <i>Manjush Koshy, Siddharth Vora, Nitish Thakkar, P.M. Sreekant, J. Shaji</i>	367
A GIS-based Avalanche Hazard Mapping for Manali Region, Himachal Pradesh <i>Snehmani, Satish Kumar, A. Ganju, M. R. Bhutiyani</i>	375
Landscape Visualisation for Participatory Approach to Village Master Plans: A Case Study of Alsisar Village in Rajasthan <i>Milap Punia, Arnab Kundu</i>	383
Mapping of Debris-Covered Gangotri Glaciers in the Garhwal Himalayas using Remote Sensing <i>Rakesh Bhambri, Ravinder Kumar, S.K.Kulshrestha</i>	390

SECTION VI: MISCELLANEOUS PAPERS

Population Regions in Chhattisgarh <i>Anusuiya Baghal</i>	402
Impact of Shoreline Shifting on Socio-Economic Environment <i>Jatisankar Bandhopadhyay</i>	413
Mapping of Recreational Spaces in a Planned City of Chandigarh using Remote Sensing and GIS Techniques <i>Sanjeev Goel and Preeti Chauhan</i>	417

**31st INCA CONGRESS
(Moments Memorable)**

Honouring the Chief Guest & Vice Chancellor, Panjab University



**Shri Anil K. Sinha, I.A.S, Chief Guest &
Professor Surya Kant, President, INCA XXXI**



**Professor R.C. Sobti, Vice Chancellor, Panjab University
being honoured by Shri A. Ganju, Director, SASE & Co-Chairman LOC XXXI INCA**

Inaugural Session



Inaugural Session



Professor Surya Kant, President, INCA XXXI delivering Presidential Address



Shri Anil K. Sinha, Chief Guest delivering Inaugural Address



**Professor R. C. Sobti, Vice Chancellor, Panjab University
Sharing his Concluding Observations**

Chief Guest Releasing the Souvenir & NATMO Publications



Guest Speakers



Guest Speakers



Dr. A.P. Singh



Dr. S.P. Aggarwal



Dr. Shahnawaz



Professor Ravinder Kumar



Professor J. L. Jain



Dr. Anu Kapur

Honouring the Guest Speakers



Chairpersons of Technical Sessions



Speakers in Technical Sessions



Dr. S. C. Chaturvedi



Professor Smita Bhutani



Dr. Anuradha Banerjee



Dr. S. Muralikrishnan



Dr. P. C. Moharana



Dr. Ahilya Sukumar



Dr. Jayshree



Shri Snehmani

Speakers in Technical Sessions



Professor Dhian Kaur



Shri Gursewak Singh Brar



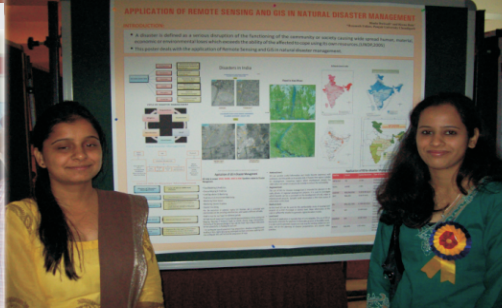
Dr. Vishwa B. Chandel



Poster Session



Poster Session



Reena Bala & Bindu Dwivedi



Dr. Baisakhi Sarkar



Dr. Anuradha Banerjee & Dr. S. Muralikrishnan

Technical Sessions in Progress



Valedictory Function (Shri B.K. Srivastava, I.A.S., Director General delivered the Valedictory Address)



Conference Exhibition



Shri Anil K. Sinha, I.A.S. Opening the Exhibition



Cultural Evening



Post - Valedictory Bonhomie



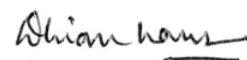
From Editor's Desk

It is a matter of great pride and privilege for me to have been the Editor of 31st issue of the INDIAN CARTOGRAPHER. The volume includes the selected 58 papers which were presented in various technical sessions of the annual INCA Congress held from 15th – 17th October, 2011 at Chandigarh. The Congress with focal theme 'Cartography for Disaster Management' was organized by the Department of Geography, Panjab University, Chandigarh under the auspices of the Indian National Cartographic Association (INCA). It was inaugurated by a very able and experienced administrator, Sh. A.K. Sinha, IAS (Retd), Vice-Chairman, Bihar State Disaster Management Authority, Patna. For the benefit of those who could not attend the inaugural session, the volume includes full text of his inaugural address. In addition, the text of memorial lectures delivered by very eminent geographers has also been incorporated. These scholarly contributions are deeply acknowledged.

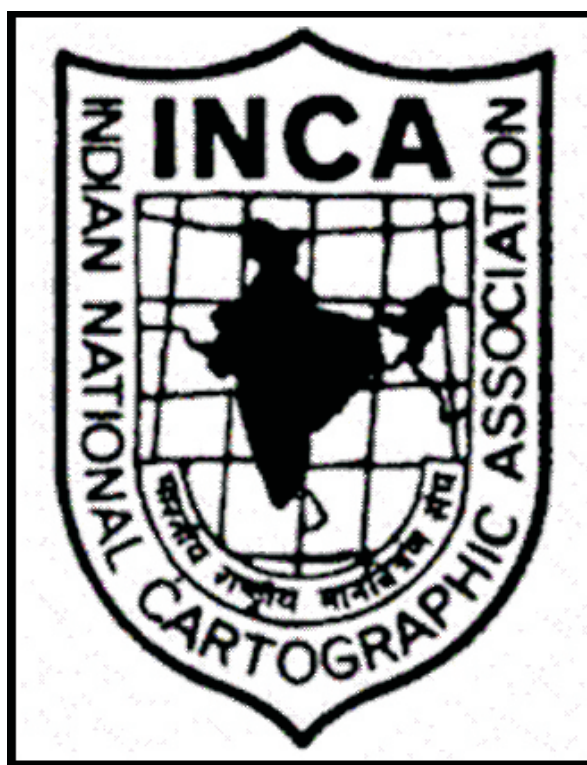
Reviewing and editing the technical papers of experts has been an uphill task but a very rewarding personal experience. Though I enjoyed reading each paper but in a few cases I had to be harsh by either rejecting them or by deleting the diagrams which could not be reproduced due to their poor quality. My discussions with colleagues especially Professor Surya Kant (President, INCA) helped me to come out of such situations. I deeply admire his efforts of reaching back to the contributors for revisions and corrections. This volume could not have been published without his support as well as the help extended by distinguished members of the Editorial Board. I am confident that the ideas expressed by experts in their papers have reinforced the importance of cartography in problem solving and would be used as good reference material not only by geographers and cartographers but also by policy makers in applying cartography in managing disasters of different types.

I would like to thank members of the INCA Executive and the Local Organizing Committee of the 31st INCA Congress for providing me the opportunity of editing the technical contributions made by the authors.

Department of Geography,
Panjab University,
Chandigarh.
July, 2012

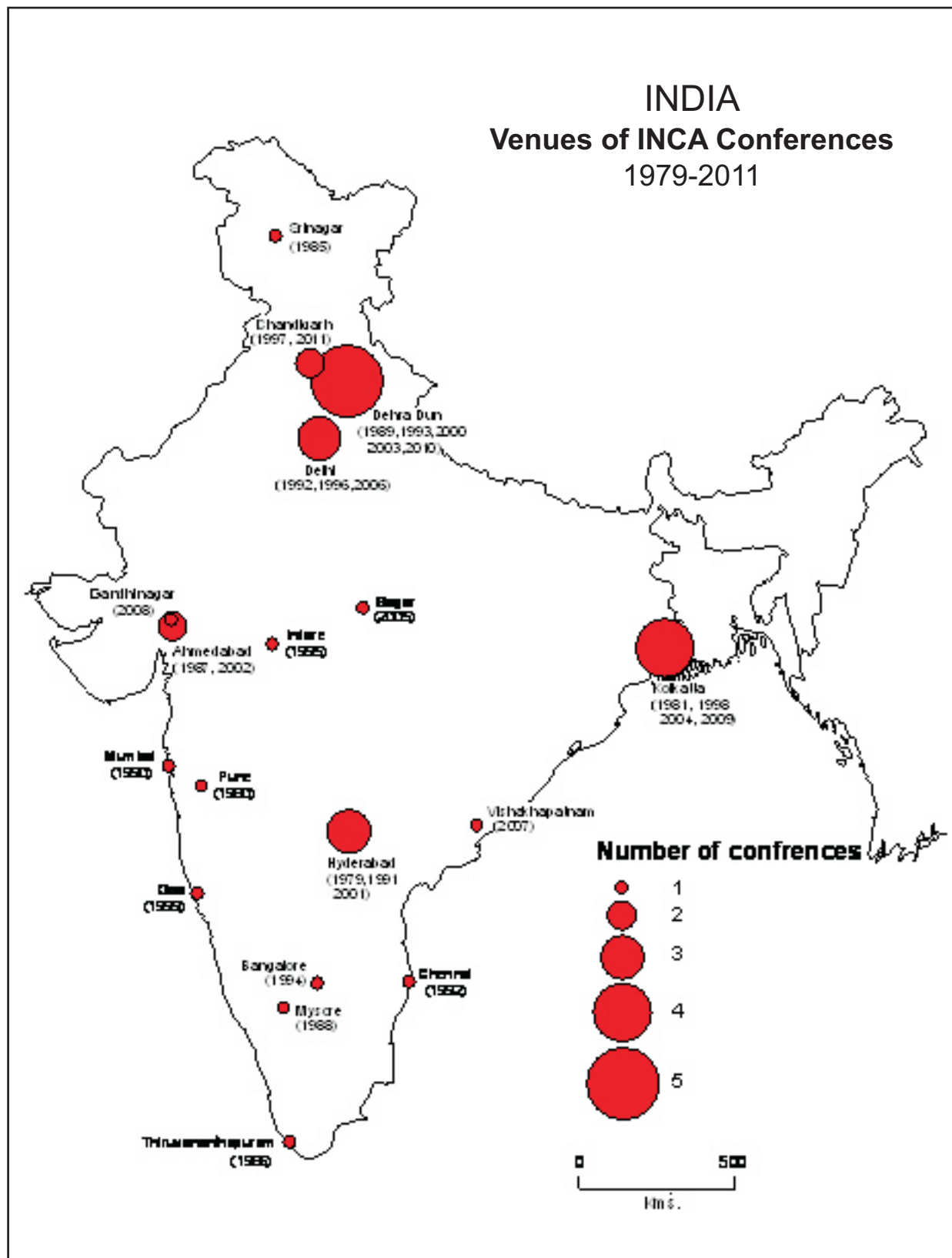

DHIAN KAUR
Editor, INCA

INDIAN NATIONAL CARTOGRAPHIC ASSOCIATION



MAPPING THE SUCCESS STORY

INCA ON PATH TO GLORY 1978 - 2011



INCA FLAG BEARERS 1978-2011

Sl. No.	President	Year	Place
01	Major Gen. K.L. Khosla	1979	Hyderabad
02	Major Gen. K.L. Khosla	1980	Pune
03	Professor S. Manzoor Alam	1981	Calcutta
04	Professor S.P. Dasgupta	1982	Madras
05	xxx	1983	xxx
06	xxx	1984	xxx
07	Brig. M.M. Datta	1985	Srinagar
08	Professor A. Ramesh	1986	Trivandrum
09	Lt. Col. (Dr.) L.R.A. Narayana	1987	Ahmedabad
10	Professor P.D. Mahadev	1988	Mysore
11	Major Gen. S.M. Chadha	1989	Dehra Dun
12	Professor B. Arunachalam	1990	Bombay
13	Professor B.L. Deekshatulu	1991	Hyderabad
14	Professor Majid Husain	1992	New Delhi
15	Major Gen. D.P. Gupta	1993	Dehra Dun
16	Sh. A.K.S. Gopalan	1994	Bangalore
17	Sh. B.M.L. Sharma	1995	Indore
18	Lt. Gen. S.P. Mehta	1996	New Delhi
19	Professor Gopal Krishan	1997	Chandigarh
20	Dr. P. Nag	1998	Calcutta
21	Rear Admiral K.R. Srinivasan	1999	Goa
22	Lt. Gen. A.K. Ahuja	2000	Dehra Dun
23	Professor Afzal Mohammad	2001	Hyderabad
24	Sh. A.R. Dasgupta	2002	Ahmedabad
25	Maj Gen (Dr) B.C.Roy	2003	Dehradun
26	Sh G.N.Saha	2004	Kolkata
27	Professor J.L. Jain	2005	Sagar
28	Maj. Gen. Gopal Rao	2006	New Delhi
29	Rear Admiral B.R. Rao	2007	Visakhapatnam
30	Dr P. K. Srivastava	2008	Gandhinagar
31	Shri. A.K. Malik	2009	Kolkata
32	Major Gen. Manoj Tayal	2010	Dehradun
33	Professor Surya Kant	2011	Chandigarh

INCA CONFERENCE THEMES 1978-2011

Name of Congress with Theme		Year	Venue
01	New Trends in Cartography	1979	Hyderabad
02	Maps as Tools of Analysis & Communication	1980	Pune
03	Thematic Mapping and Surveying	1981	Calcutta
04	Map Makers & Users	1982	Madras
05	xxx	1983	xxx
06	xxx	1984	xxx
07	Cartography in National Planning	1985	Srinagar
08	Cartography in Environmental Planning	1986	Trivandrum
09	Satellite Images in Cartographic Applications	1987	Ahmedabad
10	Cartography and Planning	1988	Mysore
11	Digital Cartography and Potential Users	1989	Dehra Dun
12	Advances in Cartography	1990	Bombay
13	Cartography&Geo-Information System for Planning	1991	Hyderabad
14	Mapping of Environment&Sustainable Development	1992	New Delhi
15	Cartography-The Technological Transition	1993	Dehra Dun
16	Mapping from Space- Cartographic Challenges	1994	Bangalore
17	Cartography- Emerging Technologies and Alliances	1995	Indore
18	Carto-Vision 2001- Earth Resources Management	1996	New Delhi
19	Cartography and Administration	1997	Chandigarh
20	Cartography in Action	1998	Calcutta
21	Modern Cartography for Ocean and Land Management	1999	Goa
22	Cartographic Challenges at the Dawn of New Millennium	2000	Dehra Dun
23	Cartography & E-Governance	2001	Hyderabad
24	Convergence of Imagery, Information and Maps	2002	Ahmedabad
25	Cartography for Sustainable Development	2003	Dehradun
26	Cartographic Technologies for Water, Land & Infrastructure Development	2004	Kolkata
27	Bridging the Digital Divide, and Taking Cartography to Grassroots Level	2005	Sagar
28	Cartography Expanding Horizons	2006	New Delhi
27	Cartography for Costal Management	2007	Visakhapatnam
29	Collaborative Mapping and Space Technology	2008	Gandhinagar
30	Technological Solutions in Urban & Regional Mapping	2009	Kolkata
31	Cartography for Sustainable Environment	2010	Dehradun
33	Cartography for Disaster Management	2011	Chandigarh

XXXI INCA Conference, Chandigarh

NATIONAL ADVISORY COMMITTEE

Shri P.K.Bansal

Cabinet Minister, MoS&T

Shri A.E.Ahmad

Secretary, BM, MoHA

Shri Navin Kumar

Secretary, MoUD

Prof. Ved Prakesh

Chairman, UGC

Dr. K.Radhakrishnan

Chairman, ISRO

Dr. P. Nag

Director, NATMO

Dr. P.S. Roy

Dean, IIRS, Dehradun

Shri K.K. Singh

CMD, Rolta Group

Dr. M. P. Narayanan

President, CSDMS

Prof. Manjoor Alam

Ex-President, INCA

Brig. M.M. Datta

Ex-President, INCA

Dr.L.R.A. Narayanan

Ex-President, INCA

Maj Gen S.M. Chadha

Ex-President, INCA

Prof. B. Arunachalam

Ex-President, INCA

Prof.B.L. Deekshatulu

Ex-President, INCA

Prof. Majid Hussain

Ex-President, INCA

Shri B.M.L. Sharma

Ex-President, INCA

Lt. Gen S.P. Mehta

Ex-President, INCA

Shri A.K. Malik

Ex-President, INCA

Prof. Jaymala Diddee

President, IIG

Shri M.Shashidhar Reddy

Vice-Chairman, NDMA

Dr. Shailesh Nayak

Secretary, MoES

Shri B.K.Sinha

Secretary, MoRD

Prof. G.K. Chadha

President, S.A. University

Shri Swarna S. Rao

Surveyor General

Maj. Gen.(Dr) R.Sivakumar

CEO, NSDI & Head, NRDMs

Shri Sanjoy Kumar

CEO, GIS Development

Shri Rajiv Kapoor

CEO, RMSI

Shri G.N. Saha

Ex-President, INCA

Prof. J.L. Jain

Ex-President, INCA

Maj Gen M Gopal Rao

Ex-President, INCA

Prof. Gopal Krishan

Ex-President, INCA

Rear Admiral K.R. Srinivasan

Ex-President, INCA

Lt. Gen A.K. Ahuja

Ex-President, INCA

Shri A.R. Dasgupta

Ex-President, INCA

Maj Gen (Dr.) B.C. Roy

Ex-President, INCA

Vice Admiral B.R. Rao

Ex-President, INCA

Dr. P.K. Srivastava

Ex-President, INCA

Maj Gen Manoj Tayal

Ex-President, INCA

Prof. Nina Singh

M.D.U. Rohtak

Shri Brijender Ola

Minister, DM (Raj. Govt.)

Dr. T. Ramasami

Secretary, DST

Shri R.K.Khwaja

Special Secy. MoEF

Shri P.G.DharChakarvarty

Exe. Director, NIDM

Dr.S.C. Dhiman

Member Secy., CGWA

Dr. V.S. Hegde

Director (EOS), ISRO.

Shri Rajesh Mathur

President, ESRI

Dr. J. R. Sharma

Director, RRSSC, Jodhpur

Dr. A.P.Singh

D R G(Map),R.G. Office

Dr. R.R.Navalgund

President, ISRS

Prof. M.H.Qureshi

Ex-President, NAGI

Dr. Jagtar Singh

Commissioner, IT

Prof. M.S. Nathawat

Head, RSD, BIT, Ranchi

Admiral S.K. Jha

Senior Vice President, INCA

Dr. V. K.Dadwal

Vice-President , INCA

Shri R.N.Nanda

Secretary General, INCA

Dr. S.C.Kulshrestha

Chairman,Shriram College Group

Dr. S.N. Chauhan

Ex. Dir, SDCET

Prof. Surya Kant

President, INCA

Dr. Anu Kapur

Professor, DSE, D.U.

INCA NATIONAL EXECUTIVE COUNCIL 2010-11

President

Professor Surya Kant

Co-President

Surveyor General of India

Past Presidents

Dr. P.K. Srivastava

Shri A.K. Malik

Major Gen. Manoj Tayal

Senior Vice President

Rear Admiral S.K.Jha

Vice President

Dr. Vinay K. Dadhwal

Shri S. Subha Rao

Secretary General

Shri R. N. Nanda

Past Secretary General

Shri K.C.Rout

Secretary

Dr. S. Muralikrishnan

Shri Rajesh Kumar

Treasurer

Shri G. Devender Rao

Editor

Shri Mahipal Singh

MEMBERS

Dr. A. K. Goswami

Dr. A.K. Sarkar

Dr. Anuradha Banerjee

Prof. A. Kamalkar Reddy

Maj. Gen. Ashok Kumar Sinha

Dr. Balak Ram

Shri B. Gopal Krishna

Maj. Gen. (Dr.) B. Nagarajan

Shri B. Niranjana

Shri G.Prasanth Nair

Dr. Jayashree

Dr. J. A. Siddiqui

Dr. Krishna Mohan

Maj. Gen. K.S. Kali Prasad

Prof. O.P. Sarna

Cdr. Prashant Srivastava

Smt. Premlata Singhi

Shri P.V.Srinivas

Dr. Rajendra K.Rawat

Maj. Gen. S.Chodhury

Shri S.S. Chauhan

Shri Shyam. V. Singh

Dr. T.Neelakantan

Shri T.Sanjeev Kumar

Cdr. Vinay Badhwar

Shri K.K.Dash Sarkar

LOCAL ORGANIZING COMMITTEE

Patron

Professor R. C. Sobti
Vice-Chancellor
Panjab University, Chandigarh

Co-Patron

Professor Emeritus G.S. Gosal
Department of Geography
Panjab University, Chandigarh

Chairman

Professor Emeritus Gopal Krishan, Geography Department, Panjab University

Co-Chairman

Shri A. Ganju, Snow & Avalanche Study Establishment (SASE), Chandigarh

Organising Secretary

Dr. Krishna Mohan, Geography Department, Panjab University

Co-Organizing Secretaries

Professor Smita Bhutani, Geography Department
Er. Snehmani, SASE

Treasurer

Professor J.N.Sharma, Gandhian Studies, Panjab University

Secy. Tech. Committee I (Technical Sessions)

Professor Swarnjit Metha, Geography Department, Panjab University

Members: Professor Dhina Kaur, Dr. Ravinder Kaur, Dr. Ashu Pasricha

Secy. Tech. Committee II (Technical aids and Transport)

Additional Surveyor General, NW Zone, Chandigarh

Editor: Professor Dhian Kaur, Geography Department, Panjab University

Professor K.D. Sharma
Dr. Karanjot Kaur Brar
Dr. Gaurav Kalotra
Dr. Naveet Kaur
Er.Gaurav Sapra, UIET

Shri O.P. Sarna
Shri Mehar Singh
Shri Mohan Singh
Shri Vishva B. Singh
Shri Jimmi Kansal, SASE

LOCAL ADVISORY COMMITTEE

Prof. B.S. Brar, DUI
Prof. B.S. Ghuman, Dean, Arts Faculty
Shri G.K.Chatrath, Senator, P.U.
Prof. R.C. Chandna, Geography
Shri Madhva Shyam, Punjab Census
Dr. Sodhi Ram, CEO, MMU, Mulana
Shri J.K. Gupta, Dir. Bhaddal Arch. College

Prof. A.K.Bhandari, Registrar & CEO
Prof. Shashi K. Sharma, Dean, Research
Dr. Anmol R. Sidhu, Addl. Advocate Gen.
Prof. Karan Vashisht, Chairman, UIPS
Dr. T.V.Singh, Chemistry
Dr. Asok Kaushal, SDD, Rolta
Shri Jarnail Singh, G.M. PR

LOCAL SUB-COMMITTEES

Souvenir Committee

1. Dr. Krishna Mohan (Chairman)
2. Dr. Ravinder Kaur (Convener)

Members

3. Prof. Neelam Grover
4. Dr. Pawan Kumar Sharma
5. Dr. Navneet Kaur
6. Dr. Gaurav

Reception Committee

1. Shri O.P. Sarna (Chairman)
2. Prof. Smita Bhutani (Convener)

Members

3. Shri Mehar singh
4. Er. Snehmani
5. Shri Jummi Kansal
6. Shri R.A. Nirvikar
7. Prof. Neelam Grover

Stage Committee

1. Prof. Nina Singh (Chairman)
2. Dr. Ravinder Kaur (Convener)

Members

3. Ms. Esha
4. Ms. Ketaki Rana

Publication of INCA Journal

1. Prof. Dhian Kaur (Editor)

Members Editorial Board

2. Prof K.D. Sharma
3. Prof Smita Bhutani
4. Dr. Ravinder Kaur
5. Dr. Karanjot Kaur

Transport Committee

1. Sh. R.A. Nirvikar (Secretary)
2. Er. Pankaj Misra, SOI (Coordinator)

Members

3. Shri Sandeep, (Geog. deptt.)
4. Shri Chandram, (Geog. deptt.)
5. Shri Jimmi Kansal (SASE)
6. Col. Rajal Kshetrapal (Geog. deptt.)

Accommodation Committee

1. Shri Harban Singh (Chairman)
2. Dr. Ripudaman Singh
3. Shri Jagannath Dhiman
4. Dr. Sanjeev Goel
5. Inderjeet Singh
6. Shri Utpal Kumar
7. Ms. Ketaki Rana
8. Shri Pawan Kumar Dhaka
9. Shri Vishal Singh

Press/Media Committee

1. Dr. Krishna Mohan (Chairman)
2. Dr. Karanjot Kaur (Convener)
3. Dr. Ashu Pasricha
4. Dr. Gaurav kalotra
5. Dr. Ripudaman Singh
6. Shri Sunil Jangra

Technical Session Committee

1. Prof. Swarnjit Kaur (Chairman)
2. Prof. Nina Singh (Convener)
3. Prof. Dhian Kaur
4. Dr. Ravinder Kaur
5. Dr. Ashu Pasricha
6. Dr. Snehmani
7. Dr. Navneet Kaur
8. Dr. Gaurav
7. Sh. Mohan Singh
8. Dr. Vishwabandhu Singh
9. Dr. Pawan Kumar Sharma
10. Shri Chandram
11. Shri Sandeep
12. Shri Pawan Kumar Dhaka

Certificate Committee

1. Shri Mohan Singh (Chairman)
2. Dr. Sanjeev Goel (Convener)
3. Ms. Reena Bala
4. Ms. Ketaki Rana
5. Ms. Anuradha Sharma

Registration Committee

1. Prof. K.D. Sharma (Chairman)
2. Prof. Dhian Kaur (Convener)
3. Dr. Sanjeev Goel
4. Ms. Preeti Chauhan
5. Dr. Vishwabandhu chandel
6. Ms. Ketaki Rana
7. Ms. Anandvir Kaur
8. Ms. Reena Bala
9. Ms. Pradita Gupta

Banner Committee

1. Dr. Krishna Mohan (Convener)
2. Dr. Ravinder Kaur
3. Shri Sunil Kumar Jangra

Cultural Committee

1. Dr. Ravinder Kaur (Convener)
2. Ketaki Rana

Refreshment Committee

1. Shri O.P. Sarna (Convener)
2. Shri Mehar Singh
3. Dr. Pawan Kumar Sharma

XXXI INCA INTERNATIONAL CONFERENCE
Carrying the Flag to Greater Glory



CHANDIGARH
15-17 OCTOBER, 2011

THEME AND SUB-THEMES 2011

CARTOGRAPHY FOR DISASTER MANAGEMENT

The Sub-themes:

I. Conceptualizing Cartography for Disaster Management

- Cartographic techniques and disaster management
- Sources of data for disaster mapping and management
- Data mapping and modeling techniques for disaster management

II. Mapping Disasters

- Earthquakes and volcanic eruptions
- Landslides and avalanches
- Tsunami, floods, cyclones and droughts
- Air, rail, road traffic accidents
- Mining blasts, oil spilling and fire accidents
- Nuclear and chemical explosions, wars and internal conflicts
- Forest fires

III. Mapping Vulnerability

- Physical hazard zonation and mapping
- Ground water zonation and mapping
- Haphazard urban growth, poverty and slums
- Land degradation
- Human settlements: congestion, densification and high-rise buildings
- Coastal zone mapping
- Mountain/hills mapping

IV. Disaster Management

- Infrastructure planning and management
- Agricultural land use planning
- Drought mitigation and flood management
- Urban land management and planning
- Public policies for disaster management

V. Climate Change and Biodiversity

- Mapping climate change at global, national and local levels
- Mapping change in rainfall regime at global, national and local levels
- Modelling climate change at different spatial scales
- Biodiversity mapping

VI. Geo-Spatial Technologies and Disaster Management

- Mapping hazardous slope processes using digital data
- Snow cover monitoring using remotely sensed data and GIS technology
- Flood monitoring and management using digital data and GIS modelling

XXXI INCA INTERNATIONAL CONGRESS: 2011

LAYING THE REPORT

Indian National Cartographic Association (INCA), a professional body of Cartographers in India with headquarters at Hyderabad, held its **XXXI Annual Congress** at the Department of Geography, Panjab University, Chandigarh from 15-17 October 2011. **Cartography for Disaster Management** was the theme of the International Conference organized to mark the occasion. The main theme was further divided into six sub-themes: *Conceptualizing Cartography for Disaster Management, Mapping Disasters, Mapping Vulnerability, Disaster Management, Climate Change and Biodiversity, and Geo-spatial Technologies and Disaster Management*. By the gracious presence of the four hundred fifty delegates and participants from India and abroad, attending the Congress, the Venue, Hotel Parkview, Sector 24, Chandigarh presented a festive scene.

Sixteen states and the three union territories from India and the three foreign countries were represented in this three day Conference. Delegates from the far flung areas such as Andaman & Nicobar Islands attended the conference. The representation of the government organizations, such as Survey of India, National Hydrographic Office, Indian Space Research Organization, and National Atlas & Thematic Mapping Organization was impressively large. In addition, faculty members, research fellows and students from universities and colleges participated in a big way with great enthusiasm. Presence of Surveyor General of India, Chief Hydrographer of India, Director, National Atlas & Thematic Organization, Director, Snow & Avalanche Study Establishment, and Director, National Data Centre, NRSC added flavor to Conference and generated enthusiasm among the young and budding officers and scholars present in the Conference Hall. International Cartographic Association (ICA), headquartered at, was represented by its President, Professor Georg Gartner of Vienna Technical University, Austria, Centre for Geo-Informatics, University of Salzburg, Austria by its Director, Professor Josef Strobl, UNIGIS International by its Director for South and South East Asia, Dr. Shahnawaz, and University of Western Michigan, USA by Professor David G. Dickason and the Centre for Asia Study, University of Pecs, Hungary by Professor Wilhelm Zoltan.

XXXXXXXXXXXX

On October 15, inaugural function started at 9.30 a.m. with lighting of lamp by the dignitaries on the dais and recital of *saraswati vandana*. Professor A. Ganju, Co-Chairman, LOC, and Director SASE, welcomed the dignitaries, guests and the delegates and Shri R.N. Nanda, Secretary General, INCA and Superintendent Surveyor, SOI, Hyderabad presented the annual Report on INCA activities.

Inaugural address delivered by Shri Anil Kumar Sihna, formerly Secretary Agriculture, Govt. of India and the current Vice-Chairman, Bihar State Disaster management Authority stressed on the importance of disaster risk reduction strategy to minimize the loss to life and property due to disasters and highlighted the role and importance of modern cartography in mapping and management of disasters. Citing examples from the recent happenings in Haiti and Sikkim, he expressed concern over natural hazards getting converted into (un) natural disasters to cause unprecedented loss of life and property. He emphasized on building a culture of prevention to minimize the loss to life and property and prevent economic growth to slow down. He recalled that an earthquake measuring 8.8 on Richter scale hit Chile in March 2010 and Haiti by a 7.0 temblor in the same year, and stated that in case of former country the loss of life were just 600 persons, against more than 250 thousand, in case of the

latter. Development of a seismic design code for all the new buildings and its strict implementation by Chilean government made the difference. To him, Japan is perhaps the best example of disaster risk reduction (DRR) in the world and we in India must learn from the experiences of this country. Detailing on the recent developments in India in field of disaster management, he found DM Act 2005 as a landmark policy document and hoped that disaster preparedness and planning will now take a quantum jump in the direction of comprehensive and holistic planning with the help of modern technologies, techniques and tools. Highlighting the role modern Cartography equipped with GIS, RS and GPS technologies) can play in disaster management he stated that accurate digital maps produced by the Cartographers will act as the multipurpose and multi-dimensional tools, displaying many layers of information. The maps facilitate in promoting cooperation between national and local authorities 'in mitigating the impacts of disasters by providing varied, classified and accurate data for use and application. Use of geographical database, topographic and thematic maps and statistical data are the key to the success in disaster preparedness and mitigation'.

Inaugural address was followed by the presidential address, delivered by the INCA President, Professor Surya Kant. He shared with the august audience that as a President of this august body his three main dreams were to project the INCA as the promoter of India's development process, bring the relevance of Cartography in focus, and highlight the role that Geography can play in realizing the first two dreams. He stated that the main theme and sub-themes of the present conference were also selected and fabricated toward this end, and hoped that the deliberations at this conference will help him to realize his shared dreams. Acknowledging the recent shift in government policy from 'relief centric' to 'management based' approach to disasters, changing the focus to prevention and preparedness in place of cure and wait policy, he expressed satisfaction on the significant contributions made by the various wings of the INCA, such as SOI, ISRO, NHO, NATMO and the Geography departments in the last some years through application of cartography, space technology and GIS mapping. He added that, however, there are miles to go for cartography to resolve a variety of conceptual and methodological issues pertinent to disaster management. Also, he raised the pertinent issues like identification of most effective cartographic techniques to represent the various parameters of natural hazards, human induced disasters, and management strategies, major sources of data for this purpose, and contents of a pro-poor cartography needing urgent and immediate attention of the cartographic community in India.

Professor R.C. Sobti, Vice-Chancellor, Panjab University and the Patron of the XXXI INCA Congress, who was gracious in accepting the organizers' request to chair the inaugural session, shared his thoughts and raised several important issues for consideration of the scientists, scholars and experts, who have come from various parts of the country and abroad for the Conference. As a scholar of bio-technology, he emphasized on the role which bio-technology can play in seeking solution to several problems currently faced by humanity, including the disasters. He thanked the National Executive Council members of the INCA for deciding to hold INCA Annual Congress second time at Panjab University, Chandigarh and wished a grand success to the conference. He expressed confidence that the deliberations and discussions in the three day conference will be fruitful and useful for planners and policy-makers in the country.

Then the Chief Guest released the **Souvenir** and the **Abstract of Papers** brought out by the organizers on this occasion. On the occasion, the Chief Guest also released several other publications and the maps relating to Punjab State, prepared by National Atlas and Thematic Mapping Organization, Kolkata. Shri A.K. Malik, Additional Director, NATMO was also present on the dais.

For several years, the INCA has been organizing national level map quiz, INCA National Map Quiz Contest, to generate interest of young minds in reading and making maps. Students at the school level participate in this. The Eicher India, Gurgaon (Haryana) has been quite generous to sponsor the running trophy for the first three winners at the national level. The awards are given every year by the Chief Guest to the winners in the inaugural ceremony of INCA Congresses. This year Rashtriya Indian Military College, Dehradun, Oak Grove School Jharipani, Mussorie Hills, Dehradun and St. Kabir Public School, Chandigarh, the first, second and third winners were presented trophies by the Chief Guest, Shri Anil Kumar Sinha.

The inaugural session ended with a vote of thanks presented by Professor Krishna Mohan, Organizing Secretary of XXXI INCA Congress and the Chairperson, Department of Geography, Panjab University, Chandigarh. While proposing vote of thanks to dignitaries, guests, and delegates, he expressed special thanks for organizations and individuals those providing sponsorships and financial support by way of advertisement in the Souvenir and putting stalls in the exhibition.

This was followed by opening of the Exhibition, organized at the occasion, by the Chief Guest, Shri Anil Kumar Sinha. National Remote Sensing Centre, Hyderabad, National Atlas and Thematic Mapping Organization, Kolkata, National Water Ways Authority of India, New Delhi, NIIT, New Delhi, and Neotal Technologies, Chandigarh put their stalls on the Exhibition Ground. The state of art technology in field of remote sensing, GIS, and GPS was displayed by the exhibitors. In addition, NATMO displayed latest district level resource planning and city maps by the organization.

After the tea break, the two Memorial Plenary Lectures, which INCA organizes every year in memory of legendary Raja Todar Mal, the revenue minister of Emperor Akbar in sixteenth century, and Professor S.P. Chatterji, doyen of Indian Geography and former Director of NATMO, Kolkata were delivered. This year, Todal Mal lecture was delivered by Professor David G. Dickason, Western Michigan University, Michigan (USA) and Professor S.P.Chatterji lecture by Professor Josef Strobl, Centre for Geo-Informatics, University of Salzburg, Austria. These were chaired by Professor G.S.Gosal, Professor Emeritus, Geography Department, and Professor B.S.Brar, Dean University Instruction, Panjab University, Chandigarh, respectively. Speaking on 'The Future of Historical Cartography', Professor Dickason expressed that much of historical cartography will be increasingly affected by digitization. No doubt, he added further, many of the uses for historic maps will continue, however, the ways we analyze historic maps will be almost entirely mediated by geospatial technology. This is going to happen in India as well. Hence, professional bodies like INCA and NAGI should lead the way to make a future for India, consistent with Raja Todar Mal's vision centuries ago.

For the S.P.Chatterji memorial lecture Professor Josef strobl chose to speak on 'Map Interfaces for Disaster Management'. In a forceful presentation he discussed various dimensions of this interface and raised a number of questions.

X X X X X X X X X X X

Special Lectures

The organizers had requested a number of eminent scholars and experts in the field to deliver special lectures. As many as thirteen scholars were kind enough in acceding to our request. However, for reason of pressing problems or engagements some scholars could not make to the Congress. In all **nine special lectures** were delivered, five in the post-lunch session of the first day, one on the second day and remaining two on of the third and the final day.

The scholars, who could not make to the Conference to deliver the invited talks, included Dr.

V.K.Dadhwal, Director, NRSC, Hyderabad, Maj. Gen. Dr. R. Siva Kumar, CEO, NSDI and Head, NRDMS, DST, New Delhi, Professor K.R.Dikshit, Formerly Professor and Head, Department of Geography, University of Poona, Pune, Dr. P.S.Roy, Director, IIRS, Dehradun, Dr. J.R.Sharma, Director, RRSSC, Jodhpur. However, Dr.P.S.Roy was kind enough to depute Dr. S.P.Aggrawal, Head Water Resources Division, IIRS, as his replacement and Professor K.R.Dikshit and Dr. J.R. Sharma send the manuscripts of their presentations, on our request, for publication in INCA journal, INDIAN CARTOGRAPHER, as the Conference Proceeding. In the paper by Professor K.R. Dikshit in-depth analysis and detailed mapping of McMahon Line drawn between India and China during the British period in Indian Subcontinent has been made. Dr. J.R. Sharma discussed in details the recently developed and launched Water Resources Information System by the ISRO, Bangalore.

Those attending the conference and delivering the invited talks included Professor Georg Gartner, President, International Cartographic Association (ICA) and Professor at University of Technology, Vienna (Austria), Professor Zoltan Wilhelm, Associate Director, School of Geography, University of Pecs, Hungary, Dr. Shahnawaz, UNIGIS Director for South and South East Asia, University of Salzburg, Austria, Professor Ravinder Kumar, Formerly Professor and Head, Department of Geology, Panjab University, Chandigarh, Dr. Anu Kapur, Chairperson Department of Geography, Delhi School of Economics, University of Delhi, Delhi, Dr. S.P.Aggrawal, Head Water Resources Division, Indian Institute of Remote Sensing, Dehradun, Admiral S.K.Jha, Chief Hydrographer, NHO,Dehradun, Dr. A.P.Singh, Dy. Registrar General and Map Officer, Census of India, New Delhi, and Professor A.Ganju, Director, SASE, Chandigarh.

The nine special lectures were presented in four sessions, chaired by eminent personalities such as Shri S.Subba Rao, Surveyor General of India, who presided the very first session after the lunch on the opening date. In the second session was chaired by Shri V.K.Raina, Former Dy. Director, Geological Survey of India. The third special lecture session, on 16th October, was chaired by Professor A. Ganju, Director, SASE, Chandigarh. Professor P.S.Tiwari, Formerly Professor & Head, University of Madras and Ex-President, NAGI, presided over the fourth and final special lecture session on 17th October.

In the first session, making his presentation on 'Modern Cartography and the Role of International Cartographic Association', Professor Georg Gartner raised a number of pertinent issues relating to fast changing nature of cartography, needing urgent attention. To him, one of the most important issues is how to create a harmonious relationship, based on give and take, between the traditional cartography and modern technology based especially on mobile and web-based mapping. Also, he explained in details the working of ICA and its role for the advancement of cartography.

In presentation on 'Floods in Hungary', Professor Zoltan Wilhelm shared that location of Hungary in the Carpathian Basin presents a unique situation with regard to surface water, 96 per cent of it having its sources outside the national borders of Hungary. The technical solutions applied by earlier generations are now facing environmental risks and damages. A detailed scientific analysis of the drainage in the two largest river systems in the country and the causes and consequences of flash floods in recent decades the country presented by the scholar was greatly appreciated by the audience. Dr. Shahnawaz made presentation on 'Dynamic Cartography for Efficient Disaster Management'.

In the second session, Professor Ravinder Kumar shared his views of Geologic Hazards with a focus on earthquakes and landslides. Dr. Anu Kapur, Chairperson Department of Geography, Delhi School of Economics, Delhi University, Delhi spoke on the theme 'Mapping the idea of Disaster'. She raised a

number of ethical issues relating to gender, poverty and marginality in the context of consequences of disasters.

In the third session, Dr. S.P. Aggrawal, Head Water Resources Division, Indian Institute of Remote Sensing, Dehradun making his presentation on 'Land use Land Cover Dynamics in Indian River Basin', focused on implications of changes in land use/cover changes in the Ganga Plains. He shared that IIRS, Dehradun is working on a big project jointly with other organizations/institutes; and the preliminary results are highly rewarding and encouraging. Admiral S.K. Jha presented a insidious picture of the future of integrated hydrographic products and services and their utilization for disaster management.

The fourth session held on 17th October, Er. Snehmani, Joint Director SASE, who presented on behalf of Professor A. Ganju discussed the details of the 'high resolution terrain mapping of Himalayan region' with special reference to avalanche prone areas. Dr. A.P. Singh in presentation on 'GIS based Census in India' provided a detailed account of use the Census of India, 2011 has made of GIS technology to produce digital maps along with attribute database up to the level of the sub-division for the entire country.

Paper Presentation in Technical Sessions

On second and third days, that is 16th and 17th October, 2011, paper presentation by the participants was organized in three Parallel Sessions. In all, fifteen technical sessions along with Poster Presentation were held in these two days. In the sessions, papers relating conceptual and methodological issues in Cartography with specific reference to disaster management and its application in mapping of disasters, hazards and vulnerability, disaster management, mapping climate change, and bio-diversity were presented. Some of the papers were on resource mapping with use of geo-spatial technology and its use in disaster management. Nearly 90 papers were presented in these two days.

The technical sessions were chaired by eminent scholars including Shri A.K. Malik, Former President INCA and Additional Director, NATMO, Kolkata, Professor M.S. Nathawat, Professor & Head Geography, School of Sciences, IGNOU, New Delhi, Dr. R. Nagaraja, Head, NDC, NRSC, Hyderabad, Professor S. Chattopadhyay, CESS, Trivendrum, Admiral S.K. Jha, Chief Hydrographer, NHO, Dehradun, Professor (Mrs.) Swarnjit Mehta, Formerly Professor of Geography, Panjab University, Chandigarh, Dr. Ashok Kaushal, Senior Manager, Rolta India, Mumbai, Professor Zoltan Wilhelm, University of Pecs, Hungary, Professor Ravinder Kumar, Panjab University, Chandigarh, Professor J.L. Jain, Ex-INCA President and Formerly Professor & Head, H.S. Gaur University, Saugar, Sagar. Professor David G. Dickason, University of Eastern Michigan, all helped by Dr. Ravinder Kaur, Associate Professor, Department of Geography, Panjab University. She organized the Poster session as well.

X X X X X X X X X X X

INCA General Body Meeting

INCA General Body Meeting was held in the evening of 16th October 2011. The main business transacted covered announcement and rectification of decisions taken by the INCA Executive Council Meeting held on 14th October, 2011 evening at the same venue, and taking over of INCA Presidentship by the President elect, Admiral S.K. Jha. Secretary General, Er. R.N. Nanda, placed before General Body for rectification the decisions taken in EC meeting regarding the vacant posts in EC. The decisions were

rectified by the general house by the voice vote. Secretary General thanked the member for smooth conduct of elections to EC.

This was followed by Admiral S.K.Jha taking over INCA President Chair from Professor Surya Kant. After exchanging Chairs with Admiral S.K.Jha, the new President, Professor Surya Kant thanked the EC members as well as INCA fraternity for their kind cooperation, help and guidance in smooth conduct of his duties as President and managing INCA affairs with grace and dignity. In a lighter vein, Professor Surya Kant acknowledged that he finds more value in ex-presidency than presidency; he was President INCA for one year but would remain ex-President INCA for his whole life. While congratulating Admiral Jha for his taking over as President of this great professional body, he expressed his faith and confidence in new leadership for taking the INCA to the new heights of name and fame. The new President thanked the INCA fraternity for imposing faith in him by electing President and sought the help and cooperation of each and every member for furtherance of the cause of INCA as a professional body of Indian Cartographers. He outlined the road map he has for INCA in 2012.

Towards the close of General Body Meeting Shri A.K Malik, Additional Director NATMO and Ex-President INCA spontaneously congratulated and complimented the President and his team for organizing XXXI INCA Congress in a highly successful manner. He described it as one of the best organized INCA Congresses. He added that conventionally valedictory function is right place to thank and compliments for successful organization of a conference but I could not resist at the occasion congratulating the organizers for such an excellent show.

While accepting the sentiment in all humility, President XXXI INCA said if it was a grand success, the credit for it goes jointly to Survey of India, North West Circle, Snow and Avalanche Study Establishment (SASE) and Panjab University among others. These organizations worked hand-in-hand to take the present conference to the victory stand.

Cultural Program

After the hectic activities of the day including special lectures, technical sessions and the General Body Meet, a cultural program was arranged by the organizers to entertain and re-energize the conference delegates. Artists of a cultural group, Tanusiya, entertained the guest by presenting folk songs Punjabi, Hindi, Haryanavi and Rajasthani languages, Punjabi bhangara, music and other cultural presentations. The delegates and the guests appreciated the presentations and encouraged the artists with clapping.

X X X X X X X X X X X

Valedictory Function

The three day INCA Congress culminated by way of a valedictory function addressed by Shri B.K.Srivastava, Senior I.A.S., with the designation of the Director General, Mahatma Gandhi Punjab State Institute of Public Administration (MGPSIPA), Chandigarh. Professor G.S.Gosal, former Dean University Instruction and Emeritus Professor of Geography, Panjab University, Chandigarh chaired the session. Admiral S.K.Jha, Chief Hydrographer, NHO and President elect 2012 graced the occasion as the Guest of Honour. Delivering the Valedictory address, Shri B.K.Srivastava emphasized on the need to devise cartographic symbols, which may be called as cartographic symbols representing disaster events on topographic and daily weather sheets, which even a layman could recognized. He appreciated the diversity of themes covered and quality, and contents of the papers presented during the past three days. He added that he could have benefitted more if by joining missed a great opportunity by not attending the whole conference.

Before the address by the Chief Guest, Professor (Mrs) Smita Bhutani, the senior most colleague in the Geography Department, Panjab University and the Co-organizing Secretary, XXXI INCA, presented a report on the Congress giving details of different activities including the geographical representation in the Congress, highlights of inaugural function, themes covered and the number of papers presented in technical sessions and the guest/special lectures delivered. She observed that there has been very wide geographical representation from different parts of India and good representation of foreign delegates and invited speakers in large number making it an International Conference in real sense of the word, and very wide representation of the students, research scholars and young scientists and good quality presentations made by them.

The INCA added a new feature of honouring the outgoing President and General Secretary at its annual congresses. It starts with XXXI INCA Congress at Chandigarh. The President of XXX INCA held at Dehradun, Ex-Maj. Gen. Manoj Tayal and Secretary General, K.C. Rout were felicitated with shawl and citation for their contribution to the INCA.

Professor David G. Dickason of Eastern Michigan University and Professor J.L.Jain, Ex-President INCA expressed their laudatory assessment of the XXXI INCA. At the occasion, organizers of XXXI INCA invited the individuals and local organizations, who helped them in collection of or contributed funds for the successful organization of XXXI INCA, to the stands to honour them all with a shawl and a memento in recognition of their contribution. In the end Professor Krishna Mohan, Organizing Secretary XXXI INCA proposed a vote of thanks.

INAUGURAL SESSION

PRESIDENTIAL ADDRESS

Professor Surya Kant
President, INCA
Department of Geography
Panjab University, Chandigarh

Ladies, Gentlemen and Distinguished participants

Hon'ble Shri Anil Kumar Sinha, Vice-Chairman, Bihar State Disaster Management Authority and Chief Guest of the Conference, Professor R.C. Sobti, Vice-Chancellor, Panjab University and the Patron, Professor G.S. Gosal, Pro-Patron, Shri A. Ganju, Director SASE and the Co-Chairman LOC, honourable Members of Local Organising Committee, Shri R.N. Nanda, Secretary General, INCA, Dr. Krishna Mohan, Chairman, Geography Department and Organising Secretary, Members of the National Advisory Committee, Honorary Fellows, Fellows, EC members and INCA delegates, invited guests from India and abroad, ladies and gentlemen, it is in all humility that I am addressing you as the President of Indian National Cartographic Association at this prestigious ceremonial occasion. This organisation dedicated to the cause of cartography as a collective mode of communication by the government, autonomous research institutions and industry in the service of the nation has a membership of no less than 2500. It has been nurtured by as many as my 30 predecessor presidents preceding me and many others who devoted their time, efforts, and energies to its making. The outcome in the form of this grand edifice is there for all to behold and admire.

May I acknowledge that I had never a dream of attaining the Presidentship of this august organisation but on getting elevated to this position, I started having a number of dreams, some personal but most of these directed to building of a greater eminence of the INCA as a national level professional body of

cartographers in India. Three specific among these are as follows:

- i. to project the role of INCA in promoting and protecting the country's development process;
- ii. to bring in focus the relevance of cartography in general; and
- iii. to highlight the way geography is vital to realisation of the two dreams enunciated above.

As such, the main theme and sub-themes of the present conference were selected and fabricated toward that end. One critical problem that our country is facing is the unabated occurrence and reoccurrence a variety of disasters, which are to be attributed to human factors or can be ascribed to natural hazards or both. These not only cause colossal loss of life and property in different parts of the country but also put economic growth on the back foot. A country posed for a high growth trajectory can hardly afford any loss to its human resource and development infrastructure. Rebuilding infrastructure is always intensive of time and resource investment for it takes not only time but also requires huge financial investment.

There is, of course, now a much better realization of adverse effects of disasters on human life and economic development. This is evidently reflected in the shift of government policy from the previous 'relief centric' approach to now 'management based' approach to disasters. Prevention and preparation have been substituted for cure and wait. For this we

need to have a better understanding of natural processes and human actions and their mutual interactions. In the last some years, the various wings of the INCA, such as Survey of India, IIRS, NRSA, ISRO, NHO, SAC, NATMO, and university geography departments have been contributing significantly in this sphere through application and promotion of cartography, space technology and GIS mapping. An effort is made to regularly update the requisite information for planning and management.

Having said this, may I add that there are miles to go for cartography on resolving a variety of conceptual and methodological issues pertinent to disaster management? What are the most effective cartographic techniques to represent the various parameters of natural hazards, human induced disasters, and management strategies? Which are the major sources of data for this purpose? What will be the contents of a pro-poor cartography atlas? In this context, mapping of vulnerability become all the more important. Mapping of hazardous locations and/areas, substandard surface and ground water quality zones, degraded lands, congested and high density-areas, high-rise buildings, slum localities, disaster prone coastal and mountainous/hill areas becomes imperative on priority basis. These, among others, are still the least explored themes in cartographic research. And, here lies the rationale of having Conceptualized Cartography for Disaster Management as the prime theme of this Conference.

In no way belittling the outstanding contribution being made by the Survey of India and other government and private organisations engaged in practice of cartography and geospatial techniques for a variety of purposes, allow me to emphasise that geography has a special and specific role to play in promotion of cartography for disaster management. This is so particularly for two reasons. First, only geography has a sound knowledge of the conceptual basis of cartography, while other stakeholders in the field are primarily engaged in technology based methodology of mapping. Secondly, geographers are well-versed with the locational aspects of natural phenomena and human action activities, a knowledge which is basic to any mapping. Here I am happy to mention the outstanding contribution already being made to mapping of disasters by scholars like Anu Kapur through her book *Vulnerable India*, R.B. Singh through his research on *sustainable development*, S. Chattopadhyay on resource management, Milap Chand Sharma, and Man Mohan Nath Koul on *Climate Change*. There is much for geographers and others to learn from and emulate their work.

I must stop here. You have been kind in being patient with the narration of my three interlinked dreams. But I can't resist the temptation of sharing one of my personal dreams. Simply put, it is as follows: may the deliberations at this conference help me in realization of my three dreams shared with you today?

Thank you one and all.

INAUGURAL ADDRESS

Anil K Sinha, IAS (Retd.)
Vice Chairman,
Bihar State Disaster Management Authority, Patna

Ladies, Gentlemen and Distinguished participants

I feel most privileged and highly honoured to have been invited to XXXI International Congress of Indian National Cartographic Association (INCA) with its theme of “Cartography for Disaster Management”. My special thanks to the organizers and especially Professor Surya Kant to have thought of me for this important occasion in this historic and wonderful city of Chandigarh. I congratulate the distinguished members of the INCA who have maintained and upheld this tradition of annual international event for more than the three decades and I am indeed very happy to be associated with your event.

The critical importance of Cartography as a science and its use as a tool in effective disaster management is beyond any doubt; and that it can further strengthen the whole spectrum of disaster management. Considering the importance of cartographic tools to manage the various components of disaster management, it is required to put greater emphasis on development and application of the same. Thus the recourse to geographical information proves to be essential while bringing information to the various actors, who intervene around various facets of managing and more so reducing the risk to disasters.

A recent study from the World Bank argues that for too long, we have done too little to prevent the transformation of natural hazards into (un)natural disasters, and then moved too slowly once they occur. And now the risks are growing with rapid urbanization and climate change. We need to think of disaster prevention

in broader development terms and look at the possible economic impact of hazards.

Recent events in Haiti and most recently in Sikkim have shown how natural hazards convert into (un)natural disasters bringing about unprecedented loss of lives and property setting back decades of development process, while on the other hand Chile and Japan have demonstrated how with sustained work towards creating a culture of prevention helps in minimizing the loss of lives and property. There are numerous lessons to be learnt especially from Japan, which should not be lost sight of in our march towards disaster risk reduction. It will be worth recalling that an earthquake measuring 8.8 on Rickter scale hit Chile in March 2010, just a few weeks after Haiti was hit by a 7.0 temblor. While the Haiti toll in January 2010 was more than 250 thousand persons, just 600 persons died in Chile. The 2001 earthquake of Bhuj of 6.9 magnitudes had claimed more than 13,000 lives (including 400 children) as per the official figures. Though 9.0 percent of Chileans became homeless yet their toll remained low, as buildings did not collapse. This is mainly because of the strict building codes in Chile. After a massive 9.5 magnitude earthquake in 1960 (the strongest ever recorded), the Chilean government developed a seismic design code for all new buildings, again revised in 1993 to include advances in technology.

The east Japan earthquake of March 2011, a 9.0 magnitude, considered to be the seventh strongest in history, followed by 262 aftershocks of greater than magnitude 5 (including 49

greater than the magnitude of 6.0 and three greater than magnitude of 7.0) resulted in fewer than 100 deaths from collapse of structures. This is probably the best example of successful disaster risk reduction (DRR) in recent times. Hundreds of people were also saved from the Tsunami because of repeated Tsunami drills and evacuation measures practiced in Tohoku region from an early school going age.

India, one of the Asia's largest and most vulnerable countries, is exposed to variety of natural disasters. The country has highest occurrence of natural disasters and about 85.0 percent of the country area is exposed to one or the other kind of disasters viz., avalanches cyclones, droughts, earthquakes, floods, landslides, etc. There are also various environmental hazards, spontaneous or human-induced related to the natural forest or soil cover or over-exploitation of agricultural land.

Over the years, the Government of India had been focusing on disaster response as a disaster management strategy which did not lead to effective risk reduction. Hence, there has been a paradigm shift in approach, from re-active to pro-active, resulting in a remarkable change in the country's traditional policy towards the disasters.

Ever since UN General Assembly designated the 1990s as the International Decade for Natural Disaster Reduction (IDNDR), the Government of India and other government and non-government agencies have made significant contributions in the direction of developing and practicing different disaster management measures. In this context, formation of a High Powered Committee (HPC) on Disaster Management by Government of India in 1999 laid the foundation of paradigm shift in approach to disaster management. The HPC was instrumental in establishing a culture of preparedness in the arena of disaster management. Change of nodal ministry from Ministry of Agriculture to Ministry of Home Affairs in 2002, enactment of National Disaster Management Act, 2005 and establishment of National Disaster Management Authority

(NDMA) are important landmark decisions to evolve disaster management structure in India. Inclusion of disaster management in the Tenth Plan (2002-2007), for the first time, and its continuation in Eleventh Plan (2007-12) has given significant importance to the subject and initiatives being undertaken. National Policy on Disaster Management and 13th Finance Commission are other significant steps, boosting a favourable and sustainable environment on the subject.

Disaster Management was given its due importance in national planning process by including a chapter on it. The Chapter VII of Tenth Plan (2002-07) focused on "Disaster Management: The Development Perspective". Training and education, streamlining institutional arrangement for disaster response were the thrust areas on disaster management in this chapter. Integrated planning for disasters, setting up of a modern, permanent national command center of operations room, establishment of a quick reaction team composed of experienced professionals, creation of urban search and rescue capacity at all levels, modern unified legislation for disaster management, better understanding of systems for disaster response, procedures and systems set out to avoid confusion and ensure the proper utilization of the assistance etc. are some salient features of Tenth Five Year Plan on capacity building aspect of disaster management.

The process also continued in XI Plan (2007-2012). In this plan, disaster management was incorporated within a larger perspective of "Environment and Climate Change" in Chapter IX. The ongoing Eleventh Plan also has special focus on capacity building at district and local levels, strengthening of PRIs and involvement of corporate sector, NGOs and individuals.

National Policy in Disaster Management (2009) came as a guiding force for many new initiatives on disaster management. Priority was given to develop a community oriented disaster management system by conducting training programs depending on specific needs in view of regional diversities and multi-hazard

vulnerabilities. Capacity building of other stakeholders at state/district/local levels has also been given due importance. Institutional capacity building through training programs conducted by institutions like NIDM, ATIs, SIRDs in the states and through other departmental institutions have been recommended. Institutions like IITs, NITs and other Centres of Excellence should be helping and guiding in development of effective training programs for different sectors of economy. There will be extension and strengthening of disaster management curriculum in educational institutions. Compliance of rules and codes for ensuring disaster resilience in all structures has also been highlighted through the national policy.

While talking of this subject in the present context, it is very important to take note of the National Disaster Management Act of 2005 in terms of an enlarged and comprehensive definition of disaster as - Disaster means a catastrophe, mishap, calamity or grave occurrence affecting any area from natural and manmade causes, or by accident or negligence, which results in substantial loss of life or human suffering or damage to, and destruction of property, or damage to, or degradation of environment and is of such a nature and magnitude as to be beyond the capacity of the community of the affected areas. This has covered all possible factors causing a disaster be it natural, human made or by negligence or accident and including activities having adverse impact on environment. With this definition, disaster preparedness and planning will have to take a quantum jump requiring more comprehensive and holistic planning with the use of all possible modern technologies, techniques and tools.

Cartography and Geographic Information System (GIS) are remarkably appropriate tools for the requirements of early warning and disaster mitigation. Development and application of ICT in the last two decades, has also helped in advancing the use of maps and allowing disaster professionals to use

cartography in all stages of disaster management. This helps in obtaining more accurate data by cartographic visualizations. Cartography helps in achieving correct representations while maintaining compatibility with existing standards. A digital map, which forms the basis of cartography, presents accurate maps using global coordinates. It is a multi-purpose and multidimensional tool, displaying several layers of information and is not restricted to displaying only political boundaries.

I am highly impressed and motivated by what Erwin Josephus Raisz (1893-1968) has rightly mentioned - "The good cartographer is both a scientist and an artist. He must have a thorough knowledge of his subject and model, the Earth.... He must have the ability to generalize intelligently and to make a right selection of the features to show. These are represented by means of lines or colors; and the effective use of lines or colors requires more than knowledge of the subject, it requires artistic judgment."

Geo-climatic and seismic hazards of varying intensity affect more than a half of our country. These natural hazards have impacted India's socio-economic development to a great extent. Satellite based communication system has significantly improved real-time dissemination of information; strengthening thus the early warning system. Cartography has also grown as a discipline to become more accurate with use of remote sensing, GIS and GPS technologies. GIS has become most widely used reliable tool for data mapping, analysis, and decision-making. It helps in integrating all the actors responsible for sustainable development.

The maps developed by cartographers facilitate in cooperation of national and local authorities in mitigating the impacts of disasters by providing varied, classified and accurate data for use and application. Use of geographical information, maps (topographic and thematic) and specific statistical data are the key to success in disaster preparedness and mitigation. Standardization is another significant aspect of GIS and Cartography and the United Nations

Group of Experts on Geographical Names (UNGEGN) also considers the problems of standardization of geographical names. It aims “to emphasize the importance of the standardization of geographical names at the national and international levels and to demonstrate the benefits to be derived from such standardization” and “to study and propose principles, policies and methods suitable for resolving problems of national and international standardization”(UNGEGN, 2009).

Cartography plays a significant role at all the stages of disaster management. Prevention, preparedness and planning activities can be supported by detailed maps providing relevant information. These maps represent the peculiarities of the region and provide information about the structure, characteristics and classification of the features. Such maps can be used by local, regional and national authorities to facilitate the development of a sound disaster management strategy in an integrated manner.

In addition to pre-disaster preparations and early warning system, Cartography and GIS also facilitate through better real-time collaborative and integrated data of different types from diverse resources. Data from heterogeneous sources along with geo-spatial services can interact, in the form of better information, in a loosely coupled environment. Information systems used in the field of disaster management are often not as open and extensive as needed. With the growing demand, there is a need to develop an appropriate application framework to enable several stakeholders work on the same disaster from various locations.

The cartographic concept and use of cartography is now gaining more and more importance at national and international level, but I will like to voice my concern from this august platform that it is yet to be taken to each and every district and further to sub-district levels for making its best use. There has been familiarity with mapping at lower administrative units in the form of participatory village level mapping and it has always proved,

despite its limitations, as an effective tool in resource and disaster management planning. There is a need to advance this knowledge and use of high end technical mapping using GIS tools.

There is a need to focus on wide use and applicability of Cartography and related GIS and remote sensing tools for effective management of disasters. Starting from preparedness and advance early warning system, it can play important role in all phases of disaster life cycle. Information management, resource planning and coordinated strategy etc. can be done more effectively using these tools. It should be changed from its technical and scientific concepts to practical use by decision makers who are in the field and responsible for disaster management and finally for disaster risk reduction.

Recent Sikkim earthquake of 18 September 2011 reiterate once again the need to bring about a paradigm shift in our approach to all disasters, especially the earthquakes. It is imperative to employ all available information from landscape changes, landslide patterns, river flow patterns, paleo-seismicity to radon gas emissions which signal high pressure in subterranean rocks. Regular monitoring of low magnitude earthquakes is also needed. Cartographic community can play a very important and crucial role in making this a reality by engaging into policy advocacy and adoption of appropriate practices.

I understand that there are some sensitive issues pertaining to cartography and GIS/Remote sensing. Certain issues, such as pricing, resolution, licensing etc., need special attention of the policy makers. In order to design a new framework in pre-disaster and disaster management safety/security/privacy aspects of institutions and citizens need to be considered. Clear guidelines on these issues would help it popularize more and be used wherever needed. It also requires greater efforts and planning to spread its use and application at the all levels administrative hierarchy from top to bottom.

Learning lessons from the global best practices, we all must together work to nurture and create a culture of prevention. Prevention pays; and prevention is not always costly. It is basically a question of development model and paradigm that a society or the government chooses to pursue and follow. More it becomes a part of life the less costly and taxing it becomes in the long run. Nonetheless, very little work has been done on the front of disaster prevention. Donor agencies and the governments more often respond to disasters after they struck. We see that a large share of humanitarian aid globally is spent on relief rather than reducing and preventing risks. A successful and effective policy response consists of information, intervention and infrastructure. It is important to make information easily accessible to the community and the professionals, in addition the governments having an obligation towards achieving this end. And yet the seemingly simple act of collecting and providing information is often so difficult and complex. And even where it

is collected, it is not always shared for lack of adequate and appropriate policy prescriptions and other reasons.

I congratulate and thank organizers of XXXI International Congress of Indian National Cartographic Association (INCA) once again for selecting this important theme “Cartography for Disaster Management” for the conference. I am sure that the recommendations of this conference will help open up new vistas in the use and application of cartography in all facets of disaster management in the country and worldwide. I am most pleased and grateful to have been a part of this important event. Thank you once again.

Let us resolve together to give our fellow citizens and ourselves the peace of mind – the ultimate aim of disaster management as it is practiced in Japan.

I wish this conference all success in its deliberations and in achieving its mission.

REMARKS OF THE CHAIR

Professor R.C.Sobti, FNA Vice-Chancellor, Panjab University, Chandigarh

Honourable..... and Distinguished Delegates

It is a pleasure to be here with you at the commencement of 31st INCA International Congress. At the outset I wish to share with you a memorable event that took place fifteen years back. Yes, I'm referring to the year 1997 when the 16th INCA was hosted by Panjab University with Professor Gopal Krishan as the President. I'm told the Conference was academically fruitful. May be partly because of its reminiscence that the INCA again reposed faith in the Department of Geography in particular and Panjab University in general and handed over the reins of the Congress to Professor Surya Kant to steer it through. In fact, Panjab University has over the years become a hub for hosting such Conferences, which are interdisciplinary, providing a common platform across board for academic inputs and interventions. This is because in the last few years Departments have widened their horizons by offering new courses that are contemporary and relevant. Among the many others, Masters in Disaster Management has provided a background to hold this Conference. The Conference is also an example of public-private sectors partnership wherein different stakeholders such as The Survey of India, Indian Space Research Organization, the University and the Industry are sharing a common platform and working in close association with each other for further growth and development of this technology.

Disasters occur everywhere in the world. India is no exception. It is one of the Asia's largest and most vulnerable countries, exposed to a variety of natural and human-induced disasters-avalanches, droughts, cyclones, earthquakes, floods, environmental hazards, non-judicious use of agricultural land, poverty, deprivation,

haphazard and rapidly growing urban-industrialization and human-induced fast ecological changes especially in green revolution areas etc. These have made the people vulnerable who live in locations prone to hazards, such as seismic zones, floodplains or coastal belts. Disasters lead to tremendous loss of life and property. It derails the economy. Succinctly put, India abounds in vulnerable spaces.

The recourse to geographical information science and system proves to be essential to share the information with various actors and stakeholders. The science of Cartography has come a long way from making effective use of lines or colors to handling of sophisticated data making digital maps which display many layers of information. GIS is no doubt a very quick and effective way of storing, manipulating, retrieving, mapping information on a variety of issues affecting our day to day lives. It is a very valuable tool in disaster management. Geospatial technologies have further strengthened the accuracy of Cartography. Thus, there is a need to put greater emphasis on development and application of the same at various spatial scales.

Having said that, I wish to raise a few issues for the consideration and further deliberations by the experts assembled here from India and abroad. How can GIS be integrated as an important tool in planning and development in India at various spatial scales? How should we make it as an integral part of our planning process? How can we avoid disasters to penetrate through vulnerability?

Perspectives on vulnerability have evolved over time. For long it referred to biophysical

conditions. A great concern was felt for the adverse impact that physical phenomena like earthquake, cyclone, flood or drought left on human habitations and livelihoods. Global warming and climate change are today seen as threats that render the earth vulnerable. It led to focus on the vulnerability of people living in locations prone to hazards, such as seismic zones, floodplains or coastal belts. This brought in the role of technology in management of localities or regions. Irrigation against drought or dams across the river for flood control was seen as a possible solution. Soon it came to be realized that such techno-interventions were counterproductive. Irrigated lands became vulnerable to waterlogging while the damming of rivers initiated a process of desiccation. The political economy as an analytical tool highlighted the way economic deprivation or social marginalization or political exclusion or administrative neglect contributes to the vulnerability of a large section of society. Recently biotechnology is emerging as an area of great debate with regard to its importance in addressing the societal issues and problems. Two schools of thought have emerged on this issue. One group strongly advocates that biotechnology is a great boon for the society on the other hand it is apprehended that it can be a bane, if not handled properly. Obviously management of biotechnology is emerging as a crucial issue. Modern Cartography with the help of geoinformatics has a decisive role to play in mapping and decision-making associated with

the role and application of biotechnology in the context of development.

Importantly, in line with approach of developing countries India's disaster management priorities are more oriented towards rescue, recovery, relief, rehabilitation and reconstruction rather than focus on prediction, preparedness, prevention, participation and publicity through media. Of course, things are beginning to change with the enactment of National Disaster Management Act 2005 and establishment of National Disaster Management Authority (NDMA) at the national level. The Act of 2005 has enlarged the scope and definition of disaster requiring more comprehensive and holistic planning with the help of modern 3T's- Technology, Techniques and Tools. The subject has begun to be given its long due importance in the national planning process. A change in approach from passive to proactive is certainly desirable and needs to be carried forward.

Again, I am so glad that experts from different backgrounds will deliberate upon different facets of an issue which is not only multi-disciplinary and multi-dimensional but an idea that requires participation and involvement of different stake-holders- the Government, Private and University for it to become a reality and lessen the sufferings. I wish that the Congress is a grand success.

Thank you one and all.

Prize Winners of INCA QUIZ Contest with Chief Guest, Shri Anil K. Sinha, I.A.S.



**Students of Rashtriya
Indian Military College,
Dehradun
(First Prize Winner)**

**Students of Oak Grove
School, Jharipani,
Mussoori Hills
Dehradun
(Second Prize Winner)**

**Students of
St. Kabir Public School,
Sector 26, Chandigarh
(Third Prize Winner)**

**Students of Rashtriya
Indian Military College,
Dehradun
with Running Trophy**

Chairpersons of Sessions

Professor G.S.Gosal

Professor Emeritus
Department of Geography
Panjab University, Chandigarh

Professor B.S. Brar

Dean University Instruction
Panjab University, Chandigarh

Professor (Mrs) Swarnjit Mehta

Former Professor & Head
Department of Geography
Panjab University, Chandigarh

Professor M.S.Nathawat

Professor of Geography
School of Sciences
IGNOU, Maiden Garhi, New Delhi

Professor Srikumar Chattopadhyay

Scientist G & Head Resource Analysis
Centre for Earth Sciences Studies
Akkulam Road, Trivandrum

Dr.S.Subba Rao

Surveyor General of India
Survey of India, Dehradun

Shri V.K.Raina

Former Deputy Director General
Geological Survey of India

Shri A.K.Malik

Additional Director
National Atlas & Thematic Mapping
Organization (NATMO), Kolkata

Dr. R. Nagaraja

Head, NDC
National Remote Sensing Centre
Balanagar, Hyderabad

Professor Ravinder Kumar

Former Professor & Chairman
Department of Geology
Panjab University, Chandigarh

Rear Admiral S.K.Jha

Chief Hydrographer, Govt. of India
National Hydrographic Office
Dehradun

Professor Wilhelm Zoltan

Head, Department of Applied and General
Geography, Institute of Geography
University of Pecs, Hungary

Dr.J.L.Jain

Former Professor & Head
Department of Geography
University of Saugar, Saugar (MP)

Shri Ashwagosha Ganju

Director, Snow & Avalanche Study
Establishment (SASE), Chandigarh

Professor David G. Dickason

Professor of Geography & Director,
The W.E.Upjohn Centre for the Study of
Geographical Change, Western Michigan
University, Michigan (USA)

Professor Nina Singh

Professor of Geography
M.D.University, Rohtak

Dr. Ashok Kaushal

General Manager
Rolta India Ltd.
MIDC, Andheri (East), Mumbai

Professor Smita Bhutani

Professor of Geography
Panjab University, Chandigarh

Professor Dhian Kaur

Professor of Geography
Panjab University, Chandigarh

MEMORIAL LECTURES

The Future of Historical Cartography

David G. Dickason

Introduction

If “history is too important to be left to the historians,” as is often said, then “maps are too important to be left to cartographers”. I would like to preface my comments by saying that my INCA colleagues know vastly more about both cartography and India than I could ever know. I hope today only to stimulate renewed interest in historical cartography and to place it in the context of contemporary trends. My comments are in three parts. First, thoughts about time and historical maps. Second, reflections on how cartography (and historical cartography) is changing. Third and last, the challenges to, and opportunities for, historical cartography in the digital age¹. As a non-cartographer, I wish to view historical cartography primarily through the lens of map content and map comparison.

1. Time. Historical cartography deals with maps and map-making in through time. There are (at least) two kinds of time we must recognize.

Kairos Time: Encounters with Eternity. Kairos is a Western religious-philosophical concept with Indian equivalents. Kairos refers to deep spiritual or sacred time (“God’s time”) where people sense eternal truths. Historical maps based in kairos time show the place of humans in the cosmos. Such maps termed *mappa mundi* in the West and related concepts most often focus on an axis mundi, a sacred mountain or pole on which the world “revolves”. (Fig. 1) So places like Jerusalem, Makkah, Amritsar, Mt. Meru, the Altar of Heaven, and Kashi (among many others) are such foci. Sacred scriptures celebrate actions, stories, and places in kairos time.

Pilgrimage to sacred sites follows cosmic mental

maps and pilgrims are submerged in kairos time during their devotional journeys. A Muslim going to Mecca on the Hajj (Fig. 2), a Sikh going to Amritsar (Fig. 3), or a Roman Catholic en route to the Vatican are all immersed in kairos time.

Hindu tradition has a vast number of tirthas (or ‘fords’) where events in kairos time intersected the mundane, human world. Major Hindu temples constitute cosmic maps expressed in kairos time. (Fig. 4) Kairos time maps are yantras or mandalas, therefore. (Fig. 5) They may include whole cities like Kashi. (Fig. 6) And Hinduism is further unique is its flexibility of transposing space – there are many Kashis mirrored across India, of course.

Cartographers of kairos landscapes are monks, priests, and gurus (or their interpreters). Kairos time is eternal, and therefore it is unchanging in human terms. Study of kairos time maps is based primarily on devotional insight instead of cartographic interpretation. Relatively little further academic insight can be expected from kairos time maps because like the T-in-O maps, for instance, they have been with us for many centuries. They represent the eternal existing equally in the “past”, the “present”, and the “future”. They are, therefore, “timeless,” fixed and unchanging².

Chronos Time: Encounters with the Mundane. Chronos time is secular time more or less as employed in modern life (perhaps with differing calendar systems). Chronos, clock time, measures short time intervals like railway time and standard time. Modern cartography is based on principles of chronos time, from calculating longitudes to calibrating GPS. Time and space are linked in chronos time – so when

Wm. Lambton established the distance from Chennai to Mangalur by the Great Trigonometric Survey two centuries ago he found the distance between these places to be about 44 miles less than previously thought. (Fig. 7) This distance meant that these two places were more than 9 days closer for the caravans and armies of Lambton's day. Chronos time is also the time dimension used by Raja Todar Mal in promoting the Mughal state.

We expect many changes in chronos time. Places flourish and wither in chronos time; landscapes and settlement systems develop and are resculpted; new systems are added on top of old ones – irrigation, transportation, or legal and land revenue systems (such as developed by Raja Todar Mal). People migrate from one place to another and some places may be eclipsed by others -- for instance, Murshidabad by Kolkata, or Arcot by Chennai. Geographic change is basic to chronos time, and gives the fundamental reason for cartographers to continue making maps.

Early chronos maps in the West were portolan charts beginning in the 14th century (Fig. 8), and the many nautical charts made later were like this one of south India and the Indian Ocean showing compass directions for sea voyages rather than information about the landward interior. (Fig. 9)

The Nature of Time & Temporal Maps: Cartographers don't have to think as philosophers do about whether time is linear, circular, or goes in cycles – whether kairos time is “real” and chronos time is “illusory”, or whether both are “real”. (Hindu philosophic schools of thought can accommodate almost any conceptualization of time!) But as humans we all live in the “present” (although we like say that some of us live more in the “past”, or more in the “future”, than others). We perceive the need for maps of what we call the “present” (the “now”) and we make new maps for use in the “future” (the “nows” yet to come). We make new maps when we perceive existing maps are no longer adequate – when the “present” of past times (the

“thens”) seems different enough from our own “present” to justify the cost and effort of a new map.

Thus, every map of the world set in chronos time is actually “historic”, and even contemporary maps should be the concern of historical cartographers. So, historical cartography includes almost all other varieties of cartography because we all live inside the chronos “time-space envelope”. Historical cartography is not defined by the mildewed smell or the spotted look of old maps, or even by the medium (stone, wood, paper, palm leaves) on which the maps were rendered. Only in popular thinking does the age of a map make it “historic”. Historical cartography as an academic field was created by highly trained, future-oriented mappers who probably were not very impressed by the historicity of their work. So the idea that historical cartography is past-oriented is a myth. Wm. Faulkner reminds us “the past is never dead; it is not even past”³. Maps of “then” are available to us in the “now” and it is for us cartographers and geographers to comprehend the change these maps show as we plan for the “nows” to come. Maps surviving from pre-digital ages were the spatial databases of their time. When we compare maps of different times, we discover that maps created long ago are actually embedded in more recent maps. But we can only know this by studying them.

We must be careful when interpreting maps of the past, however. Maps as temporal snapshots do not reveal dynamic landscape processes. We must also remember that people in past chronos times did not necessarily think as we do today. So we must interpret the past consistent with their views and translate their views into our times; otherwise, we may make fundamental interpretive errors and might draw false conclusions.

2. Changing Cartography. Arthur Robinson, that towering 20th century Fig. of cartography, developed and disseminated a “one-way” model of cartography that simplified the “real world”

through the cartographer's science, art, and mentality into maps consumed by map readers. (Fig.10) This was, of course, what cartographers had been doing all along (more or less). None had noted their schematic work flow, and Robinson gave new emphasis to map users. The model gave the impression cartography was changing slowly. The geographer Peter Haggett has called this stage of cartography/geography the "ROMS" stage—"Read-Only MapS" (i.e., readers could not change the printed map)⁴. This model was perfectly suited to the age of paper maps. Cartographers interpreted available data about the world, organized it into map form, and published it in printed form for readers.

This was a "democratizing" trend in itself. The map now no longer was owned by the king, his generals, or members of the political-military-religious elite because it was printed in many copies. Before the age of printed maps, whoever controlled the only copy of a map had a significant advantage. In the printed map age, anyone with money or influence could access it.

In 18th century India, all maps were drawn one copy at a time for the East India Company (EIC). No EIC maps were printed. When EIC Directors in London requested a map, 12-14 months were required to make it, and then it had to be sent to England – so the total time was nearly two years between a map's request and its delivery in London. (Fig. 11) The map was expensive. It benefited very few.

Cartographers never knew how many copies of printed maps would sell because demand for printed maps was "latent", or hidden. Printed maps made cartography a business. Previously cartographers required patrons (like artists, poets and musicians) for their one-of-a-kind works. Now they gained independence selling printed maps to buyers. Mapmakers competed fiercely in the 17th and 18th centuries—and often plagiarized each other (there were no copyright laws). Profits were more important than accuracy because accuracy (beyond a minimum) was expensive and reduced profits. Some

inaccurate maps of India were reprinted for more than 50 years after accurate maps were available. (Fig.12.)

The Pursuit of Accuracy: Cartographers knew the benefits of accurate maps. James Rennell, "father" of the Survey of India (formally established only after the British Raj took over from the EIC after 1858), did not believe the accuracy gains of new survey techniques warranted replacing his maps based on route surveys. (Fig. 13) Historical cartography's story is of the struggles of geodesy (calculating the earth's ellipsoid and measuring magnetic anomalies), astronomy and horology (calculating correct longitudes), and applied trigonometry (good angular surveys) to create more accurate maps. These expensive activities were state/EIC funded. The search for map accuracy brought mapmaking again under the supervision and control of the state. More accurate maps were so much better that mapmakers without state support could not compete.

The first of these accurate maps was the Carte de France under the Cassinis. (Fig. 14) The second was the British Ordnance Survey. (Fig. 15) Other European states also carried out systematic triangulated surveys, as also in the U.S. – although none truly understood geodesy then. Following these efforts, came the triangulated surveys of India sponsored by the EIC. To the Trigonometric Survey benchmarks across India, local surveys could be referenced.

The project triggering this change was Aaron Arrowsmith's Atlas of South India (1822)⁵. (Fig. 16) For the first time the EIC Directors had an atlas printed at a common scale and projection (4 mi. to 1 in., or 1:253,440). This atlas showed what was possible for India. (Fig. 17) Specific demand for more accurate maps developed immediately. Large-scale mapping in India began during the 1820s and continues to the present. By the start of the 20th century, no major region of the world was more extensively mapped than undivided India! ⁶ (Fig. 18). The first of these major projects was called The

Indian Atlas, and status of work on it by 1881 is shown here. (Fig. 19)

Problems, Problems: There were many challenges. First, Aaron Arrowsmith died and his vision for mapping India was lost. John Walker, a competitor, took over this work.

Second, the Great Trigonometric Survey started in 1801 under Wm. Lambton was completed by George Everest after Lambton's death. Everest discovered Lambton's measurements were not exact. He resurveyed south India. Not enough was then known about geodesy to make accurate field measurements. The Survey of India in 1903 noted that Kalianpur's coordinates, the base for mapping India, were inexplicably wrong. Whether this was computational error or sabotage (or both), we will never know. But George Everest was a tyrant.

Third, the original coordinate base for The Indian Atlas was the Madras Observatory in Chennai. The coordinates of the Observatory were recalculated more than a dozen times in the 19th century, and only early in the 20th century were computations considered accurate. Markham said that if the coordinates of India's maps were wrong, the entire British mapping effort in India would have been wasted⁷. (The W.E. Upjohn Center has shown the inaccuracy of the original coordinates can be corrected, although not easily.) (Fig. 20)

Fourth, John Walker personally managed The Indian Atlas until 1869. Not until Atlas maps were made in India was it known that Walker established the scale of his maps incorrectly (they are actually slightly smaller scale than 4 miles to the inch). No one knew he changed the map projection so Indian Atlas maps would not tile seamlessly. And further, he arranged the map sheets to cover as much water as possible (and as little land area as possible) because he was paid for each completed map sheet. Moreover, some map sheets he compiled came from field surveys more than 30 years old. For instance, Sheet 1 (Karnataka/Mysore showing Bengaluru) published in 1828 noted C.

Mackenzie was the surveyor; but Mackenzie surveyed Mysore about 1795 and did not resurvey it later. (Fig. 21) Metadata for the manuscript maps Walker used to make the Indian Atlas does not survive. The maps sent to Walker were not indexed. Not surprisingly, the Survey of India stopped publishing the Indian Atlas in 1905 and began again to map India more accurately.

Digital Cartography: One hundred years later Google Earth was released. (Computer-based cartography had begun about 1970.) The full geospatial revolution began during the 1990s having begun in the 1960s. (Google Earth is therefore a metaphor for the digitalization of cartography.) (Fig. 22)

Undeniably, Google Earth represented a tsunami-like change for cartography. Google combined somewhat mechanistic map design with comprehensive coverage of satellite images and digital maps, and an interactive gazetteer. In the six years since introduction, Google has also introduced other software so that individual users can customize Google Earth to their needs and preferences. Google Earth, with more than 500 million users, continues to grow in popularity. Google Earth's widespread acceptance shows a huge demand to see the world in map-like ways. The cartographic communication model now focuses on digital spatial databases that can be manipulated by users, many of whom have little cartographic training. The map user is often the map maker.

The digital age offers no hope of putting the "genie" -- the djinn -- "back in the bottle". We must live in the digital age. But the digital geospatial age makes it possible to revisit Raja Todar Mal's vision of managing India's land resources. In realizing his vision, geospatial technology and digital cartography could become an exploding career field in India for decades to come.

3. DIGITAL Historical Cartography. Puristic historical cartographers continue to study the history of cartography and maps, and to "deconstruct" maps of earlier times. That is,

they study maps as instruments of power and domination, and of ethnocentric, class, and/or gender bias⁸. A small, hardy band of outstanding scholars continues this tradition. It promises, however, to remain a rather small group with somewhat esoteric, non-digital focus.

But historical cartographers face a major new dilemma. Much map information today is being “born digital”. That is, many maps are no longer issued as paper maps. They are issued in digital form. No integrated clearinghouse, indexing, or metadata system exists. This is a big problem with no comprehensive solution in sight.

Historical cartographers also have, for the most part, not tried to study geographical change. This part of historical cartography has been ceded to others who study “global change” or “human dimensions of global change”. Because most global change scholars are not familiar with historic maps, this opportunity holds great promise⁹. If little change seems to have occurred, it is because the past is embedded in the present. For instance, “path dependence” shows in road patterns. (Fig. 23) To know this, historic maps must be geospatially enabled; they must become “re-born” in digital form. This is particularly important because so much geographic change has occurred over the last 200 years during the “Anthropocene” Age -- the era coinciding with accurate map-making. We must try to generate a 200-year perspective, not just a 20-year perspective (based on satellite images) to understand our changing world. India has a rich collection of chronos maps for this purpose.

At The W.E. Upjohn Center we have developed a new hyper-accurate topographic map that is also publication-quality. We have completed full coverage of the United States. These maps are designed to be used over other images, aerial photos, or maps so that it is easy to detect change visually¹⁰. This is our “Authoritative U.S. Topos” initiative. We want to include in this collection all topographic maps of the U.S. What we have started for the U.S. we can do for India. There is equal need for an “Authoritative Topos of India” initiative to preserve in digital, geospatial form

all topographic maps of India, including Indian Atlas and manuscript maps (Figs 24 & 25).

Finally, historic maps are being created now by people who are not primarily map users. Data for chronos time maps can be collected through “crowd-sourcing”, also known as volunteered geographic information (VGI). To do this is fairly easy and low-cost. Informants use their GPS-enabled mobile phones to add data to a spatial database. One illustration: mapping India's third coastline – that is, the limit of the sea surge (the 2004 tsunami) above high tide level. Local residents still can indicate how far the ocean poured over their coastal village lands. The collective effect of hundreds of thousands of telephone calls made at the landward edge of the tsunami can define the greatest extent of sea encroachment on India's coast in the last two centuries. It could also help India's NDMA to develop disaster management plans using crowd-sourced information on floods, earthquakes, and epidemics when they occur¹¹.

Conclusion. Cartography continues to evolve in both expected and unexpected ways. Although some dimensions of traditional historical cartography continue into the 21st century, much of historical cartography will be increasingly affected by digitalization. More than preserving historic maps, historical cartography will “curate” (i.e., organize) these documents digitally. Many of the uses for historic maps continue. The ways, however, we analyze historic maps will be almost entirely mediated by geospatial technology.

This will happen in India as INCA, NAGI, and related professional societies adopt the vision of digitalization of map resources. INCA and NAGI can provide the leadership to make a future for India consistent with Raja Todar Mal's vision centuries ago. In so doing, each of you can become modern day “Navaratna”, and cartography/geospatial technology/geography together can become one of the thematic “Nine Jewels” of this great nation. Namaskaar!

References

This talk relates to South Asia, but is more general than, and views cartography 20 years later than J.E. Schwartzberg (Assoc. Ed.) and J.B. Harley and D. Woodward (Eds.) (1992). **The History of Cartography: Cartography in the Traditional Islamic and South Asian Societies**. Chicago: University of Chicago Press. pp. 579. It does not attempt to revisit the same materials as treated in so masterly a way by J. Schwartzberg. This talk also makes no effort to incorporate the many excellent previous Raja Todar Mal lectures relating to historical cartography available on the INCA website. Nor does it revisit the excellent work of S. Gole (1989). **Indian Maps and Plans: From Earliest Times to the Advent of European Surveys**. New Delhi: Manohar. pp. 207.

Kairos time, so far as is known, has heretofore not been identified by historical cartographers -- although well known to theologians. Axis mundi have long been identified by scholars, as has been sacred and profane space. M. Eliade (1959). **The Sacred and The Profane: The Nature of Religion**. W.R. Trask (trans.) New York: Harcourt, Brace & Co. In Asia perhaps the best known discussion of axis mundi is the work of P. Wheatley (1971). *Pivot of the Four Quarters: A Preliminary Inquiry into the Origins and Character of the Ancient Chinese City*. Edinburgh: Edinburgh University Press. For Kashi, the magisterial work of Prof. Diana Eck must be noted. D.L. Eck (1982). **Banaras: City of Light**. New York: Alfred A. Knopf. pp. 427. See also H.F. Hirt, "The Dravidian Temple Complex: A South Indian Cultural Dominant," **Bombay Geographical Magazine** (1961), p.95-103.

W. Faulkner (1951). **Requiem for a Nun**. New York: Random House.

P. Haggett (1996), "Geographical Futures: Some Personal Speculations," in I. Douglas, R. Huggett, and M. Robinson (eds.), **Companion Encyclopedia of Geography: The Environment and Humankind**. London: Routledge. p. 963-974.

A. Arrowsmith (1822). **Atlas of South India**. Privately Printed. For a more extensive discussion of this atlas, its importance, and contents, see D.G. Dickason (2010), "The Geospatial Re-Discovery of India", The Arthur Geddes Memorial Lecture, 32nd NAGI Conference. Available online at: <<http://www.wmich.edu/ucgc/>>.

J.G. Bartholomew (1890). "The Mapping of the World," **Scottish Geographical Magazine**, Vol. 6, p.293-305.

C.W. Markham (1878). **A Memoir on The Indian Surveys**. London: W.H. Allen & Co. See also: C.E.D. Black (1891), **A Memoir on the Indian Surveys: 1875-1890**. London: W.H. Allen & Co., and R.H. Phillimore (1945ff.) *Historical Records of the Survey of India*. Dehra Dun: Survey of India. 4 vols.h

J.B. Harley and D. Woodward, eds. (1992ff). **The History of Cartography**. 6 vols. Chicago: University of Chicago Press. See also M.H. Edney (1997). **Mapping an Empire: The Geographical Construction of British India, 1765-1843**. Chicago: University of Chicago Press; and J.W. Crampton (2010). **Mapping: A Critical Introduction to Cartography and GIS**. Chichester: Wiley-Blackwell.

In the past, regional geographers did much of this work. See O.H.K. Spate and A.T.A. Learmonth (1967). **India and Pakistan: A General and Regional Geography**. London: Methuen & Co., Ltd. See also A. Geddes (1982). **Man and Land in South Asia**. A.T.A. Learmonth, A.M. Learmonth, C.D. Deshpande, and L.S. Bhat (eds.) New Delhi: Concept Publishing Company.

Current activities of The W.E. Upjohn Center may be accessed through its website at the following address: <<http://www.wmich.edu/ucgc/>>.

A. Kapur (2010). **Vulnerable India: A Geographical Study of Disasters**. Shimla: Indian Institute of Advanced Study, provides an excellent small-scale overview of the recent incidence of natural hazards in India. VGI would add accurate local information that, when

aggregated across the nation, would provide large-scale accuracy for viewing and analysis.

(**David G. Dickason** is Professor of Geography & Director of The W.E. Upjohn Center for the Study of Geographical Change at Western Michigan University (WMU). He received the following degrees: B.A. (College of Wooster), M.A. (University of Pittsburgh), and Ph.D. (Indiana University). He also did post-graduate studies at the University of Chicago and University of California-Berkeley. He chaired the University's Asian Studies Program (1974-80), directed its Malaysian community college (1995-97), and chaired WMU's Department of Geography (2000-06). He has taught in six university units (Geography, Public History, Asian Studies, Environmental Studies, General Studies, and WMU-Sunway College, Malaysia). He edited *The East Lakes Geographer*. He developed interactive computer mapping software (1981-85) and introduced GIS to Western Michigan University and west Michigan. He co-founded WMU's Computer Mapping Laboratory in 1980 and its Regional GEM Center in 1989. He founded the GIS Research Center in 1992 and The W.E. Upjohn Center in 2005. He has

authored more than 100 publications and technical reports. He has received more than \$7.5 million in grants, contracts and awards.

This lecture has been made possible by a Digital Innovation Fellowship from the American Council of Learned Societies. This lecture has also been supported by The W.E. Upjohn Center for the Study of Geographical Change at Western Michigan University, established by the generosity of Edwin E. and Mary U. Meader.

This document is protected by Creative Commons Copyright (2011). It may be disseminated freely for individual use. It may not be used for commercial purposes without the specific approval of the author.



Fig. 1

The Hereford Mappa Mundi. Possibly the most ornate of the T-in-O Maps.



Fig. 2

The Grand Mosque in Makka. After its most recent enlargement. The Ka'aba in the center may be discerned. Small numbers of pilgrims are visible in gray around the Ka'aba, indicating that this season was not that of al Hajj. Source: Google Earth.



Fig. 3

The Golden Temple at Amritsar. Source: Google Earth.



Fig. 4

Sri Ranganathaswamy Kovil Temple, Srirangam. On the Kaveri River near Tiruchirrapalli, Tamilnadu. Source: Google



Fig. 6

Modern Varanasi, with traditional Kashi located between the Varuna and Asi Rivers. Banaras Hindu University is visible in the geometric campus plan at bottom. Hindu conceptualization allows transposition of space, so that there are many Kashis mirroring this Kashi. Source: Google Earth.



Fig. 5

Yantras of Hindu tradition, and mandalas and thangkas of Tibetan Buddhist tradition.

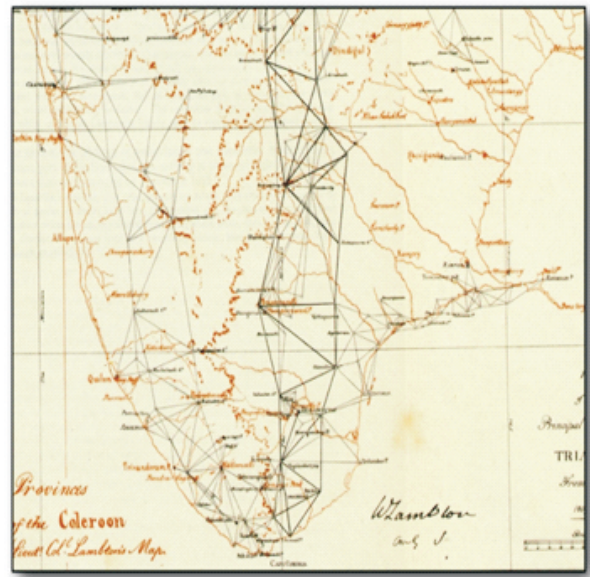


Fig. 7

Southern tip of India from Kanyakumari northward to Dindigul showing triangulations of Col. Wm. Lambton of the Great Trigonometric Survey -- with secondary triangulations of others. Into these local surveys were "snapped". Arcot was 9 miles closer to "Madras" (Chennai) than previously thought. Triangulation error at Bengaluru (Bangalore) was thought to be only 7 inches!



Fig. 8

A portolan-like chart of the 17th century. Notice the compass directions given clearly over the Atlantic Ocean, and relatively greater detail for coastal areas than for inland regions. Whether this chart was based on a map projection, as we understand them today, is unknown.

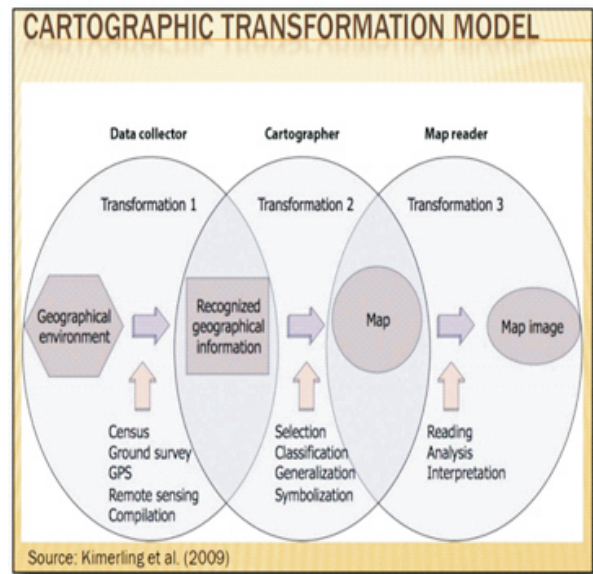


Fig. 10

The Robinson-Petchenik Model that distinguishes between cartography and map-makers, and the map users-map readers.



Fig. 9

An 18th century equivalent of earlier portolan charts. Compass directions are highlighted. Coastal settlements, to the extent known, are listed. Essentially no information is given about the Indian or Sri Lankan hinterlands.



Fig. 11

A "Fair Drawn" (i.e., finished) Manuscript Map of part of Dindigul District (1815). This map was not available to Arrowsmith for his Atlas of South India. Note drainage, triangulation lines, tree-shaded roads, tanks (light blue), irrigated rice fields (in green), and dry cultivated fields (black dashed lines), and villages small and large. Orthography is, of course, "colonial phonetic". Source: Phillimore.



Fig. 12

Letts' Atlas of India i (1883) 12 plates were hand-tinted versions of SDUK (Society for the Diffusion of Useful Knowledge) maps issued between 1828 and 1842 with railway and telegraph lines overprinted very approximately.



Fig. 14

Sheet One of the Carte de France, showing the observatory to the south of Paris on which the coordinate system for France was based. (Library of Congress).



Fig. 13

J. Rennell's Hindoostan. (1782). Based on route map surveys. His geographical memoir describes how he inferred city locations, and how he drew this map. He did not favor trigonometric surveys replacing his work.



Fig. 15

Part of London in the 1st edition of the British Ordnance Survey of England (1801). (Bottom r.) the Greenwich observatory. (Top l.) on the Thames R. is the Tower of London.

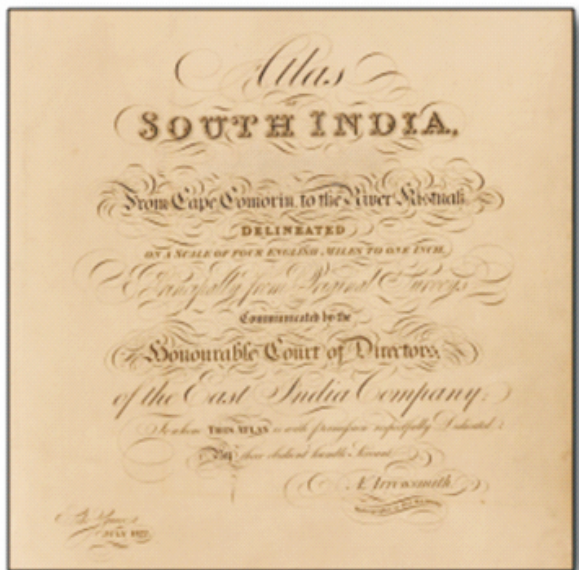


Fig. 16

Only six copies of the Arrowsmith atlas survive in public repositories. It was not a commercial publication. It stimulated revolutionary change in mapping India.



Fig. 18

Regions of the world mapped by trigonometric surveys before 1900. Source: Bartholomew.



Fig. 17

Scope of the Atlas of South India. It included territory immediately surrounding Mysore/Karnataka, excepting Mahratta lands.

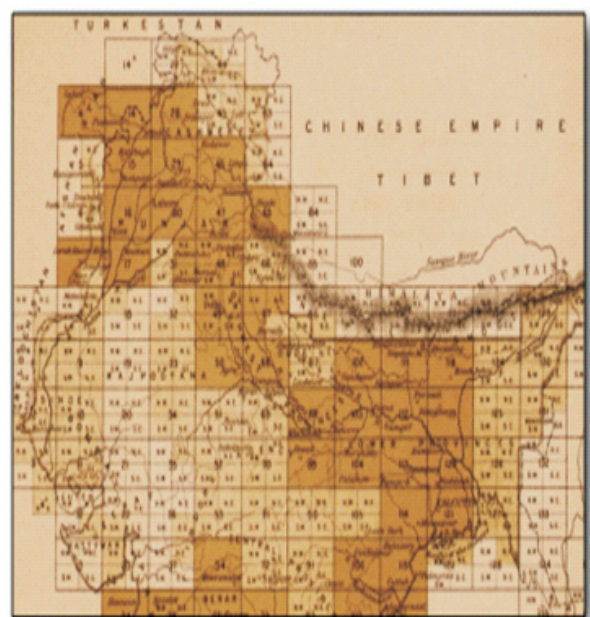


Fig. 19

Indian Atlas sheets completed for north India by 1881. (All south India had been completed. Brown color means sheet issued as one sheet. Khaki color means sheet issued as quarter sheets. Other color means not yet mapped. Index map created for 1881 International Geographic Conference.



Fig. 20

Arrowsmith's Madras sheet corrected to modern coordinates so that it overlays Google Earth's coordinates correctly. Given the 1822 sheet is 4 miles to the inch, there is quite a clear correspondence to modern features -- i.e., tanks, rivers, coast line, Fort St. George.



Fig. 22

Opening view of Google Earth. Intuitive controls allow easy view of any part of the earth.



Fig. 21

The first Indian Atlas sheet published in 1828 shows Bangalore (Bengaluru), whose territory is defined by the line of trees and vegetation around the city. This map was probably surveyed about 1795 by Mackenzie.



Fig. 23

1947 Survey of India map overlaid over Arrowsmith's 1822 map of Tiruchirappalli, Tamilnadu region. Main roads extending south from the city follow surprisingly similar corridors.



Fig. 24

Sheet 28 of the Indian Atlas (1857). Srinagar is at bottom right and Wular Lake at top left. Haramukh Glacier is at top right. Scale: 4 miles to the inch.



Fig. 25

Vale of Kashmir (1911). New lakes exist around Srinagar, with extensive wetlands. Haramukh Glacier has expanded. By 1911 Wular Lake (top left) had almost disappeared. Scale: 1 inch to the mile.

GUEST LECTURES

The 2011 Census of India and GIS Technology

Aji Pal Singh

Historical developments

The history of the Census of India goes back to the 3rd quarter of the 19th century, when the 1st Census was conducted during 1872-75. However, the first systematic and complete Census was conducted in the year 1881. Since then, decennial Census, on regular basis, is being conducted in this Country. Even during the year 1921, when the country was passing through a very critical phase of Non-Cooperation movement and Satyagrah, Mahatma Gandhi supported the conduct of the Census in view of its importance for the National Development. Even the Indo-Pak War in 1971 could not affect the Census operations and the Census was conducted successfully. The Census 2011 is the 15th Census in the series the 7th since independence. It is the 2nd Census of the nation in the 21st Century.

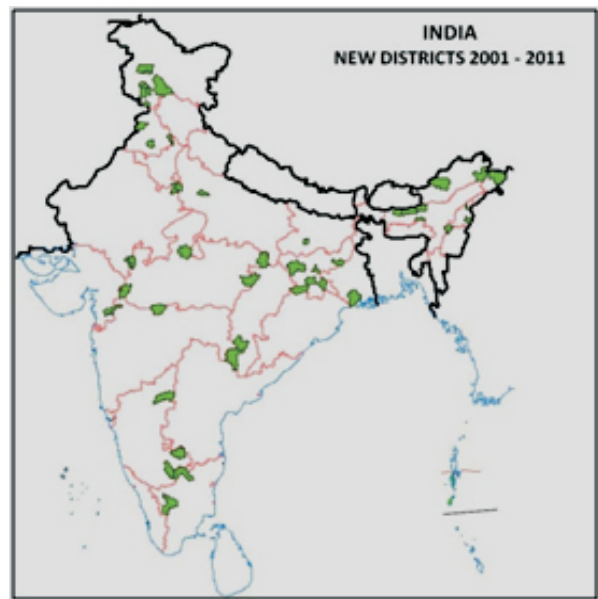
Census-a constitutional obligation

Conducting the decennial Census is a constitutional obligation of the Government of India. Conducted under the Census Act, 1948, it binds the Census functionaries to conduct the Census and failing to discharge their duties is liable to get punishment. The citizens of India are also bound to co-operate and liable to answer the questions asked by the enumerators under the Census Act. The entire Census operation is planned, executed, funded and supervised by the Union Government with active participation and assistance from the respective State Governments.

The Census of India 2011 is termed as the largest administrative exercise in the world where approximately 2.7 million functionaries were deployed at a time of the conduct of census. This number is more than the total population of several countries in the world. Now, we are a 1.21 billion population strong nation in the

world. If we form a human chain on the Globe, then every 6th person will be Indian. Of this 1210 million population, 680 million are males and 580 million females.

To complete this gigantic exercise, a systematic planning is an essential prerequisite; made well in advance before the conduct of the Census. The Census operation is planned purely on existing administrative set up of the Country i.e. states/Ut's, districts, sub-districts (Tehsil, Taluka/PS etc.), villages and wards in towns. That is why maps on all the administrative units are prepared and updated as per the latest jurisdiction.



During 2001-2011, several administrative changes took place, almost at all the levels. During this decade, it is true that neither a new state nor a union territory was created but several new districts, sub-districts, villages and towns were created. For a proper coverage of the entire geographical area of the country, without omission or duplication, administrative changes are to be incorporated in maps of administrative units and these updated maps are handed over to the appropriate Census

functionaries, e.g. state maps to the Principal Census Officers, district maps to the District Census Officers and sub-district maps showing villages to the Sub-district level Officers, generally acting the Charge Officers of that area for Census operations. The Charge Officer divides the entire area into supervisory circles for proper supervision and making the enumeration blocks. On an average, the six Census Enumeration Blocks (CEB's) are supervised by one supervisor. An enumeration block consists of 120-150 Census houses where approximately 600 to 700 persons reside. An enumerator covers this area from 9th to 28th February of the Census year for filling the Census schedules. As a preparatory plan, the enumerator prepares a layout map of the allotted area showing all the houses and other landmark features for easier identification, ensuring total coverage without any duplication and overlapping. The surrounding enumeration block numbers/ details are marked on these layout maps. The enumerator draws the houses and other details as per the pre-fixed legend, already printed on blank Layout maps. The conventional symbols for religious places (Temple, Mosque, Church and Gurudwara), educational institutions (schools, colleges) and health centers are shown by a standard Symbology. The enumerators are trained to put the north direction arrow with utmost care and proper orientation.

The reference date

"1st March, 2011 at 00.00 hrs." is treated as reference date for the Census data. The operation started on 9th February and continued till the mid-night of 28th February, 2011. From 1st to 5th March was the revision round.

The House Listing and Housing census is conducted during the previous year i.e. 2010, which is termed and treated as a frame for the main Census. In the House Listing and Housing Census operation, a proper and systematic inventory of all houses/buildings is made and data on each household's assets and amenities are collected. In this exercise, the data on various aspects like condition of house (Kuccha or

Pucca), its wall material, roof material, number of dwelling rooms, availability and source of drinking water, source of lighting, fuel used (gas, fire wood etc.), availability of kitchen, bathing facilities (within or outside of the house), type of latrine and its availability etc. are collected. The same frame is used again during the main Census with minor changes in the inclusion or deletion of households, if any.

The ORGI with a Govt. Notification freezes the administrative boundaries on 31st December, 2009 till the conduct of the main Census 2011 is over. The creation of any new administrative unit is not permitted after 1st January, 2010 and Census data are disseminated on the basis of these administrative units only. Prior to every decennial Census such directions are issued to the concerned authorities in all the state.

The coverage

There are several in-accessible and remote areas in the country, including the snow bound areas of Leh (Ladakh district) in Jammu & Kashmir, Kinnaur district and Brahmaur (Mandi district) in Himachal Pradesh. It is ensured that these areas get covered whenever they get approachable by the enumerators in the same year. In Rajasthan desert, the villages are widely dispersed in far flanged areas, difficult to access due to non availability of proper transport network. The village hamlets, here, called *dhanis*, are located far away from the main settlement in the village. This phenomenon is quite common in Rajasthan. In the states of Himachal Pradesh, Uttarakhand and Jammu & Kashmir also villages are widely dispersed, hence difficult to approach. Sometimes, a single house is located on the hill top taking one day to reach by an enumerator.

Such village hamlets are called '*Majra*' in Haryana and Punjab, '*Nagla*' in Uttar Pradesh, '*Tola*' in West Bengal, '*Pare*' in Chhattisgarh and '*Purva*' in Bihar etc. In Andaman & Nicobar Islands, there are approximately 572 Islands and total distance from North near Coco Island to Indira point in South is approximately 800 Kms. Out of these 572 islands, approx. 36 are inhabited. It takes a day to go from one island to

another or even some times more. In Lakshadweep Islands, there are eight islands and 22 villages.

The People

Besides this, there are people in the country who are quite difficult to reach out due to one or other reason. Our defence personnel patrolling along the borders/engaged in the field operations, in Cantonment areas, on Navel Ships so on are also covered. Besides, Para Military forces in the country are also covered.

The *Gharana*, the *Mujra Ghar*, the *Chal*, the red light areas are also covered for Census taking. This time, the trans-genders are also covered under the “Others” category. Baggers sleeping on roads, pavements, under the bridges, near river course and on the banks of water drains, along the railway tracks, on railway stations, bus depot etc. are also covered in the Census.

The slums

Approximately 20-30 per cent population in each of the metros in the country is living in slums, the highest being in Mumbai where more than 40.0 per cent live in slums. All such areas are covered by the Census. In Delhi, there are about 30 lakh slum dwellers and all are counted with especially demarcated slum blocks. Last but not least, the Census covers all the physically challenged persons.

GIS technology in Census

In the latest Census, GIS has played a significant role in the Census work. One of the important achievements has been the generation of the digital geographic database going up to the sub-divisional level, showing village and ward boundaries in towns in the country before the start of census work.

One of pre-requisite of any Census is the availability of maps for the latest administrative units in order to have complete enumeration of the entire country without any omission or overlapping. After 2001 Census, several jurisdictional changes took place from district to ward (within towns) level. As a part of Censud preparations, all such changes, taking place after

the 2001 Census, were incorporated with the help of GIS technology. The organization has already completed the task of generating digital database of towns to the extent showing ward boundaries. However, the information on complete layout of buildings and other housing structures, lanes, by-lanes and important landmarks are still in the process for most of the towns in the country.

To address this problem, the organization has also taken-up the task of preparing digital geographic database of each ward showing the complete layout of buildings and other housing structures, lanes, by lanes and important landmarks for the use in delineating Census enumeration block (CEB). In view of large volume of work involved and time constraint, 33 capital cities have been taken up initially. During the field survey, the information on house number, number of floors, purpose of use, type of house and approximate number of persons living in the house was collected. The final digitized databases of geographic entities,



properly geo-referenced ward maps were used to delineate Census Enumeration Blocks.

At the post Census stage, the digital Geo-database of administrative boundaries is extensively used for disseminating Census results. Cartographic presentation of Census results provides a powerful means for visualizing and analyzing the Census results. This supports the identification of local patterns

of important demographic and social indicators. Since the organization has geo-database up to the village level for the entire country, hence is proposed to link the Census data to bring dynamic information system. Thus far the organization has been producing the thematic maps but envisaging a GIS-based Decision Support System (DSS) by bringing spatial and non spatial data together.

(Dr. A.P.Singh is Dy. Registrar General (Map), Office of the Registrar General, India, Ministry of Home Affairs, New Delhi,

Email: drg-map.rgi@censusindia.gov.in)

High Resolution Terrain Mapping of Himalayan Region

Ashwagosha Ganju

Abstract

For numerous applications including numerical modelling of mass movements/mapping of terrain changes, the digital terrain mapping is essential pre-requisite. The DTM with a spatial resolution of 10x10 metres generated using Cartosat-1 stereo ortho-kit data are currently the best terrain product available for the Himalayan region. Such a spatial resolution has limitations for use in several applications in complex terrain like the Himalayan. The present study attempted the development of a high resolution DTM of 1x1 metre spatial resolution for Manali and its environs through digital aerial photogrammetric survey data of 10-15cm GSD; captured using airplane based UltraCamXp frame. The DTM is then evaluated with GCPs collected in the field using Differential Global Positioning System (DGPS) with 95 percent accuracy level. The highest accuracy level, in relative terms, has been achieved in the case of bare and flat areas. However, the accuracy has been observed slightly lower in case of the high slope gradient and vegetated areas mainly due to mountain shadows and covered surfaces.

Introduction

Representation of 3D ground surfaces has been an important research area; various methods have been attempted to represent this phenomena. It is believed generally accepted that the contour map is one of the most important inventions in the history of mapping for its convenience and intuition to perceive. Digital representation of 3D ground surface has been an important focus in geography and surveying sciences for several decades. With the evolution of computing technology, modern mathematics and computer graphics, numerous methods of representing terrain in digital form have been developed and computers have become an important means for the representation of digital terrain surface mathematically and graphically (Li et al., 2005). Geometrical representations with regularly or irregularly distributed points, supported by points and lines are the most frequently used methods in GIS. The introduction of mathematical, numerical, and digital techniques in the field of terrain modelling owes much to the activities of photogrammetrists working in the field of Civil Engineering. Miller and Laflamme (1958) introduced the concept of the Digital Terrain Model (DTM) by defining it as a "statistical representation of the continuous surface of the

ground by a large number of selected points with known X, Y and Z coordinates in an arbitrary coordinate field".

Elevation has been recognized as one of the most essential and fundamental variables in GIS (Atkinson, 2002) for carrying out geometric and radiometric corrections on remotely sensed imagery (Riano et al., 2003). The reasons for this lie in geomorphic significance of Digital Elevation Model (DEM). Elevation models are integrated into the programming of cruise missiles (Ekütekin, 2007) to guide them over the terrain. Resource management (Wechsler, 2003); (Suganthi & Srinivasan, 2010), telecommunications planning (Sulebak, 2000), and military mapping are some of the applications associated with DEMs. As with any other geospatial dataset, DEMs are produced at a number of spatial scales (Table 1), each one has its own cost-effective techniques for data acquisition. While the DEMs with the highest accuracy and correspondingly the smallest spatial extent, are typically based on GPS field surveys, which is costly, labor intensive and time taking method, decreased production costs can be achieved for larger areas but at a lower accuracy by using photogrammetry, map digitization or Interferometric Synthetic

Aperture Radar (Li, Zhu, & Gold, 2005).

Currently, 10 meter Digital Elevation Model (DEM) is available for the most parts of the Indian territory. Nevertheless, this readily available spatial data lack the kind of resolution required to identify the small and medium avalanche starting zones, smooth slope and aspect calculations for larger and identifiable slide paths. Large format digital photogrammetric data produces accurate and precise topographic information from a wide range of photographs and images. Any

measurement taken on a photogrammetrically processed photograph or image reflects a measurement taken on the ground rather than constantly going to the field to measure distances, areas, angles and point positions on the earth's surface. Photogrammetric tools allow the accurate collection of information from rectified precision RS data products.

As the name suggests, Photogrammetry is a 3D coordinate measuring technique using photograph, although photographs are more commonly used now as the fundamental

Table 1: Typical application scales of DTM (modified from Hutchinson & JC, 2000).

Scale	Resolution	Data Sources	Examples of Applications
Micro-scale	0.1 – 5m	Field survey Photogrammetry LiDAR	Civil engineering. Large-scale mapping. Ortho-rectification of aerial photographs. Detailed hydrological modelling. Precision agriculture.
Fine topo - scale	5 – 50m	Photogrammetry Map digitization InSAR LiDAR	Spatial hydrological modelling. Spatial analysis of soil properties. Ortho-rectification and radiometric corrections of aerial photographs.
Coarse topo-scale	50 – 200m	Photogrammetry Map digitization InSAR	Broad scale hydrological modelling Sub-catchment analysis for lumped parameter hydrological modelling and assessment of biodiversity
Meso-scale	200m – 5km	Map digitization	Elevation dependent representations of surface temperature and precipitation.
Macro-scale	5 – 500km	Map digitization	Global circulation models.

medium of measurement. Photogrammetric data capture is based on the stereoscopic interpretation of photographs using suitable photogrammetric equipment (i.e. manual or analytical stereo-plotters). Digital stereo image correlation is used for automatic DTM extraction, which has been used traditionally in surveying and mapping for the reconstruction of terrain, natural targets and buildings in stereovision. Using triangulation, any feature seen in at least two photographs taken from known locations can be localized in 3D. These methods attempts to minimize the data collection effort (e. g. the number of elevation samples to be taken); while at the same time maximizing the accuracy of the resulting DTM will be medium to high. Since remote sensing is

used instead of field work, large areas may be handled in a relatively short amount of time.

In the present study, aerial UltraCamXp camera was used to acquire digital photogrammetric survey data of 10-15cm and to further generate high-resolution and accurate DEMs and ortho-images.

Study area and data used

The study area (Fig.1) falls in the state of Himachal Pradesh covering Manali town and its nearby areas, i.e. Palchan, Solang, Dhundi, Teling etc.; a sub-basin of Beas river lying in the Pir-Panjal range in the NW-Himalaya. This is high mountainous area with mean altitude of approximately 4430 m; comprises of highly rugged hills and mountains with very narrow

valleys, deep gorges of very high gradient. This area has a rapidly growing tourism sector.

UltraCamXp camera, used for the acquisition of digital photogrammetric survey data, offers large image format, reduces the number of flight lines, saves time and lowers cost without sacrificing radiometric performance. The onboard storage allows the collection rate of 2.5 Gbits per second for collecting more data in less time.

The UltraCamXp is capable of collecting stereo imagery at one inch GSD at a flight speed of 110 knots. Accurate flight planning for airborne survey is essential for a total Quality Assurance. Due to the variable and challenging nature of airborne surveys, there were various issues that

needed to be assessed properly. Since getting the suitable weather conditions for flying in Himalayan regions is difficult and also expenses related to a flight mission are very high, proper mission planning at this stage had been very important. Digital imagery was collected on 2nd, 6th and 7th December 2009, using Vexcel UCXp (Serial Number 16477) large format digital mapping camera system. The acquisition took place in clear conditions with good visibility, but a reasonable level of air turbulence. Every image captured has 'individual details' files containing all the information such as time of acquisition, lat/long, date, direction etc.

The data was collected flying between 6000m and 7200m above sea level in order to product



Fig.1 The study area

imagery with a nominal ground sample distance (GSD) of 0.25m. Consecutive photos in each flight line were acquired, having an average forward overlap of 80% to 90% to ensure full stereoscopic coverage. Side lap between adjacent parallel flight lines was a minimum of 60%. Total 23 GCPs had been collected covering the study area. Time consumed on each point was around one hour so that one can measure the point more accurately. PDOP for each point was less than three. Solution types for all the points were fixed and RMS error had been less than 0.05. Wherever possible, these GCPs were marked with paint for identification on aerial photographs. Snaps by digital camera were also taken so that one can identify these GCPs on aerial photographs

Two GPS base-station receivers were operated for the duration of the data acquisition. One receiver was located at the site 'SCHOOL ROOF' and the other at the site 'SASE VALLEY'. This data was collected for use during the processing of the camera position and orientation system (POS) data. The camera sensor positioning and orientation (POS) was determined using the collected GPS/IMU datasets and Applanix POSPac software. This work was all undertaken in WGS84 coordinate system. The data collected at the 'SCHOOL ROOF' and 'SASE VALLEY' and 'SCHOOL ROOF' reference marks were used for this purpose. As no coordinates were available for these reference marks, these needed to be computed. NZAM had available GPS receiver data collected at GCP 4 during the period that the photography collected on 6th December 2009. Single baseline GPS processing was used to compute the coordinates for the SCHOOL ROOF and SASE VALLEY SCHOOL ROOF. The quality of the POS solution was affected by location of the base stations in the valley floor, but the result is generally of reasonable quality.

Methodology

A two step process had been followed to make airborne digital images ready for photogrammetric mapping. This work had been done using the Vexcel software 'Office Processing Centre (OPC)'. For each exposure

made by the Vexcel UCXp camera, it creates 13 sub images. Nine of these images are panchromatic and the other four are the red, green, blue and infrared channels. The collection of images is referred to as the lvl0 images. A two-step process is followed to make these images ready for photogrammetric mapping. This work was undertaken using the Vexcel software Office Processing Centre (OPC). In the first step (Level 1), the 13 images are stitched together and corrected for lens distort and vignetting. In the second step (Level 2 & 3), the radiometric adjustments were made for sun hot spot effects, the exposure effects and the pan-sharpening of the red, green, blue and infrared images. Fig. 2 represents the 'Work flow' of the data processing.

Level 3 data is the photogrammetric mapping ready aerial photography. These images are in TIFF file format, 16bit per channel and contain four colour bands R/G/B/NIR.

The bore-sight calibration photos were processed using Applanix POSMMS CalQC software. Bore-sight calibration report is given in Table 2. The results confirmed that the system was operating within specification and established that the mis-alignment angles were -1.23, 4.29,-0.13 arc minutes. The supplied exterior orientation parameters have had these misalignment angles applied to them. Again, Applanix POSMMS software was used for the computation of the exterior orientation values.

Aerial Triangulation was performed to extend horizontal and vertical control from relatively few ground surveyed control points (14) to each unknown ground point included in the solution. Accuracies of control points, when used in AT, are given in Table 3. The supplemental control points, called 'pass points', were used to control subsequent photogrammetric mapping. In order to easily deal with the image files of larger sizes, a full set of Gaussian overviews had been generated for these images and overviews were used as a replacement to the actual images.

Tie or pass points, used to bridge the images had been collected in such a way that they were well-

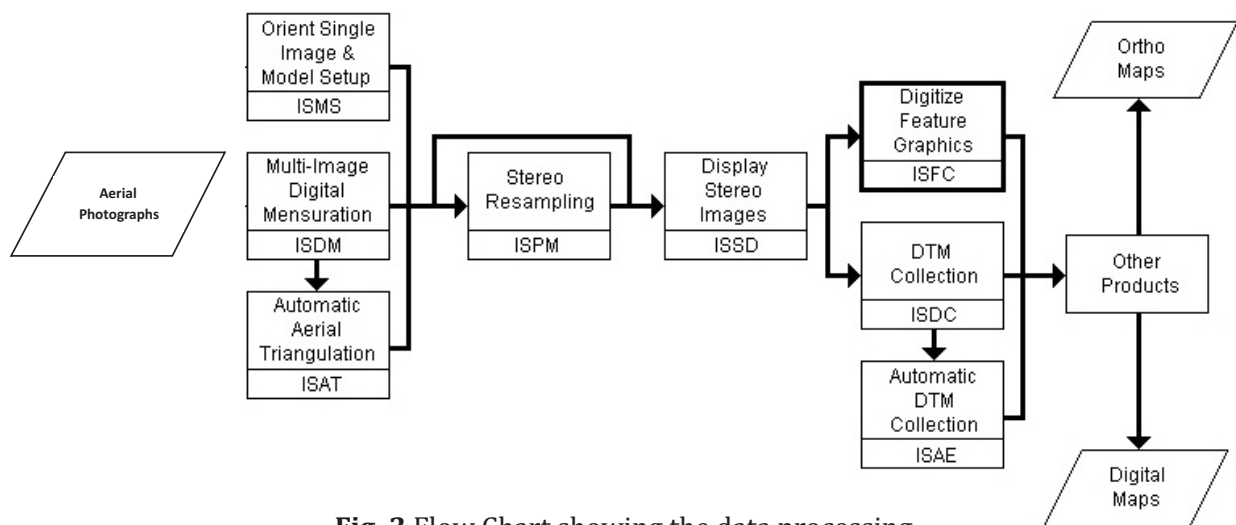


Fig. 2 Flow Chart showing the data processing

defined and well-distributed throughout the model (Fig. 4). Control and check points were measured as pass points. These had been carried through to the absolute orientation process, where they were used as control points. A suitable tie-point pattern was created using the

Project Management utility to generate a well distributed image point configuration. Five point patterns were taken. Strips were tied together in a 4 or 6 image mode, viewing 2 or 3 images from each strip. Bundle adjustment was

Table 2: Bore-sight Calibration Report

Calibration Report	
Number of Iterations	3
RMS of GCP Residuals(Meter)	0.433 0.534 0.167
RMS of Check Points Residuals(Meter)	N/A
Datum Shift X,Y and Z(Meter)	N/A N/A 0.360
RMS of image coord residuals(micron)	2.575 2.617
RMS of Ground Parallax(Meter)	0.168
RMS of Photo centre residuals(Meter)	0.00225635 0.002954 0.00885366
RMS of Photo Angular residuals(Deg)	0.0108801 0.00197574 0.015874
RMS of IMU residuals(Arcmin)	0.653 0.119 0.952
Focal length(mm)	100.500
Principal Point Offset in x(mm)	0.000
Principal Point Offset in y(mm)	0.000
Boresight Angles (Arcmin)	-1.228 4.289 -0.127

performed in relative mode to check the quality of the measured tie-points. Blunder detection was used for on-line checking of model and strip connections. Control and check points were measured. A minimum of three control points were measured to compute an 'Absolute Orientation'. The control points, measured as pass points and carried through to the Absolute Orientation process, were used as control points. Once all the points were measured, they were reviewed and modified till the sigma RMS

values had been adjusted to the tolerance limits.

Bundle block adjustment was performed on the project using all photogrammetry measurement and 14 control points with the assumed standard deviation of 1 cm. Bundle block adjustment was performed to determine the positions and orientations of each image as they existed at the time of image capturing. The process was concluded after ensuring that the RMS values are within tolerances.

Table 3: Accuracies of control points when used in AT

Sl. No.	Name	Point	GIVEN GCPs			Stereo Measured Values			Delta		
			Easting	Northing	Elevation	Easting	Northing	Elevation	Easting	Northing	Elevation
1	kothi	20	706385.35	3577718.61	2514.778	706385.07	3577718.64	2515.37	0.279	-0.032	-0.588
2	gulaba	21	707215.592	3578374.775	2845.539	707215.55	3578374.68	2845.17	0.038	0.095	0.366
3	dhundi	22	700498.611	3581826.188	2922.012	700498.77	3581826.71	2922.13	-0.156	-0.517	-0.115
4	solang nala	23	703101.721	3577476.498	2427.238	703101.89	3577476.2	2427.24	-0.168	0.298	0
5	teling	24	704036.224	3591235.582	3038.139	704036.13	3591235.75	3038.05	0.097	-0.168	0.085
6	Johnson base	25	706052.329	3570001.764	1912.043	706052.530	3570001.820	1912.058	-0.201	-0.056	-0.015
7	gcp3	3	706475.144	3570636.968	1988.58	706474.68	3570637.12	1988.78	0.464	-0.153	-0.199
8	gcp1	1	706064.111	3571895.629	2044.216	706064.86	3571895.57	2044.29	-0.749	0.063	-0.073
9	sase helipad	26	705632.934	3572385.81	1963.167	705632.86	3572385.41	1963.81	0.074	0.397	-0.643
10	marhe	27	708693.498	3581242.458	3314.122	708693.54	3581242.48	3314.77	-0.044	-0.019	-0.646
11	vyas nala	28	709065.859	3581262.966	3228.17	709066.54	3581266.82	3227.29	-0.68	-3.855	0.878
12	gramphu	29	712456.619	3586436.798	3302.362	712456.64	3586436.87	3302.07	-0.024	-0.069	0.295
13	rohtang	30	711248.958	3583467.569	3910.089	711248.96	3583467.61	3910.3	-0.002	-0.04	-0.212
14	koksar	31	710105.93	3588604.166	3094.056	710108.95	3588602.96	3095.4	-3.015	1.205	-1.341

The Planimetric and Height data were captured in blocks pre-determined by the Compilers within the model area to enable other compiler to continue the same model and in the recommended sequence of Hydrology, Road network, Structures and utilities. Break lines and Mass points were collected (Stereo compilation) with sufficient frequency and with a density of points to adequately represent the

terrain features where there is a abrupt change in elevation and where break line are necessary to represent the true geographical character of the terrain. Ridgelines, valleys, cliffs or precipices, ravines and any steep change in the elevation were collected as a break line. Necessary care was taken to ensure that break lines must not cross over one another, but can be snapped in 3D wherever they cross or close

**Fig. 3** Measurement of Tie-points

enough to snap. Break lines were generated (tagged as break lines) from the planimetric features such as roads and other feature which are on the terrain elevation. The break line data ensured that all the model area was covered with accurate height information. Mass points were collected as a regular grid of points that had been manually measured. The grid intervals had been selected in such a way that the terrain was clearly represented without any loss of undulations.

The DEMs were finally generated at 1m spatial resolution (Fig. 4) for the different mapping areas and further edited to meet the accuracy standards. With the help of generated DTM and AT files with respect to the coordinate system and Projection parameters, Ortho Process for rectification of Aerial photos/Images had been applied using the DTM data that represented real ground as closely as possible. An orthorectified image (or ortho-photo) is one where each pixel represents a true ground location and all geometric, terrain, and sensor distortions have been removed to within a

specified accuracy. Table 4 represents the accuracy statics. Orthorectification transforms the central perspective of an aerial photograph to an orthogonal view of the ground, which removes the effects of sensor tilt and terrain relief. Scale is constant throughout the ortho-photo, regardless of elevation, thus providing accurate measurements of distance and direction.

After the generation of rectified orthos, they were all loaded and checked for proper overlap. Then, the seams were captured along the overlap areas of adjacent images. Due care was taken to ensure that collection had been carried out along the hedge lines, roads without crossing any structures. Once the seam line collection and editing was completed, it was checked whether all seam lines consist of assign polygons. Images were stitched together after seam line editing (it

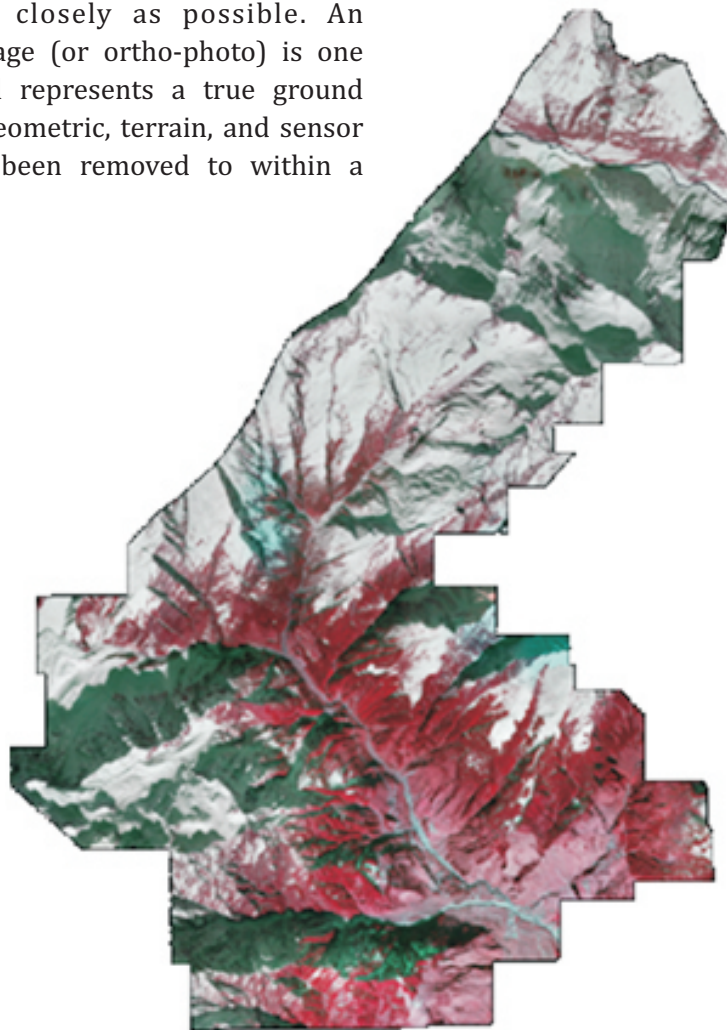


Fig. 4 Extracted DTM of the study area

was ensured that the seam lines do not cross structures and ground features are not cut in an irregular manner) and were made into a single complete Block/Tile, by assigning proper tonal balancing settings. The Production process was carried on.

The removal of hair, dust was carried out on Mosaic Block/Tile. The tiles were then checked for proper color balance along the seam lines. Any imbalances were corrected using Photoshop. After checking for wobble, the stretches were carried out throughout the Block/Tile. In case the intensity of wobble or stretch is found to be more than permissible limits at any locations, those areas were cross checked for the DTM data to be accurate. Corrections were carried out in the DTM data, if any; then re-rectification of corresponding tile had been carried out again. The Blocks /Tiles were prepared with proper color balance and no wobble or stretches. After the Production was

completed, the Block/Tile was checked for overall color-balancing and if any mismatches found; were fixed. Fig. 5 shows the orthorectified, color-balanced, mosaicked data of the study area.

Results and Conclusion

In this study, high resolution DTM of 1m spatial resolution had been generated for the Manali and nearby areas using digital aerial photogrammetric survey data of 10-15cm GSD, captured using airborne UltraCamXp Camera. Generated DTM was evaluated for two different terrain products, i.e Land Categories and Slope Classes with DGPS collected points. Evaluation results are described in Table 4. Approximately overall 95% accuracy had been achieved. The highest level of accuracy was achieved in the case of bare and flat areas, whereas it noted as relative the lower in the case of high slope gradient and vegetated areas mainly due to mountain shadows and covered surfaces.



Fig. 5 Mosaicked ortho-photo of the study area

To cover larger areas at high-resolution and high-temporal coverage, digital aerial photogrammetry is one of the more economic method, achieving comparable accuracies for slope inclinations smaller than 45° and still

acceptable accuracies for most applications for slope inclinations greater than 45°. These high spatial resolution digital aerial photographs are able to map large areas, even in otherwise inaccessible terrain.

Table 4: Accuracy statics

1	Number of Ground Control Points with RMSE	14 Points; RMSE X=0.138,Y=0.143, Z=0.026
2	RMSE for Exterior Orientation	RMS SIGMA = 0.9 um
3	Accuracy at Different Land categories	Bare land = 99%, Vegetation: 9 0%, Snow covered : 95%
4	Accuracy at Different Slope Classes	0-5=99%; 5-20=97% ; 20-45= 95%; >45=89%

Reference

Atkinson, P. (2002), Surface modelling: What's the point? **Transactions in GIS**, 6(1),pp. 1–4.

Ekutekin,V.(2007),**Navigation and Control Studies on Cruise Missiles**, Ph.D. Dissertation, Middle East Technical University.

Hutchinson, M., and J.C. G. (2000), Digital elevation models and representation of terrain shape. In J. Wilson et al. (Eds.), **Terrain Analysis: Principles and Applications**, John Wiley, New York, pp. 29–50.

Li, Z. et al. (2005). **Digital Terrain Modeling: Principles and Methodology**. CRC Press, Boca Raton, p. 323.

Miller, C. and Laflamme, R. (1958), The digital terrain model—theory and applications. **Photogrammetric Engineering**, 24, pp. 433–442.

Riano, D. *et al.* (2003), Assessment of Different Topographic Corrections in Landsat-TM Data for Mapping Vegetation Types. **IEEE Transactions, on Geoscience and Remote Sensing**, 41(5), pp. 1056-1061.

Suganthi, S. and Srinivasan, K. (2010). Digital elevation model generation and its application in landslide studies using Cartosat1, **International Journal of Geomatics and Geosciences**, 1(1), pp. 41-50.

Sulebak, J. R. (2000). Applications of Digital Elevation Models. DYNAMAP “**White paper, 2000**”.

Wechsler, S. P., (2003). Perceptions of digital elevation model uncertainty. **URISA Journal**. Vol. 15, 57-64.

(**Shri Ashwagosha Ganju** is the Director at Snow and Avalanche Study Establishment (SASE), Research & Development Centre, Him Parisar, Sector 37A, Chandigarh - 160036 (UT), India, Emails: a.ganju@sase.drdo.in)

Modern Cartography and the Role of the International Cartographic Association (ICA)

Georg Gartner
President, International Cartographic Association

Honourable..... and Distinguished Delegates

Abstract

The paper argues that cartography as discipline is probably more than ever affected and advanced by technological innovations and developments. New possibilities in acquisition of spatial data, their processing and modelling and finally their distribution are available. In the context of new technologies there is an increasing number of cartographic applications available and in process of development.

In the new situation, it is necessary to redefine the role of cartography and to integrate the theoretical fundamentals with technological developments. In this context the role of the International Cartographic Association (ICA) is crucial.

Modern Cartography

Maps and cartographic forms of expression are gaining currently increasing popularity. This can be indicated by the enormous number of map-based applications in the Internet and the mobile Internet. Maps as interfaces to abundant information systems as well as presentation forms of spatial-related information are offered ubiquitously, either through their application on mobile input- and output devices or on the Internet.

Though number and usage of cartographic presentation forms has increased, many of these popular applications partly arise without considering the fundamental theories and methods of cartography.

Therefore a characteristic of modern cartography is the ambivalence between the popularity of applications in the field of new technologies and the role of traditional cartography. This apparent discrepancy can be solved by understanding maps as medium for communicating spatial information that has various possibilities to cover users' requirements. In the context of modern cartography this involves the increasing aspect

of entertainment, though the function of the information transfer by maps remains constantly important. Briefly, we can state that beside existing cartographic products of high quality, "quick and dirty" cartographic forms of expression increased. These often show other models of usage and production (disposable map) and do not follow simple cartographic basic principles (readability, harmonisation).

Technological developments and the new cartographic applications

In the context of geodata management numerous technologic developments take place and have direct or indirect impact on cartography. This involves data acquisition, data modelling and processing as well as the presentation by cartographic forms of expression and their distribution. For example, technologies in data acquisition like Laser Scanning, Range Cameras or highly resolving satellite images can initiate new developments and applications in cartography (e.g. rapid mapping as quick the provider of cartographic decision-making support in case of disasters) as well as new basic conditions in data modelling as for example service-oriented architecture (SOA), Cloud Computing or the possibility for

data transfer in nearly real time (Real-Time Data Streaming).

The term "Neocartography" is used increasingly to express the collaborative character of integrative possibilities in modern Internet-Cartography. Others use the term "volunteered geographic information" (VGI) to express specific feature of users' willingness to make information available (Goodchild, 2007). In the Open Street Map – Project many users not only make GPS-recorded trajectories available for everyone, but also the attributes and substantial technical content (<http://www.openstreetmap.org>). Finally there are projects, in which users make their information available via simply usable predefined Web 2.0 interfaces, as done in Google Maps or Google Earth (<http://maps.google.at>). The collaborative and social aspect of the "new Internet-Cartography" also caused the term "wikification" in connection with mapping (Sui 2007).

In many discussions especially the question of user's role as the map producer is raised. Apparently many users are interested in producing their own "private" map presentations and visualising individual spatial data. There is a large number of users willing to spend a lot of time for this as volunteers (Gartner 2009). Apart from the heterogeneous quality of the thereby produced data collections and visualisations and the fact, that many presentations not correspond to cartographic standards, the trend towards user-generated data collections and cartographic presentation forms is significant. Obviously, the traditional cartography is asked to develop and adopt simply usable and efficient tools to assure the missing quality standards.

The design of maps in the field of Web Mapping 2.0 is a great challenge due to limitations and restrictions of displays as output mediums for maps in general and especially to the conditions of usage caused by the Internet. Cartographers are recently at the beginning of proposing new design guides for modern web maps, which cope with the interactive user surrounding as well as

enable efficient communication of spatial-related information and correlate to aesthetic aspects. Internet users are not necessarily familiar with existing cartographic principles. Therefore user-defined cartographic presentation forms often result in unreadable and inappropriately designed maps. In this context, there is an urgent need to combine cartographic design guides and user-defined possibilities of using web maps.

Actually the Internet is facing a new phase of development so as to become a part of all-day topics. Even all-day items are able to communicate wirelessly by means of miniaturized sensors and processes. Though, the terms "pervasive computing" or "ubiquitous computing" describe the "holistic integration" of information technology in living spaces, processes and situations of usage.

Thereby wireless communications as well as microelectronics represent key technologies, which can lead to integration of information technologies into smart spaces or smart things. Though it is possible to implement geo-sensor networks (GSN) consisting of numerous tiny, electronic, cheap devices which can monitor their environment, fulfil simple calculation steps and communicate with each other. Such geo-sensor networks will be interesting as automated methods of data acquisition in various fields of application in the future.

From a cartographer's point of view innovative infrastructures for information transfer are of high relevance. Ubiquitous available mobile equipment that can be addressed by means of wireless communication networks can be used for supporting cartographic communication processes (Gartner 2009). The aim becomes more and more realistic that an interactive, real-time, ubiquitous, location-based and permanently available cartographic communication processes can be developed, that allow context-related and individual geo data transfer by cartographic means. That would lead into tailored individual support in the solution of spatial problems or decisions. For

example, a navigation scenario can be used in which the environment itself supports a user in locating him in space of his presence and finding the desired route.

Pushed by the availability of regularly upgrading new generations of mobile input and output devices (mobile phones, smart phones), the expanding telecommunication industry and the increasing data transfer rates of mobile communication, especially the development of information services respectively entertainment services on all kind of mobile devices are of high dynamic currently. In the case the coordinates of the user's device can be used as variable for the modelling and presentation of information such systems can be called Location-based services, which gain a lot of interest from developers currently as well.

The ICA and its research agenda

The International Cartographic Association (ICA), globally well represented and internationally visible organization, has a special position and role as a promoter of Cartography and GI Science especially in this current dynamic situation. Research and development in ICA aim, in general, to create theory and methods for Cartography and GI handling, addressing all the challenges being brought up by applying new technologies for cartographic tasks. By applying theories and methods to various applications, new tools can be created for cartographic and GI practice. Such topics are addressed at the main work-forums of ICA, its Commissions. These organizations are formally established by vote at the quadrennial ICA General Assemblies, although interim Working Groups can also be established between General Assemblies by the ICA Executive Committee (EC) to address specific short-term issues.

One of the main instruments of ICA is the Research Agenda. The agenda is written in order to show ICA's actual and potential contribution to scientific research within our global society, and to serve as a moderator in that forum. In order to implement its own strategic mission, "to ensure that geospatial information is employed

to maximum effect for the benefit of science and society" (ICA Strategic Plan, 2003), the ICA must have a clear cut agenda for research covering all fields and topics under the title Cartography and GI Science. This agenda, therefore, documents current research activity in these fields, suggests areas requiring more intensive or renewed efforts, and discusses the methods by which a part of this research can be undertaken—within ICA Commissions, through international collaboration with sister societies, and under suggested programs of integrated research stimulated. It also reveals the gaps, e.g. items seen as important for the agenda but not intensively covered by the research activities of the Commission and Working Groups.

The scope of the agenda is wide, including both Cartographic and GI Science issues. Depending on the background of the interested researcher, the entire field can be approached by several ways. It is impossible to make a generic structure of the topics that fits all opinions. It is also impossible to create a non-overlapping hierarchy of research topics. What has been done on the basis of common discussions has now been organized under subtitles or keywords. The definitions as presented by ICA have also influenced the scope of this agenda. The main intention is to ensure that the topics discussed here fall within the accepted extent of Cartography and GI Science, and that we can also see synergies with closely related fields, notably in spatial data collection and handling.

The Research Agenda deals with the following aspects-

- i) Geographic Information, GI
- ii) Metadata and SDIs (In the text spatial data infrastructures (SDI) has a synonym of 'geospatial data infrastructure'; by adding the geo-prefix we can emphasize the real contents of the data in question)
- iii) Geospatial Analysis and Modelling (The emphasis is on the extraction of added value from the processing of spatial data on maps and the use of analysis and modelling techniques to initiate, support and

supplement the mapping process)

- iv) Usability (This keyword covers a range of issues which connect the human user of spatial data with its representation, its processing, its modelling and its analysis)
- v) Geovisualization, Visual Analytics (Here the visual representation of spatial data, in map and in other forms, is discussed, along with methods of using such representations)
- vi) Map production (This keyword stands for the numerous stages in mapping and map production as technical processes, but also production of various map types from Atlases to Internet maps.)
- vii) Cartographic Theory (The fundamental concepts which form the basis of all our spatial data handling are incorporated under this keyword)
- viii) History of Cartography and GI Science (The importance of the development of methods and practices throughout history was recognised in the brainstorming session: all current-day activity is informed by detailed accounts of such development)
- ix) Education (To ensure a valid and viable future for our current activity, we need to research and implement methods to educate and train future generations: methods of doing this fall under this research heading)
- x) Society (A dominant research topic throughout has been the examination of how such spatial data handling is grounded in societal structures and how it is undertaken by different groups of people)

The detailed and differentiated research agenda can be found at www.icaci.org.

Conclusion

Technological innovations have resulting in creating of parallel worlds in cartography. On the one hand, there is traditional cartography with a long history, profound knowledge and approved

methods, on the other hand there are a growing number of non-professional users, who often create and use cartographic forms of expression by using available technologies.

Strategies to connect these worlds are necessary, if postulating that this would be of advantage. These can be reached by new and modified education programs as well as the strengthened contribution of cartographic knowledge into the world of new applications. Thereby Freitag's (2008) requirement for further development of the theoretic basics for cartography can be used to explain the actual phenomena. Freitag (2008) argues that all theoretic models of the cartographic communication process miss the consideration of the social context of communication. To illustrate the all aspects of cartographic communication, he suggests a model that connects dialogue-oriented processes with collaborative ones. He also suggests that the function of the map should be clarified explicitly for certain user groups, so that the basic communication model will become relevant for concrete activities of the users. Such a model would define cartography more holistically than that of today; and would consider the social aspects within the communication model equally to technical aspects. The ICA is trying to meet this challenge by their proposed research agenda.

References

- Freitag U. (2008), "Von der Physiographik zur kartographischen Kommunikation - 100 Jahre wissenschaftliche Kartographie". In **Kartographische Nachrichten**, 58 (2), pp. 59-67.
- Gartner G. (2009), "Web Mapping 2.0", In: M. Dodge und R. Kitchin eds: **Rethinking Maps**, Routledge, 2009.
- Goodchild M.F. (2007), "Citizens as Voluntary Sensors: Spatial Data Infrastructure in the World of Web 2.0", **International Journal of Spatial Data Infrastructures Research** 2, pp.24-32.

Sui D. (2007), Volunteered Geographic Information: A tetradic analysis using McLuhan's law of the media. **Workshop on**

Volunteered Geographic Information, December 13-14 (<http://www.ncgia.ucsb.edu/projects/vgi/products.html>)

(**Professor Dr. Georg Gartner** is the President, International Cartographic Association, and Head, Research Group Cartography, Department of Geoinformation and Cartography, Vienna University of Technology, Erzherzog-Johann-Platz 1/127-2, A-1040 Vienna, Austria
Email: georg.gartner@tuwien.ac.at)

Generation of Database and Implementation of Web Enabled Water Resources Information System in India (India-WRIS WebGIS)

www.india-wris.nrsc.gov.in

Jaswant Raj Sharma

Introduction

"Generation of Database and Implementation of Web Enabled Water Resources Information System in the Country", shortly known as India-WRIS WebGIS, is a joint project of the Central Water Commission (CWC), Ministry of Water Resources, Govt. of India, New Delhi and the Indian Space Research Organisation (ISRO), Department of Space, Govt. of India, Bangalore. The project aims at to create a 'Single Window' solution for comprehensive, authoritative and consistent data and information of India's water resources along with allied natural resources in a standardized national GIS framework (WGS-84 datum and LCC projection) with tools to search, access, visualize, understand and analyze the data for assessment, monitoring, planning, development and finally the Integrated Water Resources Management (IWRM).

The main objectives of the project are to-

- i) collect available data from varied sources, create database on country's water resources and organize in standardized GIS format and provide a thin client scalable web-enabled information system,
- ii) provide easier and faster access to share nationally consistent and authentic water resources data through a centralized database and application server to all water resources departments/organisations as decided by CWC,
- iii) provide tools to create value added maps by way of multi-layer stacking of GIS database so as to provide integrated view to the water resources scenarios, and

iv) provide foundation for advanced modeling and Spatial Decision Support Systems (SDSS) including automated data collection system.

Based on the data type and availability, the present portal contains 12 major info systems, 35 sub-info systems having 108 spatial layers along with large attribute data of water resource assets and temporal data of 5-100 years. Based on National Map Policy (2005) and CWC data dissemination guidelines, public domain version has been developed and complies with both.

India-WRIS WebGIS Portal: A Brief

The India-WRIS WebGIS Portal has been designed and developed keeping in view multi-users from all sections of society, varied and multi-source data input, current map policy, existing guidelines, regular updating needs, near real time data accessibility, data security domains and scale of information. Further there are three user categories for access of GIS data and value added products as per map policy and data dissemination guidelines, listed as follows:

- General Users (public domain fast track system)-Users are able to visit web Portal and get the snapshots of the data sets on reduced scale of selected database and tools.
- Premium Users - Users are able to get access to the India-WRIS web application datasets in detail and tools by registration and password.
- CWC Intranet Users - These privileged users are able to get the full access to the India-WRIS web application and database. All the facilities developed are accessible by these users.

The information system on water resources has the four key elements besides other facilities namely: (i) Data input/entry/collection system; (ii) Interactive system for geo-visualization and temporal analysis; (iii) Data storage, analysis, and transformation into 'user friendly' information; and (iv) Information dissemination system in public domain as downloads and further processing tools for value addition and customization.

India-WRIS User Interface

Considering large number of factors such as type and volume of data, number of different users, ease of handling, diverse nature of internet connectivity in the country, information requirement by the users and available technologies, utmost care has been taken by the WRIS team to design the user interface of the portal.

This module provides the user in discovering information contained in India-WRIS of a particular geographic area. The user can select area of interest based on the Administrative units, Hydrological units and Constituency wise and is presented with a condensed list of all the

information available in India-WRIS for the area.

Home Page and Front GUI of India-WRIS WebGIS

In the following, the main menu toolbar, universal toolbar, and general information toolbar along with respective sub-menus are briefly detailed in the following.

I. Main Menu Toolbar

The main menu has six modules namely, WRIS Info Discovery, WRIS Explorer, WRIS Connect, Input Data Builder, Share Success Story and Create Your WRIS. This is the core of India-WRIS information system where all the major links to the various WebGIS modules are provided in a rich Graphical User Interface (GUI) assisted format for easy access and use.

i) WRIS Info Discovery & Data Catalog

This module provides the user in discovering information contained in India-WRIS of a particular geographic area. The user can select area of interest based on the Administrative units, Hydrological units and Constituency wise and is presented with a condensed list of all the information available in India-WRIS for the area.



ii) WRIS Explorer

This is the core module of India-WRIS WebGIS where all the data can be explored and viewed using the various tools available for the purpose.

- **Geo-Visualization** - This section provides basic facility to visualize all the layers together in any combination by turning layers on and off as per the requirements.
- **Sub-Information Systems** - There are 12 major information systems namely, base data, surface water, ground water, hydro-met, water quality, snow cover/glacier, inland navigation waterways, inter-basin transfer links, hydro-met extremes, land resources, water tourism and socio-economic. These have been further divided into 35 sub-information systems. Each sub-information system is based on a particular theme. It contains relevant layers and specially created tools to make the best use of the data.
- **Temporal Analyst** - A large amount of water resources and related data regarding hydrological, meteorological, pollution etc. are temporal in nature. In order to represent these datasets, a separate module has been created where facilities are provided to represent the time series data using suitable charts, animations and to compare the data across stations or years.

iii) WRIS Connect

The sub-modules in WRIS Connect are:

- **Query Interface** - User can have lot of queries answered directly through WRIS Explorer and associated available tools. To explore more details, user can place queries through Query Interface that contains set of fixed queries on various hydrological parameters. The answers are generated through different permutations and combinations of these fixed queries. The result of a query is displayed in spatial as well as non-spatial formats.
- **Report Generation** - This section has the utility to automatically generate report of

the user defined area / region containing the all data into tables and maps and allows Save As and Download in .pdf format.

- **Data Download** - Apart from viewing the available data, the user may also wish to take the data and perform analysis / add value. This link allows the download of GIS layers and associated attributes.

iv) Input Data Builder

This module aims at keeping the data content of the various layers of India-WRIS up to date by providing facilities to the data providing sources to ingest the current attribute data directly into the relevant layers. The authorized users can enter the respective spatial and non-spatial data in the specified format into the information system through this facility. The three sub-modules of Input Data Builder are Spatial, Non-spatial and Metadata Input Builder.

v) Share Success Story

The objective of this module is to connect people for water resources planning and management by providing platform to upload the success stories so that others can view, interact and practice.

vi) Create Your WRIS

This module provides facilities to the user to have further analysis of the downloaded data, adding new datasets using available general hydrology tools and generate report of the area.

II. Universal Toolbar

Universal toolbar is present at the top of the home page and has two sections.

First section - The toolbar at the top of the page contains the links to popup window having information required by the user at any point and toolbar is visible at all times. The links in this toolbar are:

i) About WRIS- contains a brief overview of India-WRIS project including its history, scope, vision, goals, deliverables and time-frame for completion.

ii) Accessibility- provides information for

navigating through India-WRIS like screen resolution, keyboard shortcuts for easy navigation etc.

iii) Tools - Numerous tools along with symbols for easy access are described in this part.

iv) Metadata - leads the user to the Metadata Explorer which provides comprehensive information of the source of spatial and non-spatial data.

v) WRIS Wiki - Comprehensive information for the water resources assets and projects of the country is made available through WRIS Wiki application.

vi) Help - A comprehensive and universal help is documented in this section assisted with diagrams, screenshots and short videos.

vii) Search- Consolidated search into the complete information system is provided.

Second section - The advanced information toolbar is available right below the banner. It contains links to pages containing detailed information that a user requires when visiting the home page but may not require while exploring the other sections of the information system. The links available in this toolbar are:

i) Home- leads to the main page of India- WRIS Portal.

ii) Publications - Various documents generated for India-WRIS are made available and reports being generated would be available to the users through this link.

iii) Gallery- presents the user with an image gallery of events related to development of India-WRIS project.

iv) WRIS Mobile - A precise version of India-WRIS is being developed for mobile and handheld devices.

v) FAQ - contains answer to common questions and queries about the project and outcome.

vi) Feedback- provides interface to post user suggestions and feedback.

vii) Sign In/Register- provides provision for

new user to register and get connected to India-WRIS portal for updates. For downloads and providing data inputs, login is provided based on user categories and with a password.

III. General Information Toolbar

This toolbar is available in the lower section of the home page and provides links to general information about India-WRIS as Visitor Number, Disclaimer, Sitemap, Links, Contact Us and Last Updated.

India's Water Wealth

On an average, India receives annual precipitation (including snowfall) of about 4000 km³. There exists, however, a considerable spatial and temporal gap in the distribution of rainfall and hence in availability of water in time and space all over the country. It is estimated that out of the 4000 km³ water, 1869 km³ is average annual potential flow in rivers available as water resource. Of this, only 1123 km³ is utilizable (690 km³ from surface water resources and 433 km³ from ground water resources).

The water demand in 2000 was 634 km³, likely to reach 1093 km³ by 2025. Due to rapid growth in population coupled with growing economy of the country, there will be continuous increase in demand for water, and it will become scarce in the coming decades. According to the international norms, a country can be categorized as 'water stressed' when water availability is less than 1700 m³ per capita per year, and 'water scarce' if availability is less than 1000 m³ per capita/per year. In India, the availability of water in 1991 and 2001 was 2309 m³ and 1902 m³, respectively. However, it has been projected that per capita surface water availability is likely to get reduced to 1401 m³ and 1191 m³ by 2025 and 2050, respectively. The per capita water availability in the country was 1588 m³ in 2010 against 5200 m³ soon after independence in 1951.

Some facts are stated in the following:

- Area of the country as % of world area: **2.4**
- Population as % of world population : **17.1**

- Water as % of world water : **4.0**
- Rank in per capita availability : **132**
- Rank in water quality : **122**
- Average annual rainfall 1160 mm (world average 1110 mm)
- Range of distribution 150 -11690 mm
- Range Rainy days 5-150, most rain 15 days in 100 hrs
- Range PET 1500-3500 mm
- Per capita water availability (2010) in m³-1588

India-WRIS WebGIS Application Architecture

The three major components in India-WRIS WebGIS application are:

i) Database design and generation: Water resources data are highly complex with numerous sources involved. A large part of the data is spatial in nature but the amount of associated data is vast with many layers having time series component. These data are bound to increase exponentially with the passage of time. The creation and management of such data are colossal feats, requiring state of the art tools. The database standards and relationship have been developed for all type of data. The database generation software used has the capabilities of creating maps, viewing or exploring and editing data, storing, conflation (integrating datasets from different sources) and transforming into different coordinates systems etc.

The database generation for India-WRIS has

S. No.	Water Resource at a Glance	Quantity (km ³)	Percentage
1	Annual precipitation (including snowfall)	4000	100
2	Precipitation during monsoon	3000	75
3	Evaporation + Soil water	2131	53.3
4	Average annual potential flow in rivers	1869	46.7
5	Estimated utilizable water resources	1123	28.1
	Surface water	690	17.3
	Replenishable groundwater	433	10.8
	Current utilization of total	634	15.85
	Current utilization of utilizable water	634	56.45
	Storage created of utilizable water	225	20.03
	Storage (under construction) of utilizable water	171	15.22
6	Estimated water need in 2050	1450	129

Source: Water Resources at a Glance 2011, CWC, New Delhi, (<http://www.cwc.nic.in>)

been done using the latest, state of the art software, capable of handling complex data of large sizes in multi-user environment. This data resides in the form of geo-database, which is a Relational Database Management System (RDBMS) file format for GIS data and allows the India-WRIS database to be manageable, scalable, compatible and easy to write queries for fast retrieval of results through web based applications over internet.

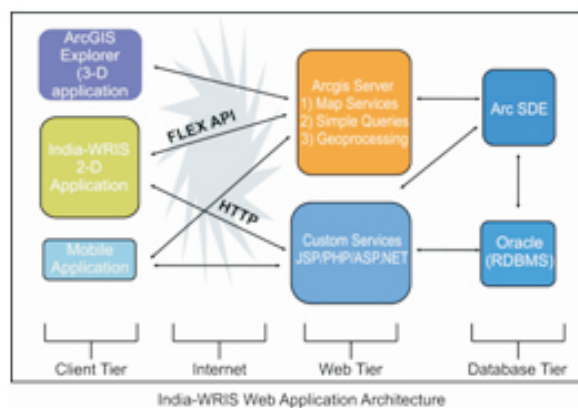
Web application and user interface technology: Data dissemination is the major user requirement from the web portal; hence an advanced GIS data processing systems at the back end augmented with the best database connectivity over the internet is used so that a user gets intuitive and real time information. A user has the facility of data visualization, analysis on the client side and it further use so as to create customized reports. Adobe Flex is able to deliver Rich Internet Applications (RIAs) across the enterprise and over the web efficiently. Using the freely available Flex API, India-WRIS combines GIS based Web services from ArcGIS Server with other Web content, which are displayed in simple, dynamic mapping applications over the Web. All the published map services are compliant with Open Geospatial Consortium (OGC) standards and the services can be accessed using Web Mapping Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS) and Keyhole Markup Language (KML) standard formats. India-WRIS system is using Oracle 11g, RDBMS which supports multi-user system. ArcSDE as well as Oracle together used to handle geospatial data and to create multiuser geo-data base.

Database storage and Web hosting: In order to ensure reliable and secure availability of the WebGIS round the clock, a robust hosting architecture has been designed. The same has been replicated at three places namely, RRSC (West)-Jodhpur for the data generation and software development centre; NRSC- Hyderabad for web hosting and CWC - New Delhi for intranet users and data validation and updation.

Tools

India-WRIS tools are organised into six categories:

1. Navigation Tools
2. Display Tools
3. Search and Query Tools
4. Personalization Tools
5. Advanced Tools
6. Sharing Tools



(**Dr. J.R. Sharma**, is the Scientist/Engineer 'H', Project Director (India-WRIS) & Chief General Manager, Regional Remote Sensing Centres, NRSC, ISRO, Department of Space, Govt. of India, CAZRI Campus JODHPUR – 342 003,

E-mail : jrsharma@hotmail.com, jrsharma50@gmail.com)

BACK TO HANDSHAKE

(A Plea to Restore Harmony between Geography and GIS/Cartography)

Jawahar Lal Jain

Abstracts

Loss of harmony between Geography and modern Cartography, so pronounced in India, that characterized the two traditional subjects in yester decades, has nearly robbed geographers of the vast new scopes of GIS-based jobs that are being hogged by the new breed of resource scientists. This situation is actually causing much damage to geographers as well as the new geospatial scientists without a geographical background from their pre-college education. Again in today's world of all-pervasive geospatial technologies a basic grounding in geospatial concepts has become indispensable, which can be ensured by making it an integral part of general school education.

With these convictions and tenets the paper seeks to bring the two disciplines back to handshake. It then briefly analyses how this rift has come about so very pronouncedly in India between the two sister disciplines, and suggests a plausible remedial way for incorporating a new, synthesized subject, e.g. 'Earth & Geospatial Science' at the higher secondary school level – as an additional subject, to begin with, available to students from all streams: Science, Biology, Humanities, and Commerce. For this it envisions an action plan with necessary concomitant preparations, and notes down the opportunities and resources and can be readily tapped for the purpose.

Any suggestion involving structural reorganization of secondary school education is sure to meet much initial resistance as the system is already quite packed and has a long chain of repercussions. Once come over that, there are many rich resources/assets that can be readily tapped for the purpose e.g. ESRI's several tutorials and lesson plans with suitable soft ware and datasets. There is already a GIS Tutorial based on indigenous GIS package, e.g. GRAM++, and other such resources. EDUSAT lessons on pertinent topics can as well be simplified to secondary school level.

If implemented as envisioned, the new subject in HSS system will: (i) acquit general educated gentry with basic understanding of how the geospatial technology works and how to efficiently use the universal gadgetry based thereon; (ii). poise a large section of matriculates to follow up the new subject of vast employment potentials at higher levels of learning; (iii) produce better grounded geospatial scientists - geographers and other; and (iv) bring the geospatial revolution full-circle in India at the societal plane, so that the common man and end user also respond coherently to the upcoming geospatial workflow of offices and institutions, etc.

Geography -Cartography Relations

At their dawn Geography and Cartography comprised nearly a common pursuit of knowledge. Subsequently there set in a long and gradual process of bifurcation and differentiation. As Cartography developed subsequently into a more and more specialized science, art and skill of map making and

mapping (i.e. surveying) essentially as an applied profession, Geography started putting pertinent pieces together and discerning layout or pattern of various natural and man-made elements heavily bearing on the life of man and on the grandiose theorization about them. Down the course, many and varied specialized sciences started taking shape; they would deal

with specific elements/aspects of nature and human life. Encompassing so varied and multitudinous elements in its scope, Geography as a discipline tended eventually to be an academic Juggernaut; though it served well as an overall general subject and as a backdrop to various other subjects. Thus, it remained essentially an academic subject – as well as a general background force contributing to other, later branches of higher learning.

The Problem

As a growing number of subjects segregated into specific sciences and humanities (or social sciences), Geography found itself precariously stumbling on the fences of this grouping, as its core roots essentially lay in the fundamental sciences and mathematics whereas its huge superstructure spawned extensively in social sciences and humanities fields. As such it was much taut between these subject categories. Varying as the history of subject development in different parts of the world has been, Geography in India nearly threw to winds its science moorings and drifted decidedly towards social sciences. The physical-astronomical foundations of the subject virtually suffered a gross neglect—much to the detriment of the larger subject as a whole. Thus the two sister disciplines of Geography and Cartography that had long been intimately and extensively interfaced drifted apart, impairing the common bond between them. And this phenomenon was much more pronounced in this part of the world due largely to certain elements of school education system in the country.

Over the last four decades map-making and mapping science (call it Cartography, or whatever) have undergone radical and revolutionary transformation resulting in an ensemble of several related technologies and their multifarious applications – now loosely and collectively called Geospatial Technology (or, simply GIS in popular image). This new subject-complex of vast applicability is rather technical in nature, and is now much coveted among graduates of many subjects from science and technology stream, despite their lack of

moorings in Geographic-Cartographic concepts in their early training – say, at the Higher Secondary or the Graduation level.

Geographers, often sweetly oblivious to and imprudently negligent of the scientific foundations of their subject, now perforce avert or circumvent this subject-complex allied to their own subject methodology. Even so, some Geographers or Geography Departments look rather indifferent to even the elementary cartographic contents of their syllabi. This growing, paradoxical situation is doing incalculable harm to Geography and to the professional careers of Geographers, depriving them of the vastly expanding job opportunities, whereas other professionals are garnering these jobs only by virtue of acquitting the geospatial tools and techniques. Does it not warrant a huge, urgent action to rectify this fallacious situation!

Manifestations of the Sanguine Affinity

It is worthwhile to notice that Association of American Geographers' (AAG's) landmark work on the position of American Geography around the mid-20th Century, edited by PE Jones & CF Jones presenting the stock position of various aspects or branches of Geography, featured a full article on 'Geographic Cartography' authored by AH Robinson and others. Prof Robinson of Wisconsin University and Prof. Erwin Raisze have been the father figures of academic Cartography in the American world. The celebrated cartographer, Prof. Raize was the Map Supplement editor to the AAG for long.

Several national and international societies in the Cartographic field started in close liaison with corresponding bodies of Geography. As the International Cartographic Association (ICA) was being mooted in late 1950's, International Geographical Union (IGU) in its 1960 Congress at Stockholm considered affiliation and liaison with ICA; and Prof. Carl Troll represented IGU at the first general assembly of ICA in Paris in 1961 (CB Mureil Lock, 1969). The First General Assembly of ICA was organized in concert with IGU Congress in 1964 in London, wherein Prof. SP Chatterjee presided over the joint IGU-ICA

session. Much the same way, the 1968 New Delhi IGC also had the ICA Congress along side, and the joint IGU-ICA session was again presided over by Prof. Chatterjee (P Nag, 1992). This hand-in-hand convention of joint or concurrent organization of their foremost international events continued through 70's and 80's; which truly bespeaks of the harmonious and symbiotic progress of the two disciplines and of the essential commonality of ethos and complementarity of their aims and methods—if maps served as basic tools and language of the cognition and communication of Geography, the latter in turn furnished perhaps the most comprehensive application of maps in the most varied and subtle ways. In fact Geographers often carry out further mapping of even very complex and composite themes in ingenious ways, topping it with comprehensive interpretation—so much so that they may be deemed partly cartographers themselves.

As a result of major revolutionary developments that made their debuts in the 70's and 80's in the field of global survey, mapping and monitoring resources, Cartography was much transformed through several, inter related, satellite-based survey and mapping technologies. Complimentary nature of relationship between Geography and the newly emerging Geospatial technologies too is manifest in the concurrent organization of IGU and the International Society of Photogrammetry & Remote Sensing (ISPRS) Congresses in Washington in 1992. There is again good liaison between the premier US bodies of AAG and the American Society of Photogrammetry & Remote Sensing (ASPRS).

In India as the National Association of Geographers, India (NAGI) was revamped and Indian National Cartographic Association (INCA) was formed anew in 1979, the two bodies had a great deal of liaison and inter-representation. INCA essentially started as a composite body of mapping technocrats (mostly the Survey of India officers), and academicians (mainly geographers). So much so that NAGI and INCA used to send their delegations to each other. However, the two sister organizations as

if soon appeared poised to part their ways; and geographers' participation in INCA dwindled as they were shying away from the emerging new forms of Cartography. Only once, perhaps as a lone exception, however, INCA and the NAGI Congresses were both organized in consecutive days by the Department of Geography, Mysore University in 1988 under the stewardship of Prof. PD Mahadevan.

Etiology of the Problem

If Cartography mutated lately into a distinctly more technical discipline through the electronic-digital transition and has become strictly computer-Sauvé in the process, the age-old academic discipline of Geography has shifted much towards social science – much to the callous neglect of its physico-natural aspects in India during the late 20th Century. And thus the two sister disciplines of yore now look poles asunder. Also the traditional Cartography stands virtually subsumed under, if not superseded by, the GIS – which is a different, if rather controversial story.

Geographers: The Looser

This shyness to newer forms of Cartography was due largely to, as said before, the Cartography rapidly and radically mutating into a more computer-suave, technical subject-complex, whereas Geography was turning more and more into a social science, particularly in this part of the world. All along, and at variance with geographers, several other professional individuals and institutions found the New Cartography, or rather the geospatial technology, much more coveted and convenient as it greatly eased field mapping and management of resources; and they started taking fullest advantage of vast opportunities of jobs through training in emerging geospatial technologies. Very many of them also started active participation in the activities of INCA.

Geographers find themselves lost and engulfed in a blind alley; and dismayed that the development planning in the backdrop of resources and environmental factors and such other socio-economic issues they had recently

taken to heart all end up today in GIS methodology – the very thing they had lately shunned away from. On the other hand, the new technocrats and resource scientists find that not only resource monitoring and planning but almost all activities fall upon, or are amenable to, the common denominator of GIS methodology and data sources. They rejoice at it as the new, opening 'El Dorado', even though they not infrequently find themselves hampered for their inadequate grounding in many Geographic-Cartographic concepts. Trained in this methodology and technology, they nevertheless stand to reap and bag nearly all job opportunities including the ones the geographers conventionally deemed central to their innate proficiency and skill – yes, that is the irony of situation!

Thus both the bodies and their professionals/ academicians now feel at loss due to the unfortunate divorce of the long, happy marriage between the traditional Cartography and the old, holistic Geography. And surely, geographers are by far more at loss, more at fault. Even so, they seem to ignore the huge range of socio-economic applications of GIS that were highlighted early on (Martin, 1991).

Deeper and Extraneous Roots of the Malaise

The basic malaise of this situation lies in the school education system in India; e.g. the drastic dichotomy of Sciences and the Humanities (the so-called Arts subjects) at higher secondary level of school education; and in the callous tardiness with which the teaching-learning of the Arts subject is pursued vis-à-vis the Science subjects in the very same schools, and even in the colleges or respective university departments. As such the nominal or incipient difference of inherent I/Q of students between these two streams at the start of bifurcation snowballs and becomes preposterously manifest by the fag end of higher secondary level. Moreover the students (as well as the teaching faculty) of the Arts subjects become utterly non-serious and complacent about their studies, and are rather beguiled into spuriousness. So too, whatever basic

fundamentals of Science & Mathematics they were exposed to till the high school level become dusted and blurred in the process.

This situation becomes grotesque and preposterous in the case of subjects that are founded strictly on Science & Mathematics but have an extensive coverage and scope extending far into the realm of social sciences. The most typical case is furnished by Geography, though several other subjects also stand on similar ground (Anthropology, Psychology, Archaeology, Criminology, etc.) Despite Geography being grouped with science faculty nearly in half of Indian universities, the subject has come to be manned mostly by graduates of Arts/Humanities streams, who inherently shun away from the physical and mathematical branches of the subject and instead focus on human aspects such as Economic, Social, Political and Regional, etc.

Renewed environmental concerns of the day and the Earth-system Science centered on them obviously demand a good deal of science, and must particularly reinstate Physical Geography in a holistic sense in the central sanctum. That, however, is the first major casualty of the preponderance of human or social geography over its physical aspects. Its content now stands more descriptive than analytical. The teaching-learning quality and professional rigor appear to have gone deplorably lukewarm. Even so, Geography—once the ubiquitous subject of school education – now figures in much fewer schools at the higher secondary level. At lower level it is simply part of the Social Studies which is taught, more often than not, by a non-Geography graduate. This does no justification to fundamental Geographical concepts which call for sound understanding on the part of the teacher for their effective explication and elucidation. Naturally, few of the students so taught will tend to later opt for Geography in this situation.

A Redressal- Initial Problems

Consideration and analysis of the problem in foregoing naturally lead to suggesting some

remedial change in the secondary school education system of the country. However, suggesting any substantial change in the structure and organization of school education system is tantamount to opening the Pandora Box. School syllabi generally are packed and encumbered, particularly at the Higher Secondary stage. In an era when so many newer sciences or new areas of concern are rapidly cropping up, voice is frequently raised to include this new subject or that in the school syllabi; however, things are easier said than done. Sometimes newer subjects are offshoots or mutations of some old subject/s. While newer things are often included easily, older things are hardly ever discarded as readily.

A Surgical Redressal

Notwithstanding all the pragmatism of avoiding to 'take the bull by horns', one cannot avoid to squarely face the real problems. To make good the deep-rooted malaise explicated in foregoing, it is imperative to implement a comprehensive and radical reorganization at the high & higher secondary school education level. It is proposed that NIEPA, NCERT and state boards, on hand one, and Geospatial institution and academicians should ponder over a comprehensive new subject – say, Earth and Geospatial Science – at the HSS level, to be offered, in the transitional phase, as an additional subject to students from all streams e.g. Science, Biology, Commerce and Humanities (Jain, 2011). This subject may include a fair amount of physical and planetary geography as well as geographic-cartographic concepts, which should be organized as a subject. Some school boards have recently included some sections on Earth Science, Environment and Climatic Change and are mooted some section on remote sensing data in their curricular schema. These sections on Environment and Climatic Change may be consolidated as Earth Science. Similarly suitable sections on Remote Sensing, GIS, GPS, etc. may be resolved as Geospatial Science, and these may be further integrated as one full-size subject, say, Earth and Geospatial Science.

Other Concomitant Preparations Needed

Obviously such a major effort would also requires other concomitant preparations like development of a syllabus and a relevant textbook, a practical workbook, and a sourcebook for teachers not only in English but also in Hindi and some major regional languages. Obviously then it will be mammoth endeavor. Properly tailored programs on EDUSAT can for schools and for higher institutions can play a huge role in this endeavor. Even then provision will be needed for properly manning the teaching positions of the subject eventually. Other Branches of Geography may be retained in somewhat augmented form under the conventional Geography for arts stream of students.

As an experiment, it may be started in a few good schools with some guest faculty delegated to them by some Govt. organization or some academic institutions/departments (may be some retiring personnel, who may act as catalysts there), along with an extensive teachers' training program being run concurrently.

Some Assets Ready to be Tapped

There are now available simple books on GIS for secondary schools such as Green's, and Audet & Ludwig's, as well as self-learning packages called GIS Tutors. ESRI has created huge source materials and packages for teaching-learning GIS in secondary schools and colleges, based often on its ArcView and its extensions like ArcExplore, ArcWorld, ArcData. Harnessing Internet, ESRI now provides downloadable packages with software and data sets on it special 'school pages' – Arc Lessons – tailored for not only introducing GIS in school teaching but also for subject teaching per se. Similarly, NCGIA in the US and AGI in Britain initiated similar projects – 'GIS in Schools', which can be used for developing Indian equivalents. There are other multi-media CDs/DVDs including data as well as software functionalities, which can be played on general utilities like Media Player.

P Venkatachalam et al of IIT, Bombay have

developed a GIS Tutor based on India's indigenous GIS package called 'GRAM ++', which can be suitably adapted for HSS level. Similarly, MN Shorts' celebrated 'Remote Sensing Tutorial' can be suitably modified with Indian data and examples. INCA's Map Quiz program may be further extended and augmented for this purpose. Survey of India's 'Map Education' and 'Working with Maps', NRSC's 'Data Users Source Book', and 'Landsat TM Data Applications – Illustrated Examples' are some initial source materials. NATMO's 'Satellite Atlas of India' can as well be adapted for this purpose.

At higher levels this larger, composite subject should be perfectly conducive to Geospatial Science, which can be easily adjusted not only in under-graduate system as one optional subject for all streams or faculties, but it can also be established as full-fledged subject/department of inter-disciplinary nature at the post graduation level in very many institutions of higher learning. Or, Geospatial Science may be incorporated as methodological segment of most field sciences. Active endeavors are already being through in spearheading this mission in colleges and universities/IIT's. Only, it needs some more blending of Geographical and Geospatial concepts.

Other Long-range Benefits of the Endeavor

This restructuring of HSS school education will render higher Geoinformatical training & education better accessible and acceptable to matriculates and graduate from all subject groups, and these young people would be better equipped to take-up vast employment opportunities. This will turn up qualified manpower to man umpteen positions of manpower needed for the proper/healthy growth of this sector in the country as well as provide huge scopes of amicable employment for educated youth in the country and abroad.

EPILOGUE—Though the paper apparently sought to reunite the old couple of Geography and Cartography, which have lately been much distracted from each other, one may quip, it actually ends up in something quite different – an offspring of the two, e.g. Earth & Geospatial

Science. It actually leaves Geography divided into Fundamental & Physical Geography and the Human/Social Geography. The resultant however leaves considerable body of either parent subjects outside the scope of the new subject proposed.

Compulsions of the situation only demand what has been suggested. The real need of the hour is certain fundamental concepts of Geography and Cartography blended and further augmented with Environmental & Resource Management concepts and methods; and all these to be simplified to suit the secondary school level. The subject purports to provide a preparatory background for the potential students to eventually blossom into various shades of Geospatial Scientists, besides infusing a general awareness and orientation among the general educated gentry regarding these portentous developments, which are pervading all spheres of our life. Moreover, it will also contribute towards the healthy geospatial transition in the country.

There are many and varied new developments in other sciences as well that call for place in school syllabi, such as Biotechnology, Bioinformatics, Nanotechnology, etc. However, these can mostly be accommodated in the respective parent subjects. However the Geospatial contents cannot be accommodated in the existing Geography syllabus; and Cartography doesn't exist as a school subject; and this warrants the need for a new subject, which may also cater to the environmental contents.

References

- Audet R.H. and G.S. Ludwig (2000), **GIS in Schools**, ESRI, Atlanta, USA
- Kish, George (1969), '21st International Geographical Congress, 1968, New Delhi – Announcements and Reports', **Professional Geographer**, 21(2).
- Green, D.R. (2001), **GIS: A Sourcebook for Schools**, Taylor & Francis, London.
- ESRI, <http://www.esri.com/ArcLessons>
- Jain, J.L. (2011), Broad-based Geospatial

Education in India: Imperatives, Hindrances and Ways out, [http:// www.geospatial world.net/](http://www.geospatialworld.net/)

Mureil Lock, C.B. (1969), Modern Maps and Atlases: An Outline, **Guide to Twentieth Century Production.**

Martin, D. (1991), **GIS and its Socio-economic Applications.**

NATMO (2000), **Satellite Atlas of India**, Kolkata.

Nag, P. (1990), 'Prof. S.P. Chatterjee, 'A Life Sketch', National **Geographic Journal of India**, Vol. 38, pp. 5-8.

NRSA, **Landsat TM Data Applications – Illustrated Examples** (compiled by Dr. L. Venkataratnam), 1990.

Data Users Source Book, (1995), National Remote Sensing Agency, Dept. of space, Govt. of India, Hyderabad.

Robinson, A.H. et. al., (1954) 'Geographic Cartography,' In Jones, P.E & C.F. Jones, **American Geography: Inventory & Prospects**, AAG, 1954, (Indian Reprint, 1988).

Venkatachalam, P. et. al., *Teaching GIS Principles through Multimedia Based GIS Tutor*, <http://www.geospatialworld.net>

Professor Jawahar Lal Jain is a former Professor & Head, Department of Geography, University of Saugar, Saugar and Past President, INCA,

Email: jain_jawa@yahoo.com

McMahon Line: Its Background and Cartographic Mismanagement during the 1962 War

Kamal Rampriti Dikshit

Introduction

McMahon line is a byword familiar to most educated Indians. Like Durand line that forms the international boundary between Pakistan and Afghanistan, or the Radcliff line that forms the boundary between India and Pakistan on the west and India and Bangladesh on the east, McMahon line is the international boundary between India and Tibet, extending from India-Bhutan-Tibet tri-junction in the west to India-Burma-China tri-junction in the east, extending over a distance of 885 km. This line separates Tibet from India. This boundary was formalized at a convention presided over and signed by Sir Arthur Henry McMahon, the then Foreign Secretary to the Government of India, on behalf of Indian Government, and Lonchen Satra, the representative of His Highness the Dalai Lama of Tibet, in March 1914. Since the initiative for this conference came from India, and Sir McMahon representing India, presided over the Conference, it is known as the McMahon line.

I

Background to Simla Convention of 1914

The Simla convention was not a sudden event; it had a long period of evolution. This involves the background events which prompted the British Government to think in terms of fixing a boundary line between Tibet and India. These included British penetration into the northern tribal territory, improving relations with tribal chiefs amicably or by force, occupation of the entire territory till the Himalayan foot hills and finally survey and demarcation of northern frontiers.

To avoid any further confusion about Simla convention, generally believed to be a single

agreement defining the boundary between India and Tibet, it may be emphasized that the definition of Indo-Tibetan boundary was, if at all, only a part of the agenda of the convention. There were equally important political matters to be settled between India, Tibet and China arising out of a conflict situation in the closing years of the 19th century and the first decade of the 20th century, during which a series of treaties were signed.

Starting with the occupation of the eastern districts of Tibet, the Chinese had virtually overrun the whole of Tibet, a situation reversed with the breaking out of revolution in China in 1911 that emboldened the Tibetans. The latter declared independence in 1912, and drove out the Chinese officials and other army personnel. In response, the Chinese declared Tibet to be at the same footing as other states of China, a proposition that militated against the autonomous status of Tibet, though the suzerainty of China over Tibet was accepted by Great Britain and even Russia.

Besides China trying to grab Tibet in 1910-12 which, in any case, they did five decades later in 1959, there were two other events which alarmed the British government.

i) the murder of Noel Williamson, Assistant Political Officer at Sadiya, and Dr. J. C. Gregorson, a doctor with tea plantation at Tinsukia, with deep interest in the culture of frontier tribes, in March 1911, by the Abors. It was earlier reported that there is no Tibetan influence in the eastern sector, and the tribes recognize that all the country up to the foot of the hills is British territory-an important factor in coming to a settlement with them. The assassination of

* In collaboration with Prof. R.C. Tewari, A-2/12 Greenwood Coop. Housing Society, Godrej Park, Kalyan 421 301, email:nishit2@yahoo.com)

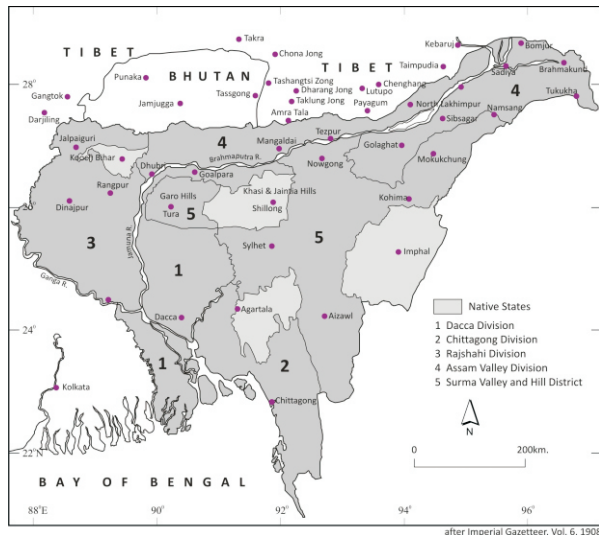


Fig. 1

Williamson and Gregorson hastened the process of giving serious thought to the frontier problem.

ii) perhaps a more important one, it alarmed the British to expedite the process of meeting the Chinese challenge by launching large scale expeditions, almost like military operations, was the occupation of Rima, an important trading centre just beyond the Lohit valley in Assam, by the Chinese (Fig. 1).

This was considered a definite indication of the expansionist policy of China. The Eastern Bengal and Assam Government expressed concern at the movement of the Chinese and it was considered essential not to allow them to move further into Lohit valley, the area under British influence and occupation. The situation that led to a serious Abor expedition to the frontier areas is reflected in the "general question of Chinese encroachments that had been the subject of discussion between the Lt. Governor, the Government of India and the Secretary of State since 1910. The entire issue is summarized in a letter addressed by Sir Lancelot Hare in Calcutta, in Nov. 1910.

"I think I hardly brought out with sufficient distinctness one important consideration which should induce us to press forward beyond the limits by which under a self-denying ordinance our frontier is at present limited. We only now claim suzerainty up to

the foot of the hills. We have an inner line and an outer line. Up to the inner line we administer in ordinary way. Between the inner and the outer lines we administer politically. That is, our Political Officer exercises a very loose jurisdiction, and to prevent troubles with the frontier tribes, passes are required for our subjects who want to cross the inner line. The country between the two lines is very sparsely inhabited and is mostly dense jungle.

Now, should the Chinese establish themselves in strength or obtain complete control upto our outer line, they could attack us whenever they pleased, and the defence would be extremely difficult. We have a chain of frontier outposts directed to controlling the main routes used by the hill tribes when they come down to trade in the cold weather. It seems to me, in view of the possibility of the Chinese pushing forward, that it would be a mistake not to put ourselves in a position to take up suitable strategic points of defence. I am, therefore of the opinion that we should take a more active line" (Letter written by the Governor of Bengal and Assam to the Viceroy of India, Nov. 1910 - Eastern Bengal and Assam Secretariat, political, A, March, 1911, Despatch Nos. 45-46 (quoted from Reid, 1942, p. 221-22).

The apprehension of Chinese advance into the frontier areas (today's Arunachal Pradesh) galvanized the British administrative and military machine to penetrate, survey, occupy and punish the tribals, wherever required, and take into their possession the entire territory of the present day Arunachal Pradesh.

Issue of a Memorandum by His Majesty's Government to convene the Simla Conference

The task of occupying the entire area of present day Arunachal was almost accomplished when His Majesty's Government, while formally declining to accept the political status of Tibet as defined and imposed by China, invited China to a conference to clearly define the political status of Tibet vis-à-vis China and asserting the conclusion of a written agreement as a condition

precedent to extending their recognition to the Chinese republic.

It was in response to this memorandum of Aug. 17, 1912, that the Simla conference materialized in which the primary objective was to settle the political relationship between China and Tibet.

Simla Conference: Achievements and Failure

The conference was opened in Darbhanga palace, on Oct. 13, 1913 and ended in July, 1914, with long interregnum in winter. It was a tri-partite conference where Sir H. McMahon represented His Majesty's Government of Great Britain, Monsieur Ivan Chen was the plenipotentiary of China and Lonchen Satra represented Tibet.

Divergent Chinese and Tibetan Points of View At the conference while Ivan Chen, the Chinese representative, insisted on their suzerainty over Tibet and right to station troops at Lhasa, Lonchen Satra, the Tibetan Plenipotentiary, stressing on Tibetan independence and the inclusion of some disputed eastern districts. In order to reconcile the differences between China and Tibet, McMahon proposed a Two-Zone organization of Tibet; an Inner and an Outer Tibet. Inner Tibet was to be governed by China while Outer Tibet was the mainland autonomous Tibet, with a clause that China has suzerainty over Tibet.

The Two-Zone Tibet draft agreement was also presented cartographically, besides the articles of agreement which included a clause of Chinese suzerainty over Tibet. This draft map of Inner and Outer Tibet was modified increasing the area of Inner Tibet to be under the Chinese control at the expense of Outer Tibet to induce the Chinese representative to sign the agreement. This tri-partite agreement never reached finality, the Chinese never signed it and a bi-lateral agreement involving Great Britain and Tibet was signed.

The Significance of the 'Two-Zone Tibet Map' - A great deal of significance is attached to this two-zone-map of Tibet (Maps 23 & 24 in the *Atlas of Northern Frontiers of India*) where the McMahon

line, that was finalized in March 1914, also appears as a boundary line between India and Tibet. This map (Map No.23 as referred above) meant 'to illustrate article No. 9 of Simla convention 1914 (is) initialed by the British representative and signed by the Chinese and Tibetan representatives. The two latter did not only initial the convention but signed it' (*Atlas of Northern Frontiers of India*-Map 23). That, this Two-Zone Tibet map with the McMahon line drawn on it and signed by Ivan Chen is an evidence of Chinese agreeing to the McMahon line, denying it on hind sight.

Inner and Outer Tibet Agreement: Relevance or Irrelev

e text of the convention about 'Inner and Outer Tibet' mentions the name of Monsieur Ivan Chen as the representative of His Excellency the President of the Republic of China as a participant, the convention, as finally modified, was not signed by him, though he attended the conference and signed a preparatory draft. The only map (27th April 1914) accompanying the agreement and signed by Ivan Chen, is often considered as evidence of the Chinese acceptance of the McMahon line as it clearly appears on the map. The existence of two maps juxtaposed to each other represents the result of sequential negotiations at the conference. By hard negotiations Ivan Chen was able to slice off a part of the inner Tibet territory and include in Chinese territory. This can be seen in the two maps which are not alike. While the black line separating the Outer Tibet from Inner Tibet remains unchanged, the red line separating Inner Tibet from China has shifted in the direction of Tibet yielding more territory to China. (See Maps. 23 & 24, *Atlas of Northern Frontiers of India*)

In any event, since the draft agreement was disavowed by the Chinese agreement even before the final agreement which remained unsigned, this aborted convention remained irrelevant for both China and Tibet. Secondly, there is a contra view which argues that there is no mention of India or British India south of the McMahon line shown on the two-zone-map of

Tibet that could make it more meaningful for advocating the acceptance of this line by China as the boundary between India and Tibet.

The tri-partite agreement drafted by McMahon with the accompanying Two-zone-Tibet map was never signed by the Chinese representative. What was signed by him was one of the two maps in the hope that the final agreement could be reached and signed. But the Chinese Government disavowed the entire agreement and hence Ivan Chen's signature on one of the maps does not carry much meaning.

II

The India-Tibet Boundary Agreement-1914: The Cartographic Wonder (!), i.e. McMahon Line

Another agreement, very relevant to India, was the Boundary Agreement between India and Tibet that cartographically determined the India-Tibet boundary line, known as McMahon line. It has to be noted that the agreement on McMahon line between the Indian and Tibetan representative was reached and signed in March 1914, even before the discussion and argument on 'Inner and Outer Tibet Agreement' that took a lot of time patience and energy yet never reached finality, as the Chinese refused to sign it, and was finally signed as a bilateral agreement between India and Tibet.

The McMahon line was merely a cartographic representation and not a treaty with many clauses. "McMahon was able to put the finishing touches to his famous red line on the map after hearing the results of an extensive survey made by Bailey and Morshead. He hoped to obviate the necessity for verbal definition of boundary line by showing frontier by line on map. This map giving the India-Tibet frontier from Isu Razi pass (India-Burma-China tri-junction) to the Bhutan frontier was accepted by the Lonchen in February 1914, subject to confirmation by his Government and to two conditions: 1. The Tibetan ownership in private estates on the British side of the frontier will not be disturbed; 2. If the sacred places of Tso Karpo and Tsari Sarpa fall within a day's march of

the British side of the frontier, they will be included in Tibetan Territory and the frontier modified accordingly" (Woodman, Dorothy-1969). The Tibetan representative, Lonchen Satra confirmed the acceptance of the McMahon line on 25th March 1914.

The Chinese representative was aware of this bilateral agreement. In fact, Ivan Chen had an adviser, Sir Archibald Rose, to advise him on the matter. "As far as available records show, Chen did not at any time complain of the bi-lateral agreement" (Woodman-ibid: 181).

This map of the North-East frontier on a scale of eight miles to an inch was, according to Woodman, the first cartographic record of the 800 miles of mountainous territory.

The Indo-Tibetan boundary marked by McMahon line came to be widely discussed immediately before, during and after the 1962 Chinese invasion of India, in what is presently known as Arunachal Pradesh in the east and Aksai Chin plateau of Ladakh in the west. There is a large volume of literature - books, journal articles, newspaper columns and even recorded speeches and press conference of politicians, published just after the 1962 war, besides a number of legal documents like treaties, conventions and agreements which often provide the basis of subsequent discussions and negotiations.

Background to the Survey, Mapping, Occupation, and Demarcation of the Indo- Tibetan Frontier

British Movement in Assam and the Frontier Region: The British, represented by the East India Company, made their first foray into Assam with the acquisition of diwani rights over Goalpara, then a part of Bengal, in 1765. Apparently, they didn't interfere with the administration of Ahom kings who were ruling over the neighbouring Assam with their capital near Sibsagar in upper Brahmaputra valley, nor did they infringe on the territorial integrity of Assam till the first quarter of the 19th century. Following a series of events that included political feuds, the involvement of Burmese

army, the defeat of the Burmese, and the treaty of Yandabo (1826) giving control of Assam to the British, and the final dethronement of the last Ahom king Purandar Singh, the East India Company took control of Entire Assam in 1828.

British Foray-Arunachal Pradesh, Nagaland, Manipur, Mizoram and Meghalaya - inhabited by tribal communities were never ruled by the Ahom kings and had their own system of administration presided by the tribal chiefs. The picture changed after the arrival of the British in the early 19th century. They gradually extended their hold on these areas, the warring and recalcitrant tribes were subjugated and their territories - Naga Hills, Lushai Hills (Mizoram) and Khasi, Garo and Jaintia hills (Meghalaya) were annexed in Assam by force, brought under the British control and became a part of erstwhile British province of Assam.

The Tribal No Man's Land (The Territory, now known as Arunachal)- The territory north of Assam, the present day Arunachal, was inhabited by many tribal groups and remained an unexplored territory, occupied in patches by tribal communities with distinct identity of their own. These groups had their own customs, beliefs and social organization and often had a hostile relation with the neighbouring tribes. Most ruling dynasties in Assam, but principally the Ahoms, had uneasy relations with these tribes inhabiting the peripheral hilly tracts.

Expansion of the British Rule in the Tribal Territory between the Brahmaputra and the Himalayan Watershed - It is to be clarified that, north of Brahmaputra, the administered British territory extended for about 40 km, beyond which lay the no man's land, occupied by different tribal groups. The line between British territory and the peripheral tribal land was called the 'Inner Line' under a Bengal regulation of 1873. No British subject was permitted to go beyond this line without the permission of the Government. Thus, there was a clear cut separation of the British territory from the tribal domain. Yet unofficially, the British had established an Outer Line as is clear from the dispatch of the governor Sir Lancelot Hare to

Lord Hardinge, the Viceroy of India.

"I think, I hardly brought out with sufficient distinctness one important consideration which should induce to press forward beyond the limits which under a self-denying ordinance our frontier is at present limited. We only now claim suzerainty up to the foot of the hills. We have an inner line and an outer line. Up to the Inner Line, we administer in the ordinary way. Between the Inner and the Outer lines, we administer politically. That is our Political Officer exercises a very loose jurisdiction, and to prevent troubles with frontier tribes, passes are required for our subjects who want to cross the Inner Line. The country between the two lines is very sparsely inhabited".

(Eastern Bengal and Assam Secretariat, political, A, March 1911, Nos 45-46- quoted from Reid Sir Robert (1942) Frontier Areas bordering on Assam, p.221).

The British administration was responsible for protecting the people in their territory from the marauding raids of Akas, Daflas or other wild tribes. These tribes used to raid villages, ransack or burn them, and abducted men and women to be treated as slaves. To ward off these tribal raids, the British, as much as the Ahoms applied a 'carrot and stick' policy to keep these tribals in check and at bay. One of the standard practices adopted by the Ahoms was to pay annual Posha, (also written as posa) a kind of appeasement money to persuade these tribes to restrain themselves from these raids. The British followed the same practice, but gradually subjugated them and occupied the entire area.

Penetration into the Tribal Land-The northern border land of British Assam was divided into two parts, the western section known as the Balipara Frontier and the Central and Eastern section known as the Sadiya Frontier. The administration as well as the British subjects encountered frequent clashes with the bordering tribes. In order to bring "under more stringent control the commercial relations of our own (the British) subjects with

the frontier tribes, living on the borders of our jurisdiction---, it was necessary to take special powers and lay down special rules” (Mackenzie, 1988). Accordingly, a regulation was drawn by the Lt. Governor and approved by the Governor General in Council to give effect to this policy. The Lt. Governor prescribed a line called 'The Inner Line' in every border district beyond which no British subject of certain classes or foreign residents could pass without a license. This was the power of summary legislation given to the Lt. Governor in 1872-73, under statute 32 and 33Vic, Cap.3, under which the Inner line came into existence on the frontiers of Assam. The Inner line was as much binding on the frontier tribes inhabiting the area beyond this line on the north, as on the British subjects, south of the inner line. Any raid by the frontier tribes south of the Inner line met with a multi-purpose punitive expedition.

The principal tribes of the northern frontier from west to east were:

The Akas, the Duphlas (Tagins), the Abors and Miris, the Mishmis, the Khamptis and the Singphos.

The British encountered resistance from each of these tribes and obtained their submission first through persuasion and giving them regular posa but ultimately by mounting punitive and exploratory expeditions. Some of the important expeditions were: **The Akas Expedition of 1883-84; The Abor Expedition, 1893-94; The Apa Tanang (Apatanis) Expedition of 1897; Bebejiya Expedition 1899-1900; The Miri Mission-August 1911, Abor Expedition 1911-12, The Akas Promenade and the Visit to Tawang, 1913-1914.**

The above mentioned expeditions launched either from Balipara in the western sector or from Sadiya in the eastern sector covered practically the entire tribal territory extending from the northern limits of Assam extending up to the Himalayan foot hills. In each of these expeditions, exploration and survey of the territory was a crucial objective, besides inflicting punishment to specific tribes and

securing their submission and loyalty. Some of these expeditions were taken much before the Simla Convention and a few were undertaken even after 1914.

The Abor Expedition (Military Operation) of 1911

The most important of all the expeditions was the Abor expedition of 1911 which paved the way for further survey and occupation of the tribal territory. The importance of this expedition was conveyed to the Secretary of State for India by the Viceroy of India

“It is of prime importance that we should take advantage of the opportunity afforded by the expedition to carry out such surveys and exploration as may be possible, in order that we may obtain the knowledge requisite for the determination of a suitable boundary between India and China in this locality, as to which at present we know practically nothing. Recent events on the frontier of Burma have shown the urgent necessity of coming to an understanding with China about our mutual frontier, of preventing Chinese intrigue within our limits, and keeping her away, as far as possible, removed from our present administered area. We accordingly propose to depute a staff of Survey Officers with the punitive force” (Telegram P-dated the 29th June, 1911, of the Government of India addressed to the Secretary of State (quoted from Reid, p.224).

It appears that the Government of India intended to take advantage of this punitive expedition to clear up the obscure boundary situation against China, both on the Abor as well as Mishmi frontier. The proposal received the approval of the Secretary of State (Lord Crewe), and included in the objectives of the expedition among other things were.

1. Exploration and Survey of as much of the country as possible, visiting if possible, the Pemkoi falls and incidentally settling the question of the identity of the Tsangpo and Brahmaputra rivers, and
2. To submit proposal for a suitable frontier line between India and Tibet in general in

conformity with the policy of the Government. No boundary, however, be settled on the ground without the orders of the Government except in cases where the recognized limits of Tibetan Chinese territory are found to conform approximately to the line adopted by the Government of India. It was also conveyed that such prominent features should be followed as are essential for a satisfactory and well defined boundary line.

The Abor expedition of 1911 achieved all its objectives including an accurate survey of the area extending as far as 28°-40' north. The whole valley of Yamne was surveyed up-to the snow ranges, the Shimang river was mapped, the course of Siyom was roughly traced, and the valley of Dihong was followed as far north as Siggig, (Lat.28°-52'). The identity of Dihong with the Tsangpo, though not absolutely proved, was at any rate practically established, and there is little doubt that part of the district traversed by Kinthup in his famous exploration from the north, was visited.

The Survey of Indo-Tibetan Frontier and Cartographic Presentation of the Indo-Tibet Boundary Line by Capt. M. F. Bailey and Capt. Morshead

Following the Chinese occupation of Tibet and Lhasa under the leadership of Frontier Commissioner Chao-Erh-Feng, and occupation and establishment a military outpost at Rima, a trading centre, just beyond the Lohit valley that was under British control, in 1910, the Indian Government initiated security measures in the North-East Frontier of India. The first step it took was to organize a number of exploratory expeditions and missions between 1911-1914 to gather knowledge of the country and its inhabitants, useful to fix a natural boundary between India and Tibet-China. As all such expeditions were undertaken from Assam side, a considerable knowledge was obtained of southern side of the Himalayas. This was not enough, and the need for knowledge of terrain on the Tibetan side of the Himalayas as well as

the actual situation of watershed for demarcating boundary line was urgently felt.

To execute this task of survey of the frontier and fixing the boundary line between India and Tibet, the Government of India commissioned Capt. F. M. Bailey and his engineer and surveyor colleague Morshead. They embarked on what is known as Dibong Valley expedition and surveyed and mapped the entire country along the Brahmaputra and Himalayas. This was a great achievement, a surveying feat accomplished by Bailey-Morshead duo in a span of six months. They started from Mipi in Dibong valley on May 16, 1913 and terminated their journey at Rangiya in Assam on Nov. 15, 1913, after travelling a distance of 1680 miles (Bailey-1914). Bailey and Morshead prepared the first map of the frontier, and drew a boundary line between India and Tibet based on watershed principle. The article, referred to above, includes two maps of the surveyed areas, the frontier zone as well as a tentative boundary line. The final map was prepared by Morshead on the eve of the Simla Treaty.

III

Absence of Follow-up Action after the Simla Conference

Following the Simla conference, it was imperative that the Govt. of India entrusted the task of producing large scale maps of the Indo-Tibet borders, to the Survey of India. This did not happen and there was an unexpected bungling by the British administration. Large scale maps of the border areas, showing the details, as finalized at Simla, were not produced not only for a year or two, but for decades.

One of the explanations generally offered is the preoccupation of the entire British administrative machinery with the First World War that ended in 1919. The Simla Agreement existed only in the official records of the Government of India. Neither the Central nor the Assam Government paid any attention to it. A more logical explanation as given in a letter of Assam Chief Secretary to the Political Officer

Balipara Frontier Tract dated 17th Sept 1936, reads as follow:

“The 1914 Convention was never published, mainly because the Chinese Government failed to rectify it, and nothing was done to give effect to Sir Henry McMahon's recommendations for the extension of administration in the Tawang area. Another consequence is that many published maps still show the frontier of India along the administered border of Assam. Another important point to notice is that the latest Chinese atlases show almost the whole of tribal area south of the McMahon line up to the administered border of Assam as included in China” (Reid, 1942, pp. 294-95).

The question of border suddenly appeared in the news in 1935 with an unauthorized entry of Sir Kingdon Ward (1936), a celebrated plant explorer, who spent six months at Dirong Dzong discovering new species. His unauthorized entry into Tibet evoked a protest from Tibet accusing him of crossing the red line (McMahon line) without any prior permission.

This incident came to the notice of Sir Olaf Caroe, then Deputy Foreign Secretary to the Government of India. He moved fast in the matter, though he discovered that “the Assam Government and the Political Officer were ignorant of the position of the frontier.” He also observed, though incidentally, that “--it does not appear that the external frontier in this sector has been correctly shown on the maps of the Survey of India” (Woodman, 1969, p 200).

It cannot be stated with certainty, when the first large scale maps of Survey of India showing the boundary between India and Tibet appeared, but it doesn't appear to be any date earlier than 1936, since the correspondence between Sir Olaf Caroe and the Govt. of Assam where he accepts the non-existence of Survey of India maps of the frontier is itself dated April, 1936.

The first map showing the border between India and Tibet appeared in 1936, following the uproar in the administrative circles. This map appears as Map 27 under the caption 'Highlands

of Tibet and Surrounding Regions. It shows NE frontier as settled at the Simla Conference by dotted line, highlighted by bold arrows pointing from the Tibetan side towards India (Atlas of the Northern Frontiers of India-1960-Map 27).

Attempt to demarcate the McMahon Line on the Ground- It was J. P. Mills, a member of the Indian Civil Service with almost unparalleled record of service in Nagaland and other regions of the NE, who was assigned the task, in his own words, of making 'the Convention boundary good'. In the course of his lecture that he delivered before the Royal Central Asian Society in January 1950, Mills expressed great apprehensions about the Chinese intensions with regard to Tibet and gave an account of the difficulties he encountered in demarcating the Indo-Tibetan border.

While addressing the society he started by saying that: “There has been much in the press, of late, as to the chances of Chinese communists occupying Tibet but nothing in regard to the complicated frontier problems which have long existed and may soon become even more complicated” (Mills-1950:152). Talking of 1943, in 1950, he says: “Even maps issued by the Survey of India do not show the boundary which we agreed upon with Tibet and that has been a source of serious trouble”.

“Our official maps, as I have said, showed the boundary along the base of the hills. The Tibetans issued no maps and said in effect that they could not find the papers about the convention.---- China was issuing maps showing Tibet as one of her provinces with the boundary about 100 miles inside of the Convention Line. These maps indicated a claim not only to the whole of the sub-montane tract but to the much of the Assam valley proper.”

It is clear, if one goes by the statement of J. P. Mills, that proper maps of the boundary line were not available in 1943. The Survey of India, the most prestigious organization of the Imperial British India, didn't or wasn't advised to prepare Indian maps showing the McMahon line that was finalized in 1914.

Cartographic Mismanagement during the 1962 War

The cartographic mismanagement during the 1962 war refers to: (i) Non-availability of proper maps on a large scale, and (ii) Lack of clarity and clarification about the ground position to be conveyed to the field commanders from the General headquarters

The Chinese invasion during the 1962 war covered almost the entire northern frontier of India but we are concerned here with the area where the international boundary was formed by the McMahon line, i.e. Arunachal Pradesh. The areas of specific thrusts by the Chinese were the Walong-Kibithu area in the eastern part in Lohit valley, Longju in the Central part, and Tawang in the extreme western part of Arunachal, especially the India-Bhutan-Tibet tri-junction.

Cartography and the Battle of Tawang - The Chinese invasion in Arunachal followed principally three axial zones - Kibithu-Walong axis in Lohit valley, Migyatu-Longju sector in Central Arunachal and Thagla-Khinzemane-Se La axis along Nyangjang river in the extreme western part of Arunachal, touching the Indo-Tibet-Bhutan tri-junction. The battle that was fought along the Thagla-Khinzemane-Sakti alignment along the Nyangjang river, and extending further south along Tawang-Jang-Se la-Dirang Dzong-Bomdila axis is commonly known as the battle of Tawang (Fig. 2). The Chinese made three major offensives. They started with their first offensive on 10th October, 1962, demolishing a platoon strength Indian patrol at Tse Jong, the second offensive that



Fig. 2

resulted in the battle of Namka Chu was on 20th Oct, 1962, and the last on 14th November 1962 when the Chinese came down rolling into the Assam plain, without having to overcome any resistance at Se La, Dirang Dzong and even Bomdila (Fig. 3).

It is beyond the scope of this paper to describe the details of the operations and actual battle, but those interested may refer to several works on the subject referred to below. Besides, a series of articles written by Inder Malhotra, a distinguished columnist of the Nehru era, in Indian Express (July-Sept. 2011), give a ringside view of the happenings in the battle zone. To have a clear picture of the war theatre and the battle zone, one has to keep in mind the area between the McMahon line starting from India-Bhutan-Tibet tri-junction, about 45 km north-west of Tawang, and Tezpur on the northern bank of Brahmaputra and the headquarters of the temporarily established 4th corps. Close to the line of defence on the frontier line was the 7th brigade of the 4th division, the former commanded by Brig. John Dalvi under the command of Divisional Commander Maj. Gen.

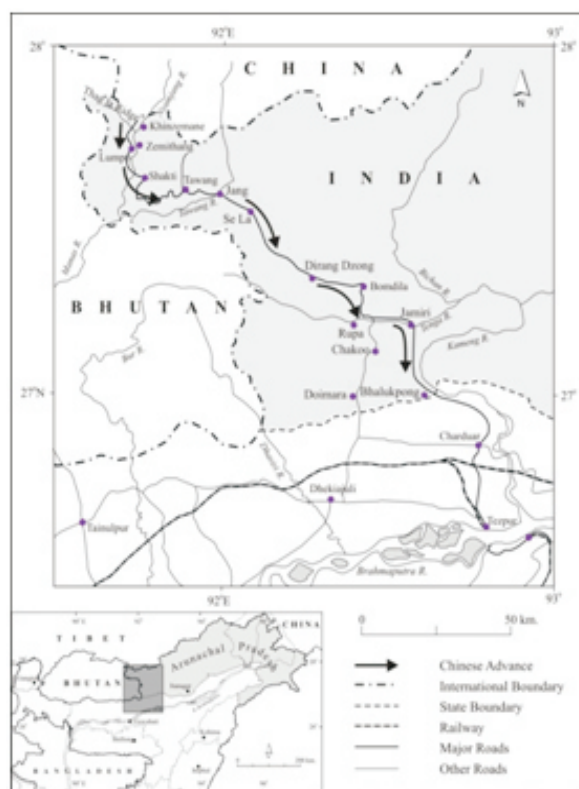


Fig. 3

Niranjan Prasad. It may be mentioned, in the passing, that Brig. Dalvi was a Chinese prisoner of War and presented his experiences in the book 'The Himalayan Blunder'.

The observations of these officers from the war zone tell the sad story of war preparedness or unpreparedness, but more specifically the cartographic inadequacies related to the maps, prepared by Survey of India and supplied to them and the cartographic representation of the border zone. One doesn't have to forget that the battle of Tawang took place almost five decades after the Simla agreement was signed, and 15 years after India attained independence.

Observations of the Field Commanders

The area from where the border was to be defended was 25 km north of Lumpu, where the supplies were dropped, but this was a treacherous terrain. The map supplied to the army was ineffective, and this is what Brig Dalvi, during a general reconnaissance, with another officer Col. Misra, observed:

"We sat within sight of a bridge, I with a solitary field sketch spread out in front of us. This sketch was the only 'map' available as there were no accurate survey maps of this area. The ¼-inch editions were very old and vaguely based on the details provided by the British Officer who was deputed to visit the area and align the McMahon line as agreed at the Simla conference of 1913-14. It showed the Namka Chu flowing from north to south, whereas it actually flowed from west to east I have often wondered if this map misled our planners into thinking that Punjab were facing east instead of north" (Dalvi-1969: 185).

The above observation of Brig. Dalvi mentions only one quarter inch map that was inaccurate and could not be relied upon. More significant is the fact that one inch sheets of Survey of India on a scale of one inch to a mile, for the frontier areas at least for the North-East, was not available to the officers on the front. Those were not the days of satellite images and only reliable information about ground position was to be obtained through maps.

Another observation about the accuracy of maps, their inadequacy and the lukewarm disposition of the General headquarters towards the queries, about the ground position, left the commanders on the frontline with a great deal of suspense and uncertainty resulting in delayed or incorrect positioning of the army units. This has been discussed in great detail by Maj. General Niranjan Prasad, commander of the 4th division charged with the responsibility of defending the frontiers. This is what he observed while preparing the defences in Tawang area.

First, his observations about the McMahon line in the extreme western sector on Bhutan border:

'The McMahon line stretches from the Burma-India-Tibet tri-junction in the east to the India-Tibet-Bhutan tri-junction in the west, delineating the border between India and Tibet. As I have stated, from the Burma-India-Tibet tri-junction westwards to just north of Khinzemane the McMahon line generally follows the Himalayan watershed. The line then comes down the Pungbost ridge to Khinzemane and thence, instead of following the main watershed of the Thag la ridge, it is drawn as a straight line running to the India-Tibet-Bhutan tri-junction. The details of the area, drawn on the map then bore little resemblance to the actual configuration on the ground, presumably because this area had not been explored when the McMahon line was drawn. It is, however, surprising that in the years since then the authorities in Delhi had not corrected this discrepancy. It is hard to understand how any purposeful negotiations could have been conducted with Communist China when such elementary details as accurate maps were not produced; or, if they were in existence, they were certainly not made available to the army who had been given the responsibility for ensuring the security of the border"(Prasad, Lt. Gen. Niranjan-1981).

These observations of Lt. General Niranjan Prasad make it abundantly clear that accurate maps of the area were not made available to the army. He is not sure if the accurate maps existed

at all. As suggested by him, it is the Army headquarters, the Ministry of External affairs or the Survey of India that was responsible for this inexcusable fault/omission, responsible for wrong assessment of ground reality.

He further observes “The McMahon line just north of Khinzemane as drawn by Sir Henry McMahon in 1914 with a thick blue pencil on an un-surveyed map, was not an accurate projection of the watershed line. Much of the territory those days had not been explored and McMahon was only guessing at geography when he drew a thick blue line (sic) from Khinzemane to the Bhutan-Tibet-India tri-junction to its east (west). In this process, the position of Thagla ridge was, to say the least, left ambiguous..... The survey authorities, ignoring physical features on the ground, joined point MM7914 to the India-Bhutan-Tibet tri-junction by a straight line. Stranger still, the Govt. of India had not corrected this obvious mistake even in 1962. Clearly, someone in External Affairs had not done his home work. This lapse cannot be easily excused or explained away; which was largely responsible for the critical dispute eventually leading to war” (Prasad-1981:16).

While it is true that accurate maps were not provided, Lt. Gen. Prasad's observation that the area was un-surveyed before McMahon drew the thick blue line (it was in fact red line) is based on inadequate information. The area was surveyed by Bailey-Morshead duo in 1913-14, as is clear from the clearly drawn sketches of the Tawang region (Fig.4) by Bailey in his book “No Passport to Tibet”, published as early as 1957 which clearly shows that the Tawang region was surveyed by the Bailey-Morshead duo.

The Question Thagla Ridge, its Cartographic Presentation and the Ambivalence of Army Headquarters

The observation of Lt. Gen. Niranjan Prasad that the 'McMahon line passes along the Thag la Ridge' that being the watershed is correct, but was left vague and not clearly shown on the map. During the course of the preparation of the

defences, 'the political representative with the column told Capt. Prasad (different from Maj. Gen. Prasad) that Thag la ridge was Indian territory; but since Capt. Prasad's maps showed the McMahon line as passing to the south of Thag la, he did not act on this information. Instead, on return to the base, he referred the matter to the divisional headquarters. We, in turn, reported to Corps Command and Army Headquarters on 20th July. Subsequently, I sent for Capt Prasad urgently and after debriefing him at length, I became convinced that the Thag la ridge was indeed the main watershed. I then prepared a comprehensive case asking for permission to occupy Thag la ridge. Had that permission been granted me promptly, this story may never have had to be written (Prasad- 1981:24).

This is a poignant revelation made by Maj. Gen. Prasad in charge of defending Tawang.

Frustrated he writes further “My anxiety, I was forced to conclude, was not shared by any one



Fig. 4

above Corps Headquarters. As it turned out, by 14 August we had missed the opportunity to forestalling the Chinese on the Thag la ridge. ----- By 8 September, I still had received no reply to my repeated request for an answer to my urgent queries submitted on 4 August and 14 August regarding our claim to Thag la ridge” (Prasad, 1981: 25).

A reading of the enclosed map (Fig. 5) will make an understanding of the ground position as well as the import of Gen. Prasad's statement clear. The figure shows Thag la ridge as the watershed on which the McMahon line passes. At the southern foot of the ridge is west-east flowing Namka chu river, a tributary of the north-south flowing river Nyamjang. It seems in desperation and not being sure of the Thagla ridge being an Indian territory or right on the McMahon line, the Indian forces pitched their defences in the valley down below. While Maj. Gen. Prasad was awaiting a definite answer from the army headquarters, Chinese occupied the ridge top from where they could unleash all the fire power at their command inflicting heavy casualty on the Indian army.

The above two statements of army officers who were a part of the battle of Tawang are enough of an evidence to show how poor cartography of border lands, and in particular the inaccurate depiction of McMahon line on large scale maps led to the disaster of Tawang. Large scale maps were certainly missing. Thus, it was not only the small scale map (1"=8 miles), and a thick red line used by McMahon and his Assistants that were responsible for the cartographic mess, five decades were a long enough period for the Ministry of External Affairs and the Survey of India to prepare clear large scale maps showing every detail that could have been consulted during border negotiations with the Chinese as well during the War.

Confusion about McMahon Line, Actual Ground Position and Faulty Communication

Some western authors have noted this lack of communication and confusion about Indian vs Chinese territory. Mention must be made of

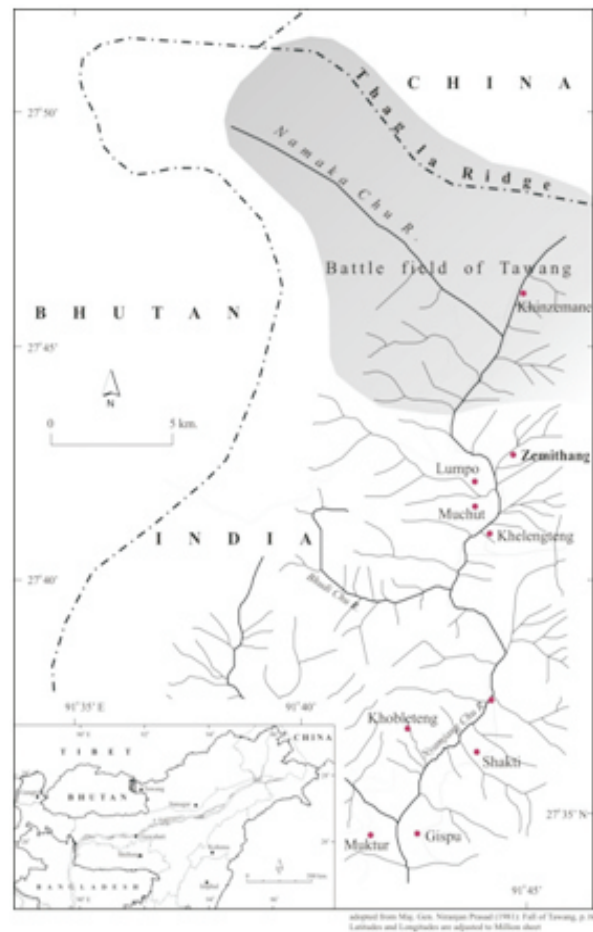


Fig. 5

Neville Maxwell (1970) who wrote India's China War. He talks of the situation on the ground and the corresponding maps. According to him “ At the officials' meeting in 1960, the Indian sides, both in maps they submitted and verbally claimed Thagla ridge as the boundary feature, putting the India-China-Bhutan tri-junction at 27°-48' North. But, while the Indian Government was thus clear and consistent in its own mind about the location of boundary in the North-west corner of NEFA, either the army was not informed about the cartographic anomalies of that area or the Army did not pass on the information (Maxwell, 1980: 294). Thus what is clear is that there was some anomaly and the maps did not reflect the actual position on the ground.

Why that anomaly was not corrected is a question? Can we pose this question?

Cartography and International Borders - While

remote sensing has helped sensing the visible landscape and all its components in considerable detail, territorial boundaries, international boundaries, both on land and in the ocean ever remaining a thorny problem. In many areas where resources are widely spread and don't respect national boundaries, disputes over boundary lines are quite common. India has many such problems not only with the neighbouring countries which, of course, of great importance nationally, there are also interstate boundary disputes which require attention of trained surveyors and cartographers. Shifting of river channels, bank erosion, appearance of land or island after the recession of floods or earthquakes could also create disputes between neighbouring settlements and sometimes even districts.

Cartography has to be taken more seriously. India an important country in world affair has not produced a decent atlas designed and printed in India. Nor do we aim at producing maps of other countries. Almost every European country produces its own world atlas. 'Where do we stand in cartography' the cartographers of India can discuss with great benefit and may perhaps decide on a course correction.

What the authors consider important in the context of this paper is the cartography of international borders. There may be historians, diplomats and political scientists in India, we are not aware, who study and know all about India's border problems thoroughly, but the boundary disputes and their resolution should equally be a concern of geographers as well as cartographers.

There should, indeed, be a geography and cartography of international borders.

Bibliography

Bailey, F.M. (1957), **No Passport to Tibet**, Rupert Hart Davis, London

Bailey, (Capt.) F. M. (1914), Exploration of the Tsangpo or Upper Brahmaputra, **Geography Journal**, 44(4), pp. 341-43

Bhargava, G.S. (1964), **The Battle of NEFA - The**

Undeclared War, Allied Publishers, Bombay

Dalvi, J. F. (1969), **Himalayan Blunder**, Thacker & Co., Bombay

Govt of India (1960), **Atlas of the Northern Frontier of India**, Ministry of External Affairs, New Delhi.

Kaul, B. M. (1967), **The Untold Story**, Allied Publishers Pvt. Ltd, Bombay.

Lamb, Alastair (1964), **The China-India Border**, Oxford University Press, London.

Lamb, Alastair (1966), **The McMahon Line: A Study in the Relations between India, China and Tibet, 1904 to 1914**, Roulledge & K. Paul, London

Maxwell, Neville (1970), **India's China War**, Pantheon Publishers, New York

Mills, J. P. (1950), Problem of the Assam Tibet Frontier, **Journal Royal Central Asian Society**, pp. 152-61

Prasad Niranjana (1981), **The Fall of Tawang**, Palit & Palit, New Delhi

Shakespeare, C.W. (1914), **History of Upper Assam, Upper Burmah and North East Frontier**, Macmillan, London

Ward, F. Kingdon (1936), Botanical and Geographical Explorations in Tibet. 1935, **Geographical Journal**, 88, pp. 385-413

Ward, F. Kingdon (1940), Botanical and Geographical Exploration in the Assam Himalaya, **Geographical Journal**, 96, pp. 1-13

Kingdon-Ward, Francis (1941), **Assam Adventure**, Jonathan Cape, London

Woodman, Dorothy (1969), **Himalayan Frontiers - A Political Review of British, Chinese, Indian and Russian Rivalries**; Chapter 8 Conference at Simla, Barrie & Rockliff, The Crescent Press, London, pp. 158-183

For a detailed study of the circumstances that led to the Chinese invasion, one can refer to

1. Dorothy Woodman. (op.cit.) 2. A series of articles written by Inder Malhotra starting, in

Indian Express, between July, 16 and Oct,31, on most Mondays. Malhotra, being stationed at Delhi, has given a ring side view of how the Indian defense Establishment and Civilian administration under Prime Minister Nehru acted and interacted during those critical days and months. His reports cover the movement between Delhi, Tejpur the Corps headquarters of corps, and Tawang the town closest to the battle field. The most readable according to the authors of this paper are:

1. How rude reality set in at Thagla, *Indian Express* July 16, 2011

2. The day we found out. *Indian Express*, August 22, 2011

3. Dark October Black November, *Indian Express*, September, 05, 2011

4. How the retreat turned into a rout, *Indian Express*, September 19, 2011

5. Panic, Pandemonium Cease Fire. *Indian Express*, October. 31, 2011

6. Defeated not Destroyed. *Indian Express*, October 31, 2011

All these columns can be read on the web.

Reid –ibid p.216

Professor K.R.Dikshit a a Former Professor & Head, Department of Geography, University of Poona, residential address: 3, Salil Apts., Sanewadi-Aundh, PUNE 411 007,
Email: r.v.dikshit d110@giaspn01.vsnl.net.in)

Geologic Hazards: Earthquakes and Landslides

Ravindra Kumar

Abstract

Mapping of natural hazards such as earthquakes and landslides is crucial in any disaster management programme. Earthquake is one of the frequently occurring phenomena in many parts of the Indian sub-continent. The Himalaya is tectonically active and is frequently subjected to seismic activity. Intra-plate seismic activity is recorded from north-western and central India. Earthquake prediction is still in early stage of research. The mitigation measures rely heavily on seismic micro-zonation that is based on the study of geological factors, geotechnical properties of the earth's material and historical records of the seismicity.

Landslides are caused primarily due to changes in hydrological conditions during the monsoon. Also the frequently occurring seismic activity in the Himalayas is an important contributing factor in slope instability and mass movements. Landslide hazard zonation contributes significantly in land use planning and disaster management programme.

Introduction

Large parts of India are prone to natural hazards, triggering either by meteorological processes or earth's internal geological processes. Cyclones, floods and droughts are the natural hazards that are governed by meteorological factors. Geological hazards such as earthquakes and volcanic eruptions are entirely controlled by the earth's internal processes. Landslides, triggered by rock structures and changes in hydrological conditions, are controlled mainly by the meteorological processes.

Understanding the earth's processes is important in land use planning and economic development. The research on geologic hazards provides sufficient information to map. There is also a continued addition to database on the geological hazards, calling for continuous updating of the hazard maps. Earthquake is a natural hazard that generally occurs without warning. The unpredictability and suddenness of earthquake have caused greater damage than other natural hazards. Landslides can also occur without warning though forewarning has been useful in preventing significant losses in landslide prone areas.

Physical characteristics of geologic hazards and their potential threat to life and property are displayed on hazard zonation maps that give historic, actual, and potential hazard levels for a region, hence useful not only in land use planning, but also in any hazard mitigation programmes. The demographic map of India has undergone a tremendous change with fourfold increase in population since independence. It is apprehended that a repeat of the Kangra earthquake that took a toll of over 19,000 lives in 1905 would be ten times more damaging in absence of proper mitigation measures in place (Arya, 1992).

Vulnerability, referring to the susceptibility of people, communities or regions to natural hazards, takes into account a combination of damage potential and coping capacity. Vulnerability map depicts the vulnerability index, obtained by weighting and combining the feasible indicators. The vulnerability map is combined with a hazard map to create the aggregated risk map for a region. Vulnerability depends upon the social, economic and environmental factors that add to the susceptibility to particular type of hazards.

Hazard potential is dependent upon the nature of the hazard and the areas that are likely to come under its influence. 'Risk' that is defined as a product of the vulnerability and hazard potential can be depicted on risk map. Cartography plays an important role in producing the right kinds of risk maps that can be used by the policy makers, government and communities in minimizing the adverse effects of hazards.

Earthquakes: intensity, magnitude and zones

Earthquake research has three objectives: (i) to understand the earth's dynamic processes and its internal structure, (ii) to study magnitude and recurrence time of the earthquakes provide basic information for taking appropriate mitigation measures, and (iii) to study properties of the seismic waves to design safe civil structures.

The earth's uppermost layer known as lithosphere consists of several 'rigid' plates. The lithospheric plates move around the globe by forces that originate mainly due to convection currents in the underlying 'viscous' asthenosphere. Lithospheric plates are subjected to stresses largely at their plate boundaries. The accumulated stresses lead to rupturing of rocks and release of the strain energy causing earthquakes. Earthquakes are common at the plate boundaries. They are either rare or non-existent within the lithospheric plates. Three types of plate boundaries are characterized by the three basic types of faulting: (i) Subduction-collision boundary, characterized by thrust faulting, (ii) Transform fault boundaries, characterized by strike-slip faulting, and (iii) Normal faulting, characteristic for ocean-floor spreading boundaries.

Magnitude of the earthquake is related to the amount of displacement associated with faulting. The point on the fault plane where the rupturing is initiated is called the focus or hypocenter. Epicentre is the point on the earth's surface vertically above the focus of the earthquake. Since the intensity of vibrations due to earthquakes rapidly decreases with distance,

the damaging effect of the earthquake is the maximum at its epicenter. Faulting rarely initiates at depths greater than 700 km. Shallow earthquakes with depth of focus less than 25 km are capable of great damage.

Severe earthquakes often cause damage to life and property over several thousand square kilometres. Intensity of damage is the maximum close to the epicentre. The affected region is divided into areas of increasing damages on a "Mercalli scale of intensity". The Mercalli scale varies from I to XII intensity classes corresponding to 'not felt' for class I to catastrophic stage for class XII.

The magnitude of energy, released during an earthquake event, is generally expressed on a logarithmic scale known as Richter scale of magnitude (M). The smallest earthquakes have the Richter magnitudes of ~2 M, and largest ones have the magnitude of ~ 9 M. The earthquakes of magnitudes less than 5 M are rarely hazardous to human life and property. Magnitude of 6 M is ten times larger than that of 5 M, and the energy released can be 30 times larger.

Seismic zoning is a complex method of depicting the variability in seismic hazards in an area. A seismic zoning map summarizes observations about the intensities and magnitudes of past earthquakes, assuming that the same pattern of seismic activity will be valid in future. It also takes in to account the variability in the geological setting and tectonics of the area. The first seismic zoning map of India was compiled by the Geological Survey of India in 1935. Since then a number of modifications have been made in the seismic zoning map of the country by the Indian Bureau of Standards as an important part of the standards for designing earthquake resistant civil structures.

The latest version of seismic zoning map of India (2002) assigns four levels of seismicity for the country, viz. Zones II, III, IV and V. About 57% of the land area of India comes under high seismic zones (III to V). Zone V covers the area with the highest risk zone that can suffer earthquake of

intensity IX or greater. It comprises of entire north-eastern India, parts of Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Rann of Kutch in Gujarat, part of North Bihar and Andaman & Nicobar Islands. Zone IV is called the High Damage Risk Zone. It covers remaining parts of Jammu & Kashmir and Himachal Pradesh, Union Territory of Delhi, Sikkim, northern parts of Uttar Pradesh, Indo-Gangetic basin, Bihar and West Bengal, parts of Gujarat and small portion of Maharashtra near the west coast and Rajasthan. Zone III is classified as Moderate damage Risk Zone. It comprises of Kerala, Goa, Lakshadweep islands, and remaining parts of Uttar Pradesh, Gujarat and West Bengal, parts of Punjab, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Maharashtra, Orissa, Andhra Pradesh, Tamil Nadu and Karnataka. Remaining parts of the country falls in Zone II that is the least seismically active region.

Five major earthquakes of magnitude greater than 8 have affected the Indian sub-continent between 1897 and 1958. Eight major earthquakes (magnitudes ≥ 6) have affected different parts of the region since 1967 alone (Fig. 1). Four of these major events (Uttarkashi in 1991, Chamoli in 1999, Muzaffarabad in 2005 and Sikkim in 2011) were located in the Himalayan mobile belt, three (Latur in 1993, Jabalpur in 1997 and Bhuj in 2001) in tectonically stable peninsular region of the country, and one (Koyana in 1967) in south-western Maharashtra.

Earthquake prediction- is based on the study of several parameters, either the cause or the consequence of fracturing of rocks. Study of the nature and space locations of active faults is most important in monitoring and mitigation of earthquakes. Occurrence of earthquakes is often accompanied by anomalous geomagnetic fluctuations and changes in the amount of dissolved radioactive gases (radon) in ground water. Monitoring the micro-earthquakes, felt several months before a major earthquake, also helps in predicting major event. Repetitive level

surveys have also been helpful since ground tilts often precede major earthquakes.

The first successful prediction of large earthquake was made in 1975 in China. Seismologists postulated in 1970 a possible earthquake event of appreciable magnitude, which was based on the historical records of the migration pattern of large earthquakes in the region. The second and third stages of predictions made in February 1974 and January 1975 gradually zeroed on the temporal information to 6 months and an area of about 100 km². The final prediction of the 7.3 magnitude earthquake was made 24 hours before the event. Thus, thousands of lives could be saved as the scientists, government agencies and public coordinated their efforts in minimizing the damage.

Reoccurrence of earthquakes follows a Poisson distribution pattern, giving a probability of 0.05 for a 9-magnitude earthquake to occur anywhere on the earth once in 20 years. A 9-magnitude earthquake that is likely to occur once in 20 years releases about 1.6×10^{18} Joule of energy corresponds to an energy budget of about 8×10^{16} Joule every year. It is important to develop techniques for predicting earthquakes of large magnitude before they hit the human settlements so as to minimize the loss to property and life. In recent years, scientific interest in earthquakes has been intensified in order to develop techniques to forecast the seismic events and to issue warnings in the same manner as they are done for other hazardous events.

Seismic Microzonation

Earthquake prediction is still in a research and experimental phase. Although a few successful predictions have been made, reliable and accurate predictions having a long lead-time, and useful location and magnitude estimates, are many years in the future. However, human casualties can be minimised by appropriate mitigation measures. Damage to life and property during earthquakes are caused mainly by the failure of buildings. Land-use zoning, and

engineering approaches such as building codes, strengthening of existing structures, stabilising unstable ground can minimise the losses to life and property. Seismic microzonation is one such tool that can help in formulating safe building codes for areas of differing response to ground motion due to earthquakes. Cost for seismic microzonation is generally small as compared to the economic impact of a major earthquake.

Depending on its size and location, an earthquake can cause the physical phenomena of ground shaking, surface fault rupture, and ground failure and, in some coastal areas, tsunamis. Smaller earthquakes, aftershocks, may follow the main shock, sometimes several hours, months, or even several years later. Ground shaking or ground motion, a principal cause of the partial or total collapse of structures, is the vibration of the ground caused by seismic waves during an earthquake. The site response is the reaction of a specific point on the earth to ground shaking. This also includes the potential for ground failure, influenced by the physical properties of the soil and rock underlying a structure and by the structure itself. The depth of the soil layer, its moisture content, and nature of the underlying geologic formation-unconsolidated material or hard rock-are all relevant factors. Shaking of the buildings gets amplified in case the period of the seismic wave is in resonance with the natural period of structure/foundation.

The first step in the seismic microzonation is to assess the probable level of ground shaking associated with the recurrence of earthquakes. Damage to civil structures in a major earthquake is influenced by the ground conditions on which the structures are built. The ground conditions include geomorphic features, geological structures and geotechnical properties of rocks and unconsolidated sediments. Amplification of certain frequencies of the seismic waves due to earthquakes is higher in ground with loose sediments than on harder rocks. For example, maximum damage in the Mexico earthquake of 1985 was caused in the Mexico City, situated 300 km away from the epicentre. This was attributed

to weaker ground conditions on which the multi-storied buildings were raised in the city. The foundation, in several cases, was made up of layers of lake sediments that responded with amplification of frequencies of seismic waves during the event.

The risk evaluation must consider vulnerability factors, such as type and age of buildings, population density, land use and time of the day. Large earthquake in remote areas is of little risk as compared to moderate earthquakes affecting densely populated areas.

Himalayan Collision Zone

The 2500 km long Himalaya has evolved into the greatest chain of mountains due to collision of the Indian and Eurasian continents. The collision began some 50 million years ago with the disappearance of a palaeo-sea known as Tethys Sea between the two continents (Rowly, 1998). Remnants of the Tethys Sea can be seen in a narrow belt of strongly deformed rocks known as Indus-Tsangpo Suture Zone (Fig. 1). The tectonic convergence has led to dismembering of the Proterozoic crust of the Indian Plate along a number of thrusts. The Main Central Thrust (MCT) separates the high peaks of the Higher Himalaya from the Lesser Himalaya in the south. The Main Boundary Thrust (MBT) separates the low lying Shiwalik Hills from the Lesser Himalaya. The Himalayan Frontal Thrust (HFT) that is not yet exposed on the surface is considered to demarcate the Himalayan tectonic unit from the Indo-Gangetic Plains.

The Himalayas have been the seismically most active region. Seismicity between the MCT and MBT is defined as the Main Himalayan Seismic Belt (MHSB). Many large ($M > 7.0$) and great earthquakes ($M 8.0$ and above) occurred in this belt (Kayal, 2007). Fourteen major earthquakes ($M > 7.5$) occurred in this region during the period 1897 and 1958. Four major earthquakes ($M > 6$) have affected the Himalayan region since last two decades (Fig. 1). Recent studies have indicated a strong possibility of major earthquake ($M > 8$) in the Himalaya in near future (Yeats and Thakur, 1998), mainly in the regions representing "seismic gap". This refers to the

region between the two great earthquake rupture zones, i.e. the epicenters of the Kangra earthquake ($M \sim 8.0$) of 1905 in the west and the Bihar earthquake ($M \sim 8.4$) of 1934 in the east. Seeber and Armbruster (1981) have estimated that the Himalaya ruptures in about 180 to 240 years that can release a great amount of energy causing the severest earthquake. This has a very important bearing on the seismic hazard in this region and adjoining Indo-Gangetic plains.

Earthquake epicentres of Uttarkashi (1991, $M - 6.6$) and Chamoli (1999, $M - 6.3$) were situated in south of the Main Central Thrust and north of the Himalayan Frontal Thrust (Fig. 1). They are located in the so called "seismic gap". In the Uttarkashi area, having a complicated tectonic setting, the main shock occurred at a depth of 15 km and aftershocks were generated at a variable depth of 0-15 km. The fault plane solution of the main shock shows a low angle thrust faulting, and the aftershocks show a reverse faulting. The Chamoli Earthquake was also caused by thrust faulting at a depth of about 21 km.

Focus of the Muzaffarabad earthquake (2005, $M - 7.6$) of the NW Himalayan Fold and Thrust Belt was located at a depth of 26 km below the surface. This region is located in the Hazara-Kashmir Syntax that is defined by a sharp bend in the major tectonic trends from NNW-SSE to NNE-SSW (Fig.1). Seismicity of the region is related to the ongoing collision of the Indian plate with Kohistan Island Arc. Focal mechanism analysis suggests that the earthquake was caused by thrust faulting on a NW-SE striking fault having dip towards NE. The faulting was also accompanied by a significant strike-slip component of slip. The rupture produced by the faulting reached to surface, named as Muzaffarabad Fault. The ground fissure produced during the Muzaffarabad earthquake faulting is considered as the surface expression of the reactivated Himalayan Frontal Thrust.

The Sikkim earthquake (2011, $M - 6.9$) was initiated by rupturing at a depth of about 20 km. This region has experienced relatively moderate seismicity in the past, with 18 earthquakes of $M 5$ or greater over the past 35 years within 100

km of the epicenter of the 2011 event. Preliminary focal mechanism analysis of the earthquake suggests strike slip faulting. It was related with an intra-plate source of energy for faulting within either the upper Eurasian plate or the underlying India plate, rather than occurring on the thrust interface plate boundary between the two. This event points to the role of transverse features in segmenting the Himalayan arc and accommodating some of the convergence of the India-Eurasia plates.

The Sumatra-Andaman Earthquake (2004, $M - 9.3$) that generated the devastating tsunami was the fourth largest event ($M \geq 9.0$) in the world during the last 100 years. The earthquake was generated by thrust faulting at the plate boundary between the Indian Plate and Burma Plate. This plate boundary is the southward extension of the frontal thrust of the Arakan - Yoma Folded Belt of the North-eastern India to the ocean floor in the west of Andaman - Nicobar Islands. The main shock rupture propagated from north of Sumatra to Andaman-Nicobar Islands for total length of 1300 km. This rupture overshot all the rupture zones of the past large earthquakes in the Andaman-Sumatra arc.

Intra-plate Seismicity

The Peninsular India has been relatively stable in comparison with tectonically active nature of the Extra-peninsular India. The Peninsula comprises the Indian Craton that consists of the Indian Shield and Platform Cover. The Indian Shield is made up of crystalline rocks of Archaean and Lower Proterozoic ages. The remnants of folded mountains and massifs constitute the Indian Shield, whereas the Plateau Mountains and the three Gondwana Grabens (Narmada - Son, Godavari and Mahanadi rifts) comprise the younger elements (platform cover) of the Indian Craton. The Platform Cover consists of Middle and Upper Proterozoic sequences in the central parts and Phanerozoic sequences of continental shelf facies in coastal and outer regions of the craton. The Indian Craton is also characterised by the presence of a vast tract of flood basalts of Early

Palaeocene age forming the Deccan Syncline.

There are three main regions of the peninsula that show some tectonic activity in the present time. Most of historically recorded seismic activity has been reported from these regions. Three major seismic events occurred in recent past in these three regions. The region around Kutch and Saurashtra in Gujarat and the areas lying within the Narmada – Son lineament in central India have witnessed repeated seismic events. South-central parts of Maharashtra had a major seismic event. While the north-western Peninsula and central India have exposed active geological structures, the fault lines in major parts of Maharashtra are covered by the volcanic rocks of Deccan Syncline.

The Saurashtra- Kutch region is bounded on the north-west by ENE-WSW trending Kutch Rift and on the east by NNW-SSE trending Cambay Rift. The region is divided into two geological blocks by a NE-SW trending fault named as Kutch Mainland Fault (KMF). This region is known for a high incidence of earthquakes both in recent times and in historical past. This is the only region outside the Himalayan Seismic Belt that falls in Seismic Zone V. In last 200 years six events of damaging earthquakes occurred in the vicinity of Bhuj which was the epicenter of earthquake of magnitude 7.7 M in 2001. This event was the second largest event in the western margin of peninsular India after the 1819 great Kutch earthquake (M ~ 8.0). Geophysical evidence has been used in inferring that the Kutch Mainland Fault was not the causative fault for the Bhuj earthquake. The causative fault is a steeply south dipping hidden fault, which was located at a depth of 25 km in the Kutch Rift Basin. The seismic data also indicated a bimodal activity of aftershocks, occurring at a depth 15–35 km.

The Narmada–Son lineament that extends across the northern parts of the Indian Peninsula has been activated from time to time since it was formed at about 1600 million years ago. Minor seismic events in recent time in the areas around Jabalpur have been related with the reactivation of ENE-WSW trending faults of

the lineament. A devastating earthquake of magnitude 6.0 M struck the town in 1997. Focus of this earthquake was located at the base of the Narmada Rift at a depth of 35 km. The seismic waves were generated by reverse faulting with some left-lateral strike-slip motion.

The south-central parts of Maharashtra were not known for seismic activity of high magnitude until the event of 1993 Latur earthquake of magnitude 6.3 M. It resulted in significantly large damage to life and property. Analysis of the seismic records showed that it was caused by reverse faulting at a depth of 6 km. The shallower aftershocks, (0–<6 km), on the other hand, occurred by right-lateral strike-slip faulting. Fault plane solutions and seismic cross-section of the main shock and deeper aftershocks, however, suggest a south dipping E-W fault.

Reservoir Induced Seismicity

Water reservoirs are known to trigger earthquakes. Over 90 sites have been identified around the world where filling of water reservoirs have induced seismicity. The most widely accepted explanation of how dams cause earthquakes is related to the extra water pressure created in the micro-cracks and fissures in the ground under and near a reservoir. When the pressure of water in rocks increases, it acts to lubricate faults, already under tectonic strain, but prevented from slipping by the friction of the rock surfaces.

Koyna, located near the west coast of India in south-western Maharashtra has been one of the most significant sites of reservoir induced seismicity. The largest trigger measuring 6.0 M occurred in 1967. The earthquake claimed over 180 human lives and damaged more than 80% of the houses in the vicinity of the Koyana dam. The earthquake had also caused the appearance of a 10-15 cm wide fissure in the ground which extended for over a length of 25 km. However it didn't cause any major damage to the dam itself except some minor cracks.

There have been several earthquakes of smaller magnitude there since 1967. Over 170 small

magnitude-earthquakes (~ 4 M) and several thousands of smaller ones have been recorded in the area close to dam in the past four decades since the water was filled in the dam. During 1990s, two events exceeding M 5 and several smaller events occurred in the vicinity of Koyna. Detailed studies have been carried out to continuously monitor the seismic events in the region. For this, 90 m to 250 m deep bore-wells have been drilled in the seismically active region for monitoring the variations in the sub-surface water levels.

Landslide

The term “landslide” comprises almost all varieties of mass movements on mountain slopes that include rock falls, topples and debris flows that involve little or no true sliding (Varnes, 1984). Sliding dynamics of large volume of the earth's material can be of different types, such as translational or rotational sliding or a combination of the two. Impact of the landslide on the life and property is limited to the area of landslide that rarely exceeds a few hundreds of square metres. However, landslides are capable of disrupting infrastructures such as roads, rail-roads, bridges and tunnels that can affect the economic activities of a larger population inhabiting the region. Landslides can also lead to temporary obstruction of the flow of water in river valleys. Such natural dams are likely to be breached by the water dynamics causing flooding and rapid erosion in lower parts of river valleys.

Slope failure and mass movements of earth's material are caused by a complex interaction of several interrelated factors such as lithology and geological structures, soil types and vegetation, and hydrological features. Mass movement on slopes is triggered by a variety of external stimuli that cause a quick increase in shear stress or decrease in shear strength of the slope material (Dai et al. 2002). Whereas lithology and structures are static in nature, soil types, vegetation and hydrological conditions frequently change with the seasons of the year. Earthquakes can also lead to slope failure and mass movements. Anthropogenic influences

that tend to modify slope conditions can also lead to landslides.

The Himalayas and Western Ghats happen to be the two most vulnerable regions to landslides in India. The Himalayas are tectonically unstable region, frequently subjected to seismic activity. Though the Western Ghats considered geologically stable but have also shown the imprints of some neo-tectonic activity. Compared to Western Ghats, the slides in the Himalayas are huge and massive.

Tectonics-climate coupling and slope dynamics

Landscape evolution of the Himalaya is seen as a response to the compressive forces in the convergent zones. Uplift of the Tibetan Plateau and the Higher Himalaya has influenced global climate and monsoon intensity. Convective removal of the lower lithosphere beneath the Tibetan Plateau has been regarded to be a possible cause for a rapid increase in the mean elevation of the Tibetan Plateau by 1000 m or more during the last few million years (Molner et al., 1993). The Asian Summer Monsoon is envisaged to have set in at the commencement of the Neogene when the uplift rates in the Himalayas gained momentum (Kumar, 2006). Piling of the thrust sheets in the Higher and Lesser Himalayas is considered to be the primary cause of the uplift under the influence of isostatic rebound of thickened lithosphere.

Tectonics controls the rate of evolution while the monsoon driven climate determines the rate of erosion. Grading of sediments in front of a rising mountain is dependent upon spatial and temporal variations in relative rates of tectonic uplift and erosion (Fig. 3). Erosion rates in the Himalayas are dependent upon the intensity of the monsoon and variability in precipitation within the mountain ranges. Spatial and temporal variations in the monsoon precipitation in the Himalayas have been well demonstrated (Anders et al., 2006).

Orographic barrier to monsoon clouds at the southern front of the High Himalaya leads to almost bulk of the annual precipitation in the

Himalayas. These high rates of precipitation and high relief of the Lesser Himalaya and the southern parts of the Higher Himalaya lead to a high rate of erosional unloading. Erosional unloading and stacking of thrust slices on the back of the Himalayan Frontal Thrust is also considered to be responsible for high rates of the tectonic uplift of the Himalayas in the north of the Indo-Gangetic Plains (Fig. 4). Dating the mineral cooling ages indicated relatively rapid rates of uplift in the southern parts of the Lesser Himalayas (Thiede et al., 2004). Geomorphic properties that have been inferred from digital elevation model (DEM) also suggest a very high rate of uplift in the Shiwalik Hills of Central Nepal (Hurtrez et al., 1999).

Landslide Hazard Zonation

Landslide hazard zonation helps in classifying areas of varying slope according to their potential stability/instability. Zonation requires field observations, analysis of satellite imageries and topographic maps of the area (Fig. 5). Field methods, used to evaluate the slopes and slope forming materials, help in determining the degree of susceptibility to landslides based on terrain, geological structures, lithology, hydrological and vegetation conditions. Theoretical evaluation use either statistical or deterministic models to predict landslide-prone areas based on landslide occurrence and the factors causing slope movement (Anbalagan, 1992). Application of GIS techniques has been found effective in slide susceptibility zone mapping (see also Sharma and Kumar, 2008).

The GIS evaluation of the landslide hazards of an area is carried out in three major steps: data collection, database generation and analysis. Topographic maps, satellite data, geological maps and ground truth data are used to compile themes. Geological, geomorphological and topographical parameters play a dominant role in landslide susceptibility zonation. It is appropriate to model these parameters with respect to their relative contribution to slope failure. Active landslides with areal extent of more than five square metre in the Parwanoo area were mapped by author dividing into

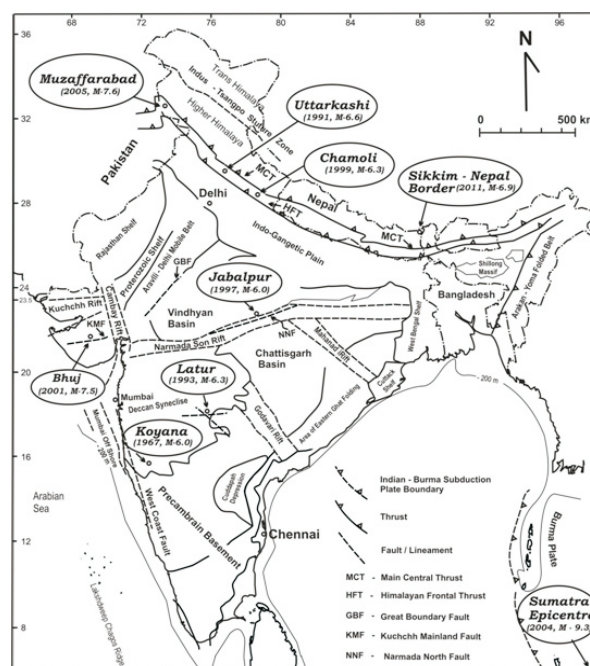


Fig. 1: Recent major seismic events in relation to tectonic divisions of India

classes according to type of mass movements, e.g. slides, falls and flows.

Factors contributing to slope instability include slope angle, lithology, distances from fault, drainage and road, water flow accumulation, and land use. Steep slope, one of the most important contributing factors, is caused the earth's material to move down the slope in response to gravity. Slope angles and rock types are grouped into convenient classes. Since the landslides are more frequent in the vicinity of major faults, the distance from the major faults is considered as a triggering factor for mass movement. Distances from the streams and from the roads are also considered as the causative factor for landslides. Hydrological factors in hilly regions undergo rapid change that is the most important contributory factor for mass movements on critical slopes. The flow accumulation map shows distribution of different domain classes based on the number of pixels contributing to the flow.

Each contributing factor is assigned a weight in terms of its correlation with the occurrence of landslides that is estimated from the observed association between landslides and the

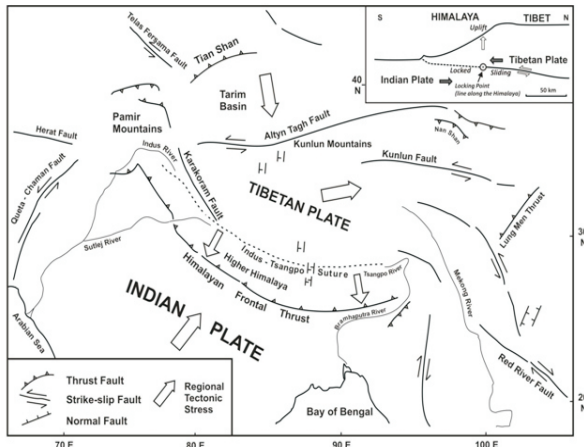


Fig. 2 Active Faults in the Himalaya and adjoining regions (Inset shows the locked part of the Himalayan Frontal Thrust.)

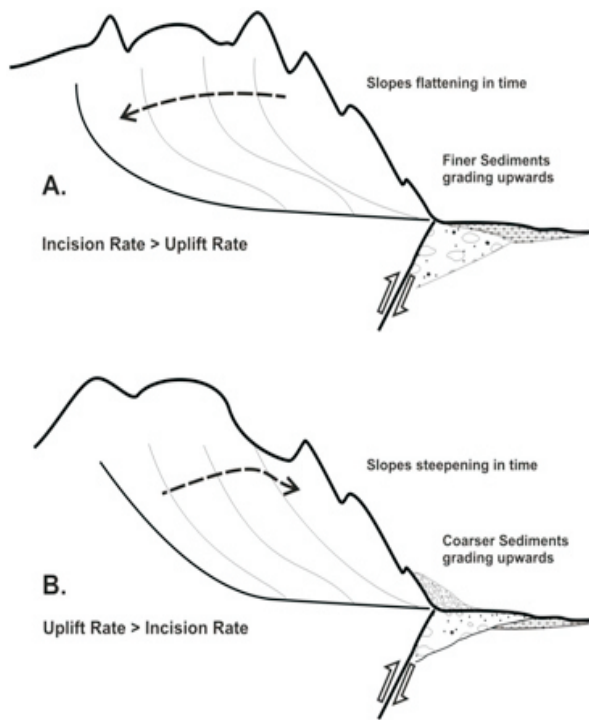


Fig. 3 Schematic diagram showing relationship between slope dynamics, relative erosion and uplift rates, and distribution of sediments in front of rising mountain

parameter. This is combined with the probability of occurrence of landslides to derive the probability of possible occurrence landslide in future. Each parameter map is reduced to discrete domain classes. In its simplest form, the pattern of the feature is binary in nature, representing either its presence or absence in pixels. Using bivariate statistics, an assumption

is made that all landslides in a given study area occur under the same combination of parameters and all sets of parameters are conditionally independent (see Sharma and Kumar, 2008). Using the slicing operation in GIS software, the landslide hazard zonation map is created from the above final weight map.

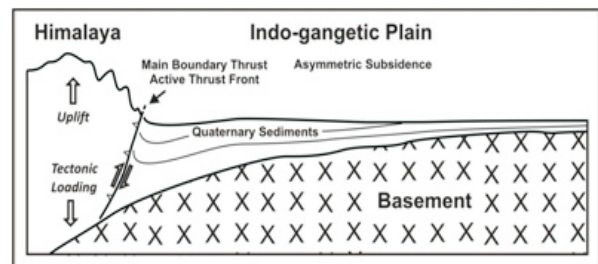


Fig. 4: Active faulting and uplift in the Himalaya related to tectonic loading of northern edge of the Indian Peninsula

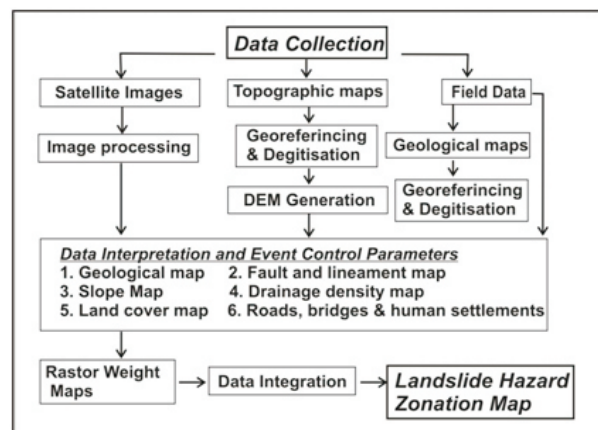


Fig. 5 Flow chart for methodology of Landslide Hazard Zonation

References

- Anbalagan R, (1992) Landslide hazard evaluation and zonation mapping in mountainous terrain. **Engineering Geology**, 32(4), pp.269–278.
- Anders, A. M. et. al. (2006), Spatial patterns of precipitation and topography in the Himalaya. In Willett, S.D., et. al. (Eds.), **Tectonics, Climate, and Landscape Evolution**, Geological Society of America Special Paper 398, pp.39–53.
- Arya, A.S. (1992), Possible effects of a major earthquake in Kangra region of Himachal

Pradesh, **Current Science**, Special Issue, 62 (1&2), pp.251-256.

Dai, F.C. et. al. (2002), Landslide risk assessment and management: an overview. **Engineering Geology**, 64, pp.65-87.

Hurtrez, J.E., et. al., (1999), Investigations of the relationships between basin morphology, tectonic uplift and denudation from the study of an active fold belt in the Siwalik Hills, Central Nepal. **J. Geophysical Research**, 104 (B6), 12779-12796.

Kayal, J.R. (2007), Recent Large Earthquakes in India: Seismotectonic Perspective. **IAGR Memoir 10**, pp.189-199.

Kumar, R. (2006), Tectonic climate linkage and rise of the Himalayas. in J. J. Bahk and B.K. Khim (eds), **Monsoon, Tectonics, Palaeoclimate and Palaeo-oceanography in East Asia and its Marginal Seas**, Proceedings of 4th International Symposium of IGCP-476, pp.3-4.

Molnar, P. et. al (1993), Mantle dynamics, uplift of the Tibetan Plateau and Indian Monsoon. **Reviews of Geophysics**, 31(4), 357-96.

Rowley, D. B. (1998), Minimum age of initiation of collision between India and Eurasia north of Everest based on the subsidence history of the Zhepure mountain section. **Journal of Geology**, 106, 229-235.

Sharma, Mukta and Kumar, Ravindra (2008), GIS Based Landslide Hazard Zonation: A case study from the Parwanoo area, Lesser & Outer Himalaya, H.P., **Indian Bulletin of Engineering Geology and Environment**, 67, pp.129-37.

Thiede, R. C. et. al, (2004), Climatic control on rapid exhumation along the Southern Himalayan Front. **Earth and Planetary Science Letters**, 222, pp.791-806.

Varnes DJ (1984) **Landslide Hazard Zonation. A Review of Principles and Practice**. UNESCO, France.

Yeats, R.S., and Thakur, V.C. (1998), Reassessment of earthquake hazard based on a fault -bend fold model of the Himalayan plate-boundary fault. **Current Science**, 74(3), 230-33.

(Professor Ravindra Kumar is the former Professor & Head, Department of Geology, Panjab University, Chandigarh,

Email: profravindra@hotmail.com)

Role of Hydrographic Department in Disaster Management

Rear Admiral Saroj Kumar Jha, NM

It is indeed a privilege for me to interact with the academicians and students. I wish to convey my gratitude to the department of geography for having helped us in organising the XXXI International Congress with a very relevant topic of today's burning issue "Cartography for Disaster Management". The themes and sub-themes selected for the congress indicates the academicians touch which I am sure, is going to benefit all of us. Today I am, going to briefly talk about "Indian Naval Hydrographic Departments Role in Disaster Management".

India's maritime history can easily be tracked back to about 4500 years and could be linked to Indus valley civilisation. There are evidence of flourishing trade between India and Mesopotamia, the modern day Iraq and Egypt. It is a well known fact as to how our forefathers used the knowledge of astronomy, trade winds and weather to their advantage. We also know how they passed information concerning underwater dangers and navigation from generation to generation. In fact, the root of hydrography stars from that era. Initially it was the mental reckoning and later it was documented. However, with the East India Company's establishing a firm grip in this part of the world, It was soon realised that for safety of their merchandise they ought to know the art and science of hydrographic data collection process and the cartographic science to develop nautical charts for safe navigation. Later in 1874 Marine Survey of India was established at Kolkata and finally in 1954 National Hydrographic Office at Dehradun was established.

Today 95 percent of our trade by volume and 70 percent by value is transported through sea routes. Sea lines of communications from Gulf/Red sea via our waters, through Sri Lankan coast and Malacca Strait is one of the busiest

routes which is used by around 600-1000 vessels per day of varying tonnage and cargo. This being one of the major oil transportation routes is extremely vital for the growth and sustenance of world economy. It is therefore extremely important to ensure the route is safe and uninterrupted flow of traffic is maintained. However, very frequently there are disasters human induced and natural which needs to be handled on a day to day basis.

The National Hydrographic Department has immensely contributed in the past during natural disasters. The department has eight ocean going hydrographic surveying vessels that perform dual role as a Hospital ship to provide Humanitarian Assistance and Disaster Relief (HADR) and for conducting bathymetric modelling of seafloor using state-of-the-art acoustic systems. To throw some light on this issue I will first take few cases:-

(a) Collision in Mumbai Port: Mumbai witnessed the collision of MV Khalijia with MV Chitra during last monsoon on 10 august 2010 resulting in environmental damage to the mangroves and the eco-sensitive beaches close to Mumbai. The busy Mumbai port was closed due to fear of underwater obstructions created by the containers that had fallen overboard. Post collision of the approach channels were cleared of obstructions by fixing (locating their exact position underwater) the fallen containers by the hydrographic survey vessel using state-of-the-art side scan sonar.

(b) MV Rak Sinking: The Panama-Flagged Mv Rak, which was on its way from Indonesia to Gujarat with 60,000 tonnes of coal, sank on 04 august 2011 off Mumbai. Thirty crew members from the cargo vessel were rescued by the navy even as 3/4th of the 225

meter-long vessel had sunk into the choppy waters of the Arabian Sea. The oil spill created extensive damage to the environment despite measures taken to control pollution. The vessel was accurately fixed by the hydrographers and its lay on the sea bed was ascertained using digital side scan sonar. This was essential for warning the mariners operating in the area. In addition this information with bathymetry was required to lay a buoy to mark it as a danger. The current and tidal stream information was utilised in assessing the movement of the pollutants towards the shore. The wreck will be monitored by the hydrographic survey vessels operating in the area periodically to report any changes that may affect safety of navigation.

(c) M.T. Pavit Grounding: In another incident, a 70-metre long, 1,000-tonne cargo carrier, M.T. Pavit, drifted all the way from Ras-Al-Madrakah near Oman to get stuck in the sands at the Juhu/Versova beach on 31 July 2011 near Mumbai. Even though grounding did not create ecological problems the vital parameters such as beach gradient derived from bathymetry, tidal levels and tidal stream rate and direction assisted in safely salvaging the vessel from the beach head.

(d) Mumbai Floods: Mumbai is surrounded by water and its natural ecosystems have been tampered in the name of reclamation/development. Mumbai Floods on 26 and 27 July 2005 highlighted the need of an integrated coastal zone management approach in which hydrographer plays a pivotal role in providing critical input for effective and efficient management of coastal areas that would go a long way to mitigate future disasters.

(e) Bhuj Earthquake: The earthquake highlighted the versatility of hydrographic survey vessels that perform dual role i.e., they act as hospital ship in the event of disaster and during hostilities in addition to charting the oceans. The disaster relief

teams were formed by the ship and commenced first aid relief measures in the scene of action as the other means of communication network was crimped due to earthquake.

(f) Indian Ocean Tsunami: The hydrographic department contributed immensely during tsunami 2004 in disaster relief measures and re-habitation programmes. During tsunami in 2004 the hydrographic ships were the first to reach Indonesia, Sri Lanka and in addition also provided relief to Andaman and Nicobar group of islands.

Hydrographers Role

The Hydrographers role in disaster management and providing support to the coastal areas can be basically summed up into:-

(a) Prediction: Hydrography has an important part to play in both prediction and response, although in most cases, these activities will take place as part of multi-disciplinary teams. Basic mapping of several parameters is fundamental to successful modelling and prediction. With the advent of Multibeam acoustic systems the hydrographers are capable of accurately mapping an area of the seafloor in the vicinity of the epicentre of the seismic disturbance. The hydrographer would be able to provide sufficient data for generalised modelling and to understand the basic mechanisms which set off a tsunami. It may be noted that run up characteristics of tsunami waves vary from coast to coast depending upon the shoreline configuration and bottom topography. Results from geology and geophysical studies can be combined with historical data of tsunami events, bathymetric data, and numerical modelling to provide the necessary information to permit the construction of a tsunami hazard map. Such a map provides basic information to the coastal planner considering development of the coastal area in this region, so that they can avoid the possible hazard caused by tsunamis.

(b) Sea Level Monitoring: An important means of monitoring and predicting tsunami activity is in the monitoring of sea level change around an ocean area. Water level data for the analysis and prediction of tides can provide this secondary important task of detecting anomalies in the form of a change of water level height caused by a tsunami. At NHO we predict tides for a network of ports/harbours all along the Indian coast and island territories with real-time tide data. Our ships observe and monitor tides whilst conducting hydrographic surveys of newly established ports and verify the predicted tides of established ports.

(c) Coastal Zone Management: Hydrographic surveys provide the base layer for environmental monitoring, impact modelling and consequence management. Physical environmental characteristics such as bathymetry are required to support numerical modelling efforts in order to provide accurate representations of the impact from a variety of man-made and naturally occurring events. Delineation of the habitat boundaries, changes in expanse or volume can be easily monitored and immediate actions taken to mitigate negative trends, where possible.

In the event of any disaster, the hydrographers efforts for ensuring safety of life and property contain following elements:-

- (a) Assess the extent of damage to navigational aids in the affected areas.
- (b) Assess and undertake preliminary re-survey for any reported changes in depths in the affected areas particularly ports, restricted navigational areas.
- (c) Issue advice to shipping as appropriate through existing network.
- (d) Identify anchorage area, landing sites for boats and relief teams.

Conclusion

It is a certainty that other disasters will occur in the future. Hydrographers have a part to play, both in their capacity as providers of various types of marine data, particularly of the seafloor and topography and the tides, but also as a part of multi-disciplinary teams that work towards improving our ability to predict future maritime disasters, their consequences and minimisation of their effects. Hydrography plays an important role in marine disaster management, both its prediction and in the aftermath. Traditionally hydrographic surveys were mainly directed towards providing data for the production and maintenance of nautical charts but today hydrography has a much broader mandate and provides data for great range of environmental and engineering studies. In the end, united effort and support for marine science in its broadest sense directed towards oceans where most of these disasters develop is essential for successful disaster prediction and mitigation.

(Rear Admiral S.K. Jha, NM s the Chief Hydrographer to Govt. Of India, National Hydrographic Office, Dehradun-

Email:sarojkjha@hotmail.com)

Earth Observations Data and Geomatics Applications for Disaster Management in India

(A Brief Survey of NRSC Contributions)

Vinay Kumar Dadhwal

Abstract

India, a highly disaster-prone nation with recurring disasters causing large-scale human distress and economic loss, needs to shift its approach from relief-centric to disaster management based on scientific inputs. In this context, ISRO has evolved successfully a Disaster Management Support Programme (DMSP) with the aim of providing the benefits of aerospace technology to disaster management. A Decision Support Centre (DSC) has been established at the National Remote Sensing Centre (NRSC) to serve as a single-window delivery point for disseminating value-added information on five major natural disasters (floods, drought, forest fires, landslides and earthquakes). The DSC uses multi-source EO data and various geomatic tools to provide near real-time information on prevalence, degree of severity and disaster persistence and damage from the disasters. New initiatives include the creation of multi-scale baseline data in hazard-prone districts, Airborne Laser Terrain Mapper (ALTM) derived close contours, strengthen the risk/damage assessment capabilities and R&D for early warning. The effective methods and tools have been designed to disseminate the disaster information to the general public and the concerned administrative agencies for reducing the disaster risk.

Introduction

Owing to unique topographic and climatic characteristics, India is highly prone to a variety of natural disasters. More than two-thirds of country's landmass is prone to drought, about three-fifths to earthquakes of various intensities, more than one-tenth to floods; nearly one-tenth to cyclones; and more than a half of the forest is subjected to forest fires. Of about 230 million poor persons in the country, a majority is living in the disaster-prone regions, especially in the arid, semi-arid regions and floodplains (Status Report, MHA, 2004). India's vision in disaster management is to build a safer and disaster-resilient country by developing a holistic, proactive, multi disaster and technology-driven strategy for disaster management through the collective efforts of all Government Agencies and NGOs.

There has been a paradigm shift in the disaster management approach from relief-centric/crisis management to prevention,

mitigation and preparedness. Most of the time, the required information is not available due to a variety of reasons, leaving decision-making to past knowledge and experiences, which may be erroneous. The process of collection of information by conventional means is not only time consuming but also expensive. In this context, the Earth Observation satellites provide comprehensive, synoptic and multi temporal coverage of large areas in near real-time and at frequent intervals, enabling the comparison of data/information in pre and post disaster phases. This paper makes a synoptic view of various activities being carried out at National Remote Sensing Centre (ISRO), Hyderabad in the field of disaster management.

Role of EO inputs and Geomatics in Disaster Management

Disaster management refers to a comprehensive strategy in all phases of disaster for effective reduction in disaster impact. A typical Disaster Management Cycle comprises of six elements,

i.e., Prevention, Mitigation and Preparedness in pre-disaster phase and Response, Rehabilitation and Reconstruction in post-disaster phase. However, there is need to add this list 'early warning phase' as a priori prediction for avoiding loss of the live during in disasters such as tsunami, cyclones, etc. Due to synoptic coverage and repetivity, EO data have a special role in quick damage assessment, as field information collection in disaster affected areas would be significantly a herculean task. Several studies have, however, demonstrated that EO data are equally useful in all phases of disaster management. The characteristics of sensors most suitable for different disasters as well as different management phase of a disaster are quite different. Joyce *et al.*, (2009) reviewed parameters and algorithm for damage assessment under various types of disaster.

It has been now accepted globally that disaster management is one of the most important application areas of space technology, comprising EO, emergency communication and navigation applications. For the major initiatives see Table 1. These include multi-lateral national programs under United Nations (UN-SPIDER) and Group on Earth Observations (GEO), a cooperative arrangement by world's space agencies (CEOS) and regional space agency led initiatives with global (ESA-GMES) and regional coverage (Asia-Pacific by Sentinel-Asia). The focus in these programs is also on providing the access to EO data, and support preparedness and mitigation activities and capacity building.

Among the Indian states, Kerala has passed through impressive demographic transition with low infant mortality rate, high life

NRSC: Activities relevant to disaster management

ISRO-Disaster Management Support (DMS) Program, by integrating space and contemporary technologies, aims at to provide reliable and timely space-based products and services for strengthening country's disaster management. In consonance with the goals, the

Table 1
Major Global Initiatives in use of EO data for Disaster Management

Initiative	Organization	Components
International Charter for Space and Major Disasters (http://www.disastercharter.org).	Committee on Earth Observation Satellites (CEOS)	On invoking of Charter by any affected nation, all space agencies use every opportunity from their satellites to image affected area and freely provide the EO data.
Emergency Response Service (GMES) (http://www.esa.int)	Global Monitoring for Environmental Security (GMES) of ESA under Living Planet Programme.	Operational GMES emergency management service delivers the essential products needed for the management of humanitarian crises, natural disasters and human-induced emergency situations
Sentinel Asia	Asia-Pacific Regional Space Agency Forum (APRSAP)	A voluntary initiative of APRSAP to support disaster management activity in Asia-Pacific through web-GIS and EO satellite data.
Disaster Management of GEOSS	Group on Earth Observations (GEO)	GEO being a multi-lateral arrangement of signatory nations promotes a Global Earth Observation System of Systems (GEOSS) for nine areas of societal benefits, including disaster management.
United Nations Platform for Space-based information for Disaster Management and Emergency Response (UN-SPIDER) (http://www.un-spider.org/)	United Nations Office of Outer Space Affairs (UNOOSA)	UN-SPIDER aims at providing universal access to all types of space-based information and services relevant to disaster management by being a gateway to space information for disaster management support; serving as a bridge to connect the disaster management and space communities;

DMS Program addresses: (i) creation of digital databases at appropriate scales for hazard zonation, damage assessment, etc., in perennially disaster prone areas, (ii) development of appropriate RS and GIS-based decision support system and demonstrations catering information needs at different levels, (iii) acquisition of close contour information for

priority areas, (iv) strengthening communications for addressing the real/near real time information transfer needs, and (v) networking of scientific institutions for exchange of data, information and knowledge (see Fig. 1 for DMS program by ISRO).

NRSC has mandated activities of (a) data acquisition from aerial and satellite platforms, making data products available, and (b) developing techniques and carrying out national scale RS application projects. The aerial acquisition to support disaster management has additional sensors such as ALTM and airborne C-

for National Remote Sensing Agency (NRSA) under. DSC is an operational service provider for online transfer of space-enabled inputs to the State and Central Govt. user departments a VSAT-based satellite communication network is also part of DSC.

Activities of DSC at NRSC

The approach of the Decision Support Centre at NRSC relating to the disasters is summarized in the following. For details on the subject see Bhanumurthy and Behera (2008). Table 2 provides a list of DSC products derived from EO data with respect to each disaster as well as the

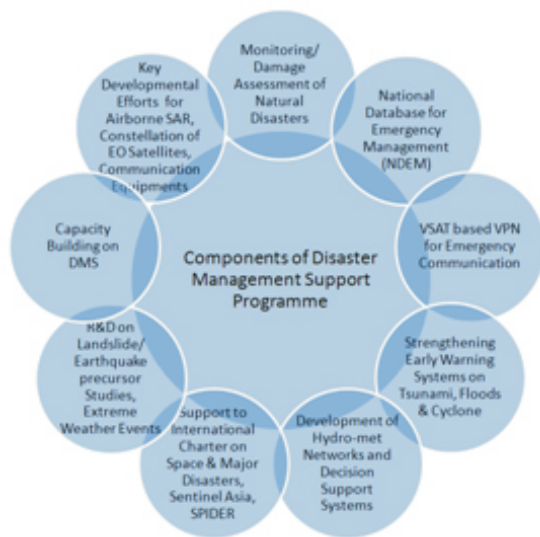


Fig.1 Components of ISRO DMS programme

band SAR developed at Space Applications Centre (ISRO). While the former sensor is useful in making close contour information for target areas, the C-SAR is useful for mapping flood extent under dense clouds. Towards enabling the operational services in field of disaster management, a Decision Support Centre (DSC) was established under ISRO Disaster Management Support Programme (DMSP) at NRSA in 2003, as a single window service provider, interfacing with the National/State disaster management agencies. DSC is currently addressing five natural disasters, viz. Flood, Agricultural Drought, Forest fires, Landslides, Earthquake and Cyclone and in order to provide

Table 2

Decision Support Centre (DSC) and EO based-products/outputs generated for various phases of management cycle of select disasters

Disaster.	DSC products in response phase	DSC products in preparedness/mitigation phase	Eo inputs for R&D in early warning phase
Flood	Flood inundation maps (m) Damage assessment	Flood hazard zonation Bank erosion maps	Hydrological modelling for flood prediction
Drought	Monthly drought report End-of-season assessment		
Forest fire	Active fire Burnt area	Fire hazard zones	
Landslide	Damage assessment	Landslide hazard zone maps	
Earthquake	Damage assessment (vhr)		Earthquake precursors
Cyclone/ tsunami	Inundated area Damage assessment (m)		Close contours for coastal area

Note : (M)= Microwave (SAR) data is essential since cloudy conditions are prevalent (VHR) = Very high resolution, including aerial data is needed to delineate building damage

phases of disaster management cycle. Information on floods and agricultural droughts is well developed, but in case of earthquakes current space-borne sensors could provide only the major damage classes. Use of aerial surveys and ALTM for deriving close contour information for major flood prone areas has also been taken up.

Flood

India, accounting for one-fifth of global deaths due to floods, is the second most flood prone country after Bangladesh in the world. About 40 million hectares (mha) or nearly one-eighth of India's geographical area is flood-prone (RBA 1980). The most flood prone areas are in Assam, Uttar Pradesh, Bihar, West Bengal and Orissa due to the high discharges in the Ganga-Brahmaputra river systems. The main causes of floods are widespread heavy rainfall in the catchment areas and inadequate capacity of the river channels to contain the flood flow within the river banks. The Himalayan rivers, the Ganga and its tributaries flowing down the hills cause flood problems in Uttar Pradesh, Bihar and West Bengal due to high discharges concentrated during monsoon months (June to September) and large volumes of sediment are carried to the plains. Drainage problems also arise concurrently if floods are prolonged and the outfalls of major drainage arteries are blocked. On account of frequent changes in river courses and braiding of channels, erosion of riverbanks also assumes importance as one of the major problems associated with floods.

Using the hydro-meteorological data from ground as well as web resources, a constant watch is kept on the flood/cyclone situation in the country. The flood situation is mapped and monitored through multi-temporal satellite data acquired of the affected areas. Accordingly, optical and microwave Synthetic Aperture Radar (SAR) data is planned and acquired from Indian and foreign satellite missions. If needed aerial data in form of SAR is also acquired and

processed for flood inundation (Chandran et al., 2006).

Currently, images from Resourcesat 1 & 2, Cartosat-1 & 2, RISAT-1 & 2 and Radarsat-1&2 are extensively used. Indigenously developed SAR instrument mounted on an aircraft is also flown on the affected areas depending on the requirement. Using automated procedures, the satellite data is analysed and flood inundation layers delineated. Flood maps are prepared at various scales: 1:500, 000 to 1:25,000. Flood maps depicting the ancillary information like administrative boundaries, settlements, roads and rails, are being widely used for carrying out relief and rescue operations specifically to airdrop relief material. The flood inundation layer is intersected with the database consisting of districts, talukas, villages, land use/cover, road and railway networks; and the flood damage statistics on flood inundated area, and submerged rail/roads, crop land, and villages submerged are estimated.

Spatial inundation maps, along with estimates on submergence are generated within 6 hours of receiving satellite data product and disseminated to the Ministry of Home Affairs, Central Water Commission and State Relief Commissioners through electronic means for further use in relief and rescue operations. There has been a systematic feedback mechanism, through which the decision makers are able to interact with the DSC to get the required value addition to the information.

Flood Mitigation

Flood Hazard Zonation information is prerequisite to undertake non-structural measures for flood mitigation. Flood inundation layers long periods can be integrated in GIS environment to identify flood inundated areas with different frequencies and prepare flood hazard maps at state and district levels.

Based upon frequency of flood occurrence in a 10 year cycle, flood hazard are classified into five categories: very low (inundated once or twice),

low (inundated 3-4 times), moderate (inundated 5-6 times), high (inundated 7-8 times) and very high (inundated 9-10 times). More than 90 satellite datasets acquired from Indian Remote Sensing (IRS) and Radarsat satellites for last one decade (1998-2007) during flood season over Assam have been analysed to create a flood hazard zonation atlas of Assam.

Agricultural drought

NRSC (earlier NRSA) initiated EO data based agricultural drought assessment project named 'National Agricultural Drought Assessment and Monitoring System' (NADAMS) in 1986 with objective of providing to Department of Agriculture and Cooperation (DAC) of Ministry of Agriculture (MOA) and various State Department of Agriculture information about prevalence, severity and persistence of agricultural drought at state, district and sub-district level. Since 1990 results are provided operationally in-time to DAC. Initially drought assessment was largely dependent on only NOAA-AVHRR derived NDVI and IMD rainfall data at district and sub-division (Thiruvangadachari, 1990).

Bi-weekly drought bulletins at district or regional were issued from June to October, based on 1km resolution NOAA-AVHRR data. Over a period of time, NADAMS project has undergone many methodological improvements such as use of moderate spatial resolution data for disaggregated level assessment, use of multiple indices for drought assessment, augmentation of ground data bases, achieving synergy between ground observations and satellite based interpretation, providing user friendly information, and enhanced frequency of information. The satellite data employed and indices derived in different projects are summarized in Table 3).

The coarse resolution NDVI from Oceansat 2 OCM, NOAA AVHRR and Terra MODIS are being used to detect crop condition and wetness anomalies respectively for detecting drought

intensity at district/state level. The AMSR-E soil moisture resampled to 25 km resolution is useful to corroborate the NDVI/NDWI based interpretation. CPC rainfall forecasts are useful to foresee the rainfall events in immediate future and interpret the expected change in the agricultural situation. The methodology of NADAMS project essentially reflects the integration of satellite derived crop condition/surface wetness indices and their anomalies to evolve decision rules on the prevalence, intensity and persistence of agricultural drought situation. Currently the

Table 3
Satellite data and Indices employed in NADAMS project for drought assessment

Year	Satellite (sensor)	Indices(a)	Scale of assessment (a)
1989	Noaa (avhrr)	Ndvi	District-level : 13 states
1996	Irs 1c (wifs) Noaa (avhrr)	Ndvi Ndvi	Sub-district level : 2 states District-level : 11 states
1998	Irs 1c & irs -1d (wifs) Noaa (avhrr)	Ndvi Ndvi	Sub-district level : 2 states District-level : 11 states
2004	Resourcesat-1 (awifs) Terra (modis) Noaa (avhrr)	Ndvi Ndwi-1;ndwi-2 Ndvi	Sub-district level : 4 states District-level : 9 states
2009	Aqua (amsr-e) Trmm (tmi, pr) Terra (modis) Resourcesat 1 & /2 (awifs) Noaa (avhrr)	Soil moisture, smi Rainfall (with cpc) Ndwi-1;ndwi-2 Ndvi Ndvi	Sub-district level : 4 states District-level : 9 states
2011	Resourcesat-2 (awifs) Oceansat-2 (ocm) Terra (modis) Noaa (avhrr)	Ndvi Ndvi/green vi Ndwi, sasi Ndvi	-do-

(A) NDVI : Normalised Difference Vegetation Index; NDWI: Normalised Difference Wetness Index; SMI: Soil Moisture Index; CPC: Climate Prediction Centre of NOAA(USA); SASI: Shortwave Angle Slope Index

(B) Study States: (s:sub-district assessment): Andhra Pradesh(s), Bihar, Chhattisgarh, Gujarat, Haryana(s), Karnataka(s), Madhya Pradesh, Maharashtra(s), Orissa, Rajasthan, Uttar Pradesh, Jharkhand and Tamil Nadu.

indices used include Shortwave Angle Slope Index (SASI), Normalized Difference Wetness Index (NDWI), Normalized Difference Vegetation Index (NDVI), Soil Moisture Index (derived from soil water balance approach) and IMD Rainfall data based indices (rainfall deviation, number of dry weeks).

SASI variations in the season which represent dynamics of surface moisture were used for assessing the Area Favourable for Crop Sowing (AFCS) from time to time. General threshold values of SASI specific to soil texture, that indicate favourable situation for crop sowings were identified. Based on SASI thresholds, discrimination of the Area Favourable Crop Sowing (AFCS) was done on weekly basis for each state. The AFCS weekly values are useful to assess the intensity of early season/sowing period agricultural drought intensity in terms of timeliness in the commencement of sowings, extent of delay or reduction in crop sowings.

Monthly drought reports of NADAMS project are disseminated to the Ministry of Agriculture,

Government of India, and respective state departments of Agriculture and Relief. The reports are also being sent to IMD, Central Water Commission and other scientific organizations. The feedback on drought reports, from Ministry of Agriculture, Govt. of India and departments of Agriculture/Relief of various states indicates effective end use of information in their crop weather watch meetings, and contingency planning during the season and declaration of drought affected areas at the end of the season. Research is under way at NRSC to define operational model-based soil moisture indices, improve historical data base to multiple satellites, define quantitative rules for drought assessment and initiate crop assessment modeling to quantify damage assessment from drought. In addition NRSC is supporting Mahalanobis National Crop Forecast Centre (MNCFC) of DAC from kharif 2012 to make operational drought assessments.

Future research activities include development of an integrated drought assessment approach using multiple parameters, development of methodology for crop sown area estimation, agricultural drought vulnerability assessment, soil water balance analysis, use of Standardized Precipitation Index (SPI), use of SWIR based indices for crop stress detection, drought impact assessment, drought early warning etc.

Forest fire

Forest fire or wild land fire is considered to be one of the most important disasters causing adverse ecological, economic and social effects worldwide. Globally, forest fires are one of the major drivers of climate change, due to their role in producing large amounts of trace gases and aerosol particles. In India, out of 67.5 million ha of forests, about 55% of the forest cover is being subjected to fires each year. Forest fires in India are mostly anthropogenic, which include slash and burn agricultural practices, controlled burning, deforestation, firewood burning and others, which bear their cause to villages in the proximity of forests.

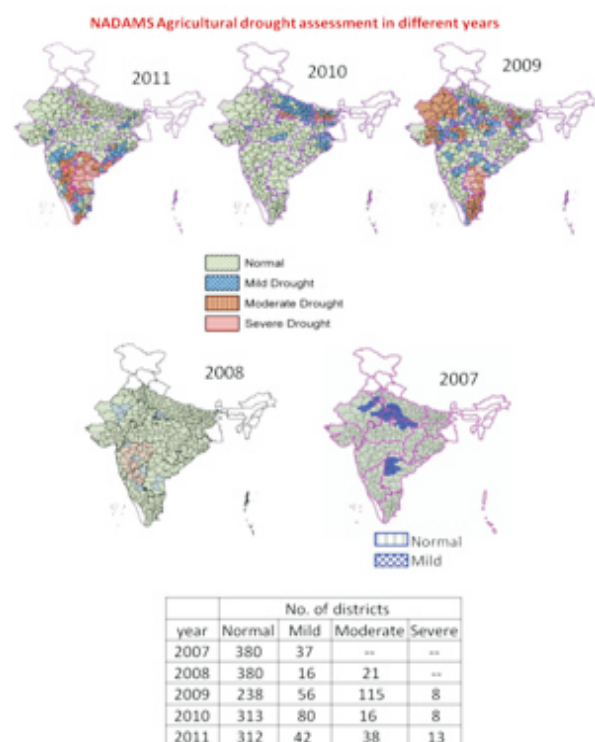


Fig. 2 NADAMS assessment of district-wise end-of season drought during 2007 to 2011.

The Indian Forest Fire Response and Assessment System (INFFRAS), established under the Decision Support Centre (DSC), does various activities including (a) Active Forest Fire Monitoring, (b) Burnt Area Assessment using multi-temporal satellite data. The outputs disseminated are with value addition of information such as forest administrative boundaries, vegetation type burnt, and proximity to the villages. During fire season, daily fire alerts are generated using MODIS and DMSP-OLS satellite data. The Moderate Resolution Imaging Spectro-radiometer (MODIS) onboard TERRA/AQUA platforms operate in 36 channels (optical and thermal) with three variable spatial resolutions i.e. 250 m, 500 m and 1km. The MODIS data is acquired at NRSC Earth Station at Shadnagar and active fire locations are mapped using enhanced fire algorithm (Giglio et al. 2003), which is based on thermal anomaly between $4\mu\text{m}$ (channel 21 or 22) and $11\mu\text{m}$ (channel 31) along with other useful information from $0.645\mu\text{m}$ (Channel 1), $0.850\mu\text{m}$ (Channel 2) and $12\mu\text{m}$ (Channel 32). Time required for the whole process of generating active fire locations is under 2 hours after satellite data reception and the products are disseminated by email to users and posted on INFFRAS website. Figure 3 shows the state-wise total fire counts observed in the country during 2011.

Landslides

The main contribution of EO data is to provide the geological details, morphological, and land use, in determining how the landslide occurs and what causes the failure. Where failure could occur can be addressed in a more regional geographic information system (GIS) analysis as a necessary first step in risk analysis. This is because the factors contributing to slope failure at a specific site are generally complex and difficult to assess with confidence. GIS techniques are used increasingly for regional analysis and prediction. Several digital data sets are typically used for such analysis. These can include an inventory of landslides; seismic

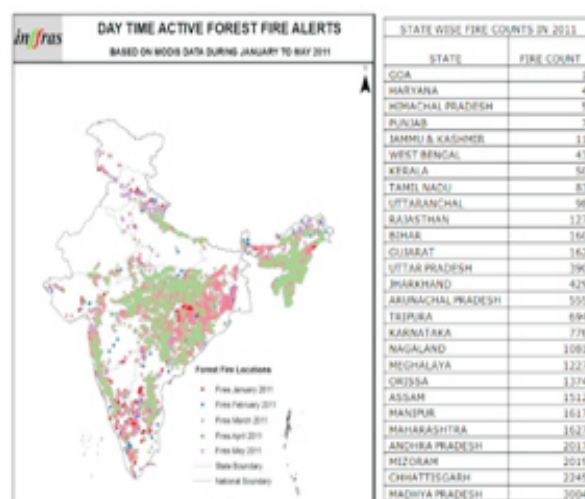


Fig. 3 Total active fire counts in India and their spatial monthly distribution during 2011

records; large-scale geological mapping, extensive geotechnical data on rock properties; high-resolution digital elevation data, suitable high-resolution remote sensing data and aerial photographs. This mapping procedure can be used to produce hazard risk maps that will assist in emergency preparedness planning and in making rational decisions regarding development and construction in areas susceptible to slope failure. Detailed slope information is essential for reliable landslide inventory maps. Martha et al (2010) have developed an object-based approach for detection and characterization of landslides.

Earthquakes

The Indian sub-continent is subjected to varying degrees of earthquake hazard, with more than 650 earthquakes of magnitude above 5 in Richter scale having been recorded during 20th century. The largest number had their epicenter in the Himalayan frontal area. Currently, operational EO capabilities have some use in the mitigation and response phases of earthquake risk management and large research effort is ongoing with many potential EO applications. Seismic hazard analysis requires an assessment of the maximum earthquake magnitude as well as characterization of called seismo-tectonic sources. The latter requires knowledge of the

regional and local geology seismicity and tectonics some of which is obtained from EO data. The lineament map can be one of the important inputs for delineating the seismo-tectonic province. In such scenario, the following aspects play an important role: distance from active faults, geological structure, soil types, depth of water table, topography and types of building. Toward this, satellite remote sensing plays an important role in the mapping of active faults, lineament and density of lineaments. The associated surface manifestation of such disaster is Fault rupture damage due to ground shaking, liquefaction and landslides, which is also manifested in EO data.

At present, availability of Very High-resolution data is useful for post-disaster assessment of infrastructure damage. The examples of successful damage assessment to built-up areas, inventory of reactivated and new landslides include (a) study of damage in Jammu and Kashmir due to 8 Oct 2005 Mw 7.3 with epicenter close to Muzaffarabad (Kumar *et al.*, 2006) using Cartosat-1 stereo and Resourcesat-1 data.

Current trends in use of space technology in disaster management

Technological advances in the fields of sensors, location-based analysis, image processing, GIS and communication networks, integration of these multiple technologies and improved understanding of the coupled use of these technologies for disaster management is a clear indicator of center stage that space technology and geomatics have come to occupy for disaster management. A brief on these trends and status of their adoption in NRSC is provided here.

(a) Satellite Constellations for Disaster Management

Most critical requirement is capability to acquire data at target locations on earth with shortest delay. Thus disaster constellations must have wider swath, agility and or multiple satellites for high probability of target area acquisition. India

with Resourcesat-2 and RISAT-1, supplemented by Oceansat-2, Cartosat-1, 2 has significant acquisition capability. Major international disaster specific constellations are (i) COSMO-SkyMed (Constellation of small Satellites for Mediterranean basin Observation) system consist of a constellation of four Low Earth Orbit mid-sized satellites, each equipped with a multi-mode Synthetic Aperture Radar (SAR) operating at X-band. (ii) DMC : The Disaster Monitoring Constellation (DMC) consists of currently 6 RS satellites constructed by Surrey Satellite Technology Ltd (SSTL) and operated for the Algerian (AISAT-1: Nov 2002-Aug 2010), Nigerian (NigeriaSAT-1, launch September 2003), Turkish (BiLsat: Sep 2003-Aug 2006), British (UK-DMC, launch September 2003 & UK-DMC 2, launch July 2009) and Chinese (Beijing-1, launch October 2005) governments by DMC International Imaging. The DMC satellites are notable for communicating with their ground stations using the Internet Protocol for payload data transfer and command and control, so extending the Internet into space. The DMC provides emergency Earth imaging for disaster relief under the International Charter for Space and Major Disasters, which the DMC formally joined in November 2005. (iii) Terra SAR consists of TerraSAR-X (launch June 2007) and TanDEM-X (launch June 2010), although more for high resolution DEM, but provide 1-3 day visibility for any part of globe and useful for emergency monitoring.

(b) Rapid Acquisition of target areas globally

Since ground stations are not distributed globally, data of beyond visibility of ground stations is acquired and recorded using on-board data recorder and played back later when satellite passes over ground station. Polar orbiting satellite data could be also collected on high latitude ground stations due to larger number of passes being visible at high latitudes. NRSC currently uses acquisition from Svalbard, Norway and is in process of establishing a ground station in Antarctica for this purpose.

(c) Short Turn Around Time (TAT)

Once images are acquired over target regions, rapid generation of data products is essential. As part of overall modernization, NRSC has implemented IMGEOS Project (Integrated Multi-Mission Ground Segment for Earth Observation Satellites) which has capability to produce high priority emergency images within 1 hour of satellite pass and make them available on the web (Radhakrishnan et al., 2009).

(d) Automated Processing for damage assessment

In view of need to disseminate RS-derived results to users, a number of automated pre-post disaster digital image interpretation techniques are being proposed and evaluated.

(e) WebGIS Technology

As disaster management requires multi-disciplinary information as well as collaboration amongst multiple agencies producing diverse data sets, it is important to use them in a holistic way, and not as separate isolated information. WebGIS technology, especially creation of mashups allows real-time integration of multiple source GIS data to support disaster management (Karnataka et al., 2012).

(f) Research for early warning

A number of R&D studies have been taken up for early assessment for drought, early warning for flood and landslides and monitors precursors to earthquakes. The most promising is use of space inputs in distributed hydrological models for predicting flood (Durga Rao, 2011).

Acknowledgements are due all the colleagues at NRSC, whose works have been presented here. My special thanks are due to Shri V Bhanumurthy, Dr MVR Sessa Sai and Ms P. Manjusree for their unfailing help in preparation of the manuscript of this paper. Financial support from ISRO DMSP is also acknowledged for carrying out this activity at NRSC.

Bibliography and References

1. Bhanumurthy V. and Behera G. (2008),

Deliverables from space data sets for disaster management – Present and Future trends. **International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences**, 37(B8), Beijing.

2. Bhatt C.M. *et al.* (2010), Space based disaster management of 2008 Kosi floods, North Bihar, India. **Journal of Indian Society of Remote Sensing**, 38(1), pp. 99-108

3. Chandran R.V. *et al.* (2006), 'Flood mapping and analysis using air-borne synthetic aperture radar: A case study of July 2004 flood in Bagmati river basin, Bihar'. **Current Science**, 90, pp. 246-256.

4. Durga Rao KHV *et al.* (2011), A distributed model for real-time flood forecasting in the Godavari Basin using space inputs. **International Journal of Disaster Risk Science**, 2(3): 31-40

5. Giglio L. *et al.* (2003), An Enhanced contextual fire Detection Algorithm for MODIS, **Remote Sensing of Environment**, 87, pp. 273-282

6. Joyce, K.E. *et al.* (2009), A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters. **Progress in Physical Geography**, 33(2): 183-207

7. Karnataka H.C. *et al.* (2012), Spatial mashup technology and real time data integration in geo-web application using open source GIS—a case study for disaster management. **Geocarto International** (in press) DOI:10.1080/10106049.2011.650651

8. Kumar, K. V. *et al.* (2006) Mapping damage in the Jammu and Kashmir caused by 8 October 2005 Mw 7.3 earthquake from the Cartosat-1 and Resourcesat-1 imagery. **International Journal of Remote Sensing**, 27(20), pp. 4449-4459

9. Martha, T.R. *et al.* (2010), 'Characterising spectral, spatial and morphometric

properties of landslides for semi-automatic detection using object-oriented methods', **Geomorphology**, 116 (1-2), pp. 24-36.

10. MHA (2004) **Disaster Management in India: A Status Report**, Natural Disaster Management Division, Ministry of Home Affairs (MHA), Government of India, New Delhi.

11. Radhakrishnan, K. et al. (2009) Developments in Earth Observation data reception, dissemination and archival at National Remote Sensing Agency. **Acta Astronautica**, 65(7-8): 1113-1120

12. RBA (1980) **Report of National Flood Control Commission**. Central Water Commission, Govt of India, New Delhi

Web sites

<http://www.nrsc.gov.in>

<http://www.bhuvan.nrsc.gov.in>

<http://www.dsc.nrsc.gov.in>

(**Dr. V. K. Dadhwal** is the Director, National Remote Sensing Centre, (ISRO), Balanagar Hyderabad - 500037, INDIA)

Email: dadhwalvk@hotmail.com

Flood Hazard and Control Measures in Hungary

Wilhelm, Zoltán

Abstract

Earlier the phenomenon of flood hazard in the Carpathian Basin was connected to riverine floods and flood closely related to the impacts of river flow regulation, started at the beginning of the 19th century. Recent assessments, however, reveal a more complex picture. Climate change is predicted to bring more frequent drought as well as irregularities in the water regimes of rivers in Hungary. Hazard due to excess water is found to occur over much larger area than previously affected. In recent years, strongly localized cloudbursts point to increasing frequency of flash floods in Hungary. As opposed to riverine floods and excess water hazard in lowlands, flash flood hazard primarily affects the mountainous and hilly regions of the country. In order to illustrate the spatial distributions of the three types of inundation hazard, they are presented by microregions on a series of maps.

Keywords: Hungary, climate change, flood hazard, flash flood, excess water, riverine flood

Introduction

Although the whole of Hungary belongs to the catchment of the Danube, for practical purposes—to contrast the hydrogeographical conditions in the western and eastern half of the country – two hydrographical axes are usually mentioned: the N to S sections of the Danube and its major left-bank tributary, the Tisza River (Fig. 1). Extensive areas on both 'halves' of the territory of Hungary are highly exposed to flood hazard (Lóczy and Juhász, 1997; Zsuffa, 1999) and, consequently, flood control has ever been a

central task of Hungarian water management policy (Kovács, 1979; Somlyódy, 2000; Wilhelm, 2001; Wilhelm, 2005). It is essentially an internationally coordinated activity since an overwhelming majority of river discharge (ca. 96 per cent) is collected by runoff from the mountain ranges encircling the steadily subsiding Hungarian plains.

Similarly to changing flood hazard assessments in several countries of Europe, in addition to riverine inundations and design floods, the relative significance of other types of inundation (by excess water and due to flash floods) has to be re-assessed in Hungary, too.

Discussion

Riverine flood hazard: The changing interpretations of overall flood hazard are clearly detectable in water management literature—and even reflected in the various textbooks on the geography of Hungary. The most comprehensive and often cited physical geography of Hungary (Bulla, 1964) describes flood hazards along the Danube and the Tisza Rivers as well as along the major tributaries. Bulla's most important statements for the water

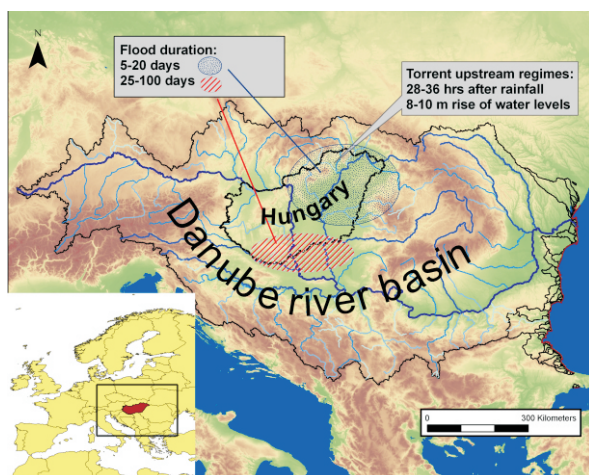


Fig. 1

* In Collaboration with Czigány, Szabolcs, Lóczy, Dénes, Pirkhoffer, Ervin, Ronczyk, Levente,

regime of and origin of floods on the Danube are the following:

- The so-called 'green floods' in March and April (carrying floating leaved twigs) are controlled by snowmelt on the Alpine catchment;
- The floods of May and June are due to rainfalls brought by Atlantic cyclones;
- Ice-jam floods are theoretically possible in every second or third year, when contiguous floating ice covers the river;
- Water discharge shows a declining trend over the summer and reaches its minimum in October;
- After a moderate rise in discharge another minimum follows in December, when the ground is frozen in the mountainous parts of the watershed.

The physico-geographical text-books (Lovász, 1994; Marton-Erdős, 1996) published more recently briefly repeat Bulla's statements with minor tell-tale shifts. The differences are: (i) floods from snowmelt are particularly enhanced by the 'rain-on-snow' phenomena; (ii) ice cover is becoming less and less reliable on the Danube; (iii) along the lower Hungarian section with reduced slope, river regime is more equable. Even more recent assessments (e.g. Szilávik, 2000, 2001; Mezősi, 2008) emphasize that nowadays snowmelt in the Eastern Alps often occurs belated, (iv) the floods caused do not cease before early summer flood waves develop; (v) the latter are more and more prolonged and, thus, present, considerable pressure on flood-control dykes.

The peculiar nature of the regime of the Drava River (Lovász, 1972, 1983), the most important tributary to the Danube along the Hungarian-Croatian border, is equally influenced by: (i) snowmelt in the hilly Alpine foreland followed by snowmelt in higher regions of the mountains (conveyed through the tributary Mura/Mur River), and (ii) Mediterranean cyclones causing a secondary maximum in October or November (Lovász, 1972).

Along the Tisza River, a typical channelized river (Cholnoky, 1934; Lászlóffy, 1982; Gregory, 2006), the flood pattern is influenced by a wider range of tributaries (Andó, 2002). Although the same flood peaks have been identified as on the Danube but some peculiarities are also found (Vágás, 1982): (i) the passage rates of flood waves are highly variable on tributaries with different channel slopes and are more often superimposed on flood waves of the trunk river; (ii) consequently, prolonged flood waves increase dyke breach hazard; (iii) the Tisza impounds the flow of tributaries along several kilometres and causes inundations along their lowermost sections; (iv) changes in precipitation types and pattern may result in floods even in winter time.

Riverine floods are usually conceived as flood waves passing along the whole lengths of major rivers. If the concept of local flood hazard is introduced and interpreted as a threat of dyke breach along any particular river sections, unstable channel sections ("wandering rivers" liable to major horizontal shifts) are more endangered (Simon, 1995; Lóczy, *et al.* 2009). The instability of river channel may depend on: (i) meandering river mechanism, and (ii) channelization between too closely spaced dykes hindering adjustment.

The natural and anthropogenic geomorphological conditions are important controls of flood (as well as excess water) hazard in the floodplain (Kis, and Lóczy, 1985; Ely, Nagyvárad, 2001, Ronczyk, and Wilhelm, 2006).

Flood frequency estimation: defining design flood

For flood-control measures, it is essential to define the level of design flood. Since it has direct implications for water management investments, the definition is also a political issue. Therefore, this is a task for authorities responsible for water management but formulated in a government decree (number 2006/1973). According to this official definition, benchmark flood is an ice-free river water level

with a probability of occurrence characterized by a given return period (Hankó, *et al.* 2003). The length of the return period is variable: (i) along main flood control dykes: 100 years; (ii) in urban and industrial areas: 120-150 years; (iii) in priority areas (e.g. near the capital city): 1000 years, and (iv) for less valuable protected areas: 60-80 years.

For instance, the level of the 1954 ice-jam flood is regarded as the 100-year design flood for the Danube section between Esztergom and the southern border of Hungary (VITUKI 1976).

The flood-control map of Hungary (VITUKI 1981) shows two categories of flood hazard: the areas affected by floods of a 100-year return period and those affected by the (largely hypothetical) those of 1000-year return period.

Out of the territory of Hungary (93,030 km²), 21,248 km² (22.8 per cent) are endangered by the 100-year return period flood of major rivers, first of all the Tisza and the Danube (Szlávik, 2000), and 23 per cent of this area is safely protected from inundation. Another estimated almost 10,000 km² of floodplain lies along smaller water-courses (10 per cent) and their extension has not yet been properly surveyed (Fig.2).

In this paper, flood hazard is not depicted by catchments but by the microregions of Hungary (as identified by a group of experts—Marosi and Somogyi, 1990) were used as basic units (Fig. 3).

By the 1980s, with the completion of extensive flood control systems, riverine flood hazard seemed to be reduced to acceptable levels (Lóczy and Juhász, 1997). However, some environmental factors contribute to growing flood hazard. These include (i) increasing flood discharges due to land use and climate changes in the upper catchments of major rivers; (ii) reduced capacity (sedimentation, enhanced surface roughness) of floodways (Schweitzer, 2001a,b; Kiss, and Fejes, 2000; Kiss, *et al.* 2002; Gábris *et al.*, 2002); (iii) the impact of drought years in the 1990s and 2000s on the (sometimes rather neglected) conditions of flood-control-dykes.

Excess water hazard:- Excess of water had been traditionally associated with river flooding and conceived as inundation remained after flood waves on rivers passed. Recently, the definitions of excess water (Pálfai, 2001) have been extended also to include upbursting groundwater in absence of a water-course. In a more practical approach, the main criterion of excess water inundation is that through surplus water inhibiting crop root growth on agricultural land and creating prolonged reductive conditions in the root zone, it causes economic damage in agriculture. Today excess water (or sheet flooding) is rather widely

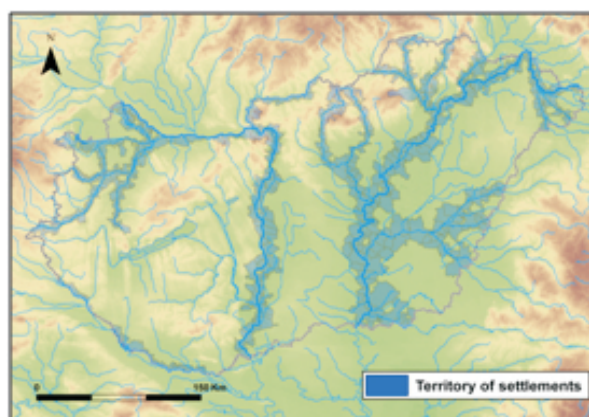


Fig.2

interpreted in Hungarian water management. In addition to groundwater levels raised on the floodplains of major rivers during flood stages, any other inundation in lowland areas is included (Pálfai, 2000). The now used definition of excess water originating from rainfall or

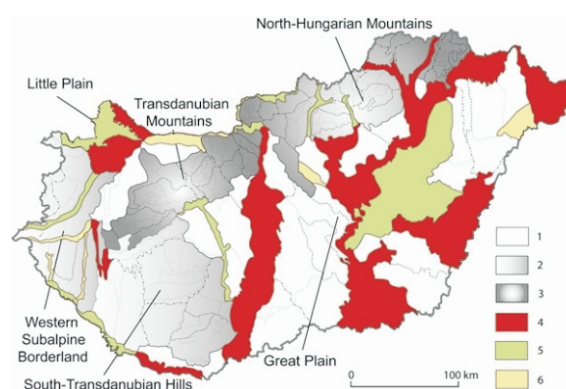


Fig. 3

snowmelt which covers any extensive but temporary inundation of lowland areas and fully saturates the soil. Whether soil saturation necessarily means surface inundation, remains to be an open question? (Rakonczai, *et al.* 2003).

In recent decades, excess water hazard has been observed to increase dramatically (Pálfai, 2000). The construction of artificial structures in the landscape (Baukó, *et al.* 1981) and the neglected conditions of land drainage systems (Goda, 1997) all contribute to the higher frequency of inundation in particular areas of the Great Plain. In some cases it is the flood-control dykes themselves which hinder the conduction of excess water back to the river channel (Pálfai, 1988).

Inundation hazard from excess water is more difficult to delimit than riverine flood hazard, both temporally and spatially. Rapid snowmelt in spring season and early summer cyclonal rains are jointly responsible for it. Although the average depth and duration of snow cover is on the decline, extreme values of such parameters often occur. The National Water Management Framework Plan (OVH 1984) includes a map of areas threatened by excess water inundation. This map was later revised using topographic, geological, pedological, groundwater depth and land use data as well as relying on the map of drainage ditch networks (Pálfai, 1994). (Based on the remote sensing interpretation of recent inundations, further revision is under way.) A simplified version of the excess water hazard map of Hungary (processed for Fig. 4) identifies four categories: (i) serious hazard, where inundations regularly recur in wet years; (ii) medium hazard, where one-time floodways and backswamps and swamps enclosed between alluvial fans are exposed to rising groundwater; (iii) moderate hazard, where natural levees in floodplains and lower sections of alluvial fans are occasionally affected, and (iv) no hazard areas, where permeable surface deposits prevent enduring inundation.

The first three categories make up more than two million hectares in Hungary, i.e. one-third of

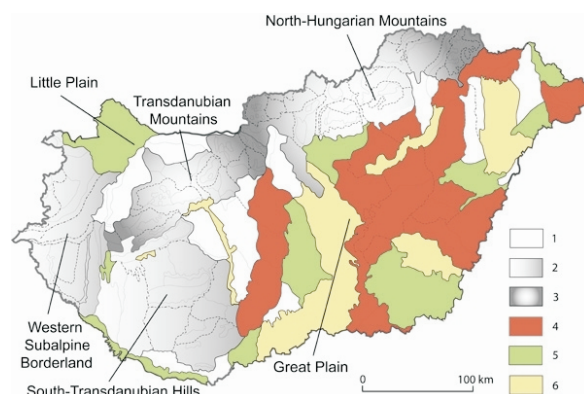


Fig.4

the agricultural area. Evaluating excess water hazard individually for each of the micro-regions of Hungary, an overview hazard map can be drawn (Fig. 4). Naturally, few micro-regions are threatened by excess water in their entirety but the map indicates micro-regions where significant portions are affected.

It can be stated that excess water hazard even became a topic at the 2009 European Parliament elections in Hungary. Some politicians called for the recognition of the damage caused by excess water by insurance companies in the same way as damage from riverine floods is treated.

Flash flood hazard:-Following recent events (highly restricted but disastrous floods in mountainous and hilly catchments in various parts of Hungary) research into flash flood hazard has intensified (Czigány *et al.* 2009). The aim was to parameterize a model which is capable of a rapid screening of the areal distribution of this hazard in Hungary. The idea is that passive ground conditions (relief, soil permeability, catchment geomorphology – Patton and Baker, 1976) are equally important in the generation of flash floods as the active triggering factor (intense and enduring rainfall). The reliability of the model depends on the resolution of input parameters, first of all on that of the Digital Elevation Model. With an increased set of parameters and a higher resolution DEM, the prediction of flash flood events can be improved.

With accumulating evidence on climate change, flash floods have been recognized recently as an

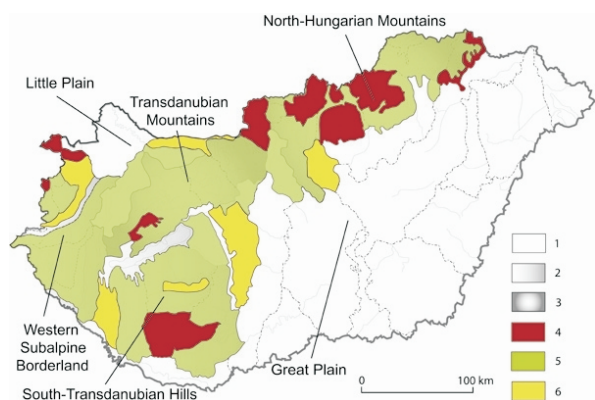


Fig. 5

increasing environmental hazard in Hungary. Being highly localized phenomena, their seasonal distribution is uneven. However, virtually all mountainous and hilly microregions of Hungary are under threat (Fig. 5), only runoff conditions cause some variation in the distribution of hazard.

Flood control measures

Apart from raising dyke heights, the response to increased flood hazard—particularly on the Tisza River—is envisioned in several ways (Mezősi, 2008): (i) Through amending water retention in the headwater areas (outside the borders of Hungary); (ii) Through enhancing the conveyance capacity of floodways; (iii) Through river impoundment beyond dams; (iv) Through constructing smaller emergency reservoirs (used as meadows or pastures in flood-free periods) along the trunk river and its major tributaries.

Emergency reservoirs represent a special category of confinement. Confinement planning aims at the prevention, restriction or (at least) delaying of the inundation of protected floodplain resulting from breaches of main defences (VITUKI 1977). Dynamic solutions for flood confinement are now being studied during the process of the supervision of plans (Szlávik, *et al.* 2003).

Along the Danube, the row of reservoirs of the Austrian river section and the Čunovo reservoir in Slovakia prevent major flooding in Hungary (Zsuffa, 1999).

Conclusions

It is often emphasized that floods are not at all common phenomena in Hungary. After effective flow regulation (since 1855) along the Tisza River, there occurred not more than 23 major flood events until now (Szlávik, 2003). The floods between 1998 and 2001, however, followed one another within "abnormally" short intervals, one major flood every year. This is an indication that riverine floods are still part of the natural hydrological system of the Carpathian Basin.

Steady rising flood levels along the major rivers are due to interacting reasons: (i) Human activities on the catchment (deforestation, housing and infrastructural development, narrowing-down floodplains); (ii) Impacts of climate change (inclination to drought but growing intensity of rainfall).

As in the past, the adjustment of the population to inundation is required. Although the maintenance of flood-control dyke systems and probably the establishment of emergency reservoirs can alleviate riverine flood hazard, it is practically impossible to avoid inundations from excess water or flash floods induced by local cloudbursts, which may occur with an increased frequency in the future.

Acknowledgements are due to the Hungarian National Science Foundation (OTKA) for financial support (grant number K 68903) and Ms. Bettina Balassa for digitization of the base map.

References

- Andó, M. (2002), **A Tisza vízrendszer hidrogeográfiája (Hydrogeography of the Tisza river system)**. University of Szeged, Szeged. p.168 (in Hungarian)
- Bulla, B. (1962), **Magyarország természeti földrajza (A Physical Geography of Hungary)**. Tankönyvkiadó: Budapest, pp. 237-263. (in Hungarian)
- Cholnoky, J. (1934), A folyók szakasz-jellegének összefüggése a szabályozással és öntözéssel

(Relationship between types of river reaches with channelization and irrigation). **Vízügyi Közlemények** 1934(1), pp. 5–25. (in Hungarian)

Czigány, Sz., Pirkhoffer, E. and Geresdi, I. (2009) Environmental impacts of flash floods in Hungary. In Samuels, P., Huntington, S., Allsop, W. and Harrop, J. (eds.) **Flood Risk Management: Research and Practice**. Taylor & Francis Group, London, pp. 1439-1447.

Ely, L. and Nagyvárad, L. (2001) Application of Paleofloods to Flood Hazard Assessment in Hungary. In: Kovács, J. and Lóczy, D. (eds.): **A vizek és az ember**. PTE TTK Földrajzi Intézet, Pécs, pp. 189-195.

Gábris, Gy., Telbisz, T., Nagy, B. and Belardinelli, E. (2002) A tiszai hullámtér feltöltődésének kérdése és az üledékképződés geomorfológiai alapjai (Sedimentation in the active floodplain of the Tisza River and its geomorphological aspects). **Vízügyi Közlemények** 84 (3), pp. 305-322. (in Hungarian)

Gregory, K. J., (2006) The human role in changing river channels. **Geomorphology** 79(3), pp. 172-191.

Hankó, Z., Bauer, M. and Kiss, Z. (2003) A mértékadó árvíz: múlt és jövő (Design flood in the past and in the future). In: **Vízügyi Közlemények** Special Issue 4, pp. 117-132. (in Hungarian)

Ihrig, D. (1973) **A magyar vízszabályozás története (History of water regulation in Hungary)**. National Water Management Authority (OVH), Budapest. p. 398 (in Hungarian)

Kis, É. and Lóczy, D. (1985) Geomorphological mapping in alluvial plain and the assessment of environmental quality. In: Pécsi, M. (ed.): **Environmental and Dynamic Geomorphology**. Akadémiai Kiadó, Budapest, pp. 181-192. (Studies in geography in Hungary 17)

Kiss, T. and Fejes, A. (2000) Flood-caused sedimentation on the foreshore of the River Tisza. **Acta Geographica** Szeged 37, pp. 51-55.

Kiss, T., Sipos, Gy. and Fiala, K. (2002) Recens üledékfelhalmozódás sebességének vizsgálata az Alsó-Tiszán (Recent sedimentation rate along the Lower Tisza River). **Vízügyi Közlemények** 84(3), pp. 456-472. (in Hungarian)

Kovács, D. (ed.) (1979) **Árvízvédelem, folyó- és tószabályozás, víziutak Magyarországon (Flood control, regulation of rivers and lakes and waterways in Hungary)**. National Water Management Authority (OVH), Budapest. (in Hungarian)

Lászlóffy, W. (1982) **A Tisza. Vízi munkálatok és vízgazdálkodás a tiszai vízrendszerben (The Tisza River: Water management and constructions in its water system)**. Akadémiai Kiadó, Budapest. 610 p. (in Hungarian)

Lóczy, D. (1997) Human impact on rivers in Hungary as reflected in changes of channel planform. **Z. Geomorph., Suppl.-Bd** 110, pp. 219–231.

Lóczy, D. (2008) Fluvial landscape pattern in an agricultural Danubian floodplain. In **Dimensions and Trends in Hungarian Geography**. In: Kertész, Á. and Kovács, Z. (eds). Geographical Research Institute Hungarian Academy of Sciences, Budapest. pp. 101-109. (Studies in Geography in Hungary 33)

Lóczy, D. and Juhász, Á. (1997) Hungary. In **Geomorphological Hazards of Europe**. In: Embleton, C. and Embleton-Hamann, C. (eds.). Elsevier Science Publishers, Amsterdam. Pp. 243–262. (Developments in Earth Surface Processes 5)

Lóczy, D. et al. (2009) Local flood hazards assessed from channel morphometry along the T i s z a R i v e r i n Hungary. **Geomorphology**. DOI:10.1016/j.geomorph.2009.03.013

Lovász, Gy. (1972) **A Dráva-Mura vízrendszer vízjárási és folyási viszonyai (Water regime of the Drava-Mura drainage system)**. Akadémiai Kiadó, Budapest, p. 158. (Földrajzi monográfiák/Geographical Monographs 9) (in Hungarian)

Lovász, Gy. (1983) **Surface runoff of the Drava-Mura drainage system**. Geographical Research Institute, Hungarian Academy of Sciences, Budapest, p. 42. (Geographical Abstracts from Hungary 25)

Lovász, Gy. (1994) **Magyarország természeti földrajza I. (A Physical Geography of Hungary I)**. JPTE, Pécs, pp. 179-192. (in Hungarian)

Marosi, S. and Somogyi, S. (eds.) (1990) **Magyarország kistájainak katasztere I-II. (Inventory of the microregions of Hungary)**. Geographical Research Institute, Hungarian Academy of Sciences, Budapest, p. 1023. + map (in Hungarian)

Marton-Erdős, K. (1996) **Magyarország természeti földrajza I. (A Physical Geography of Hungary I)**. 2nd Edition. Kossuth Egyetemi Kiadó, Debrecen, pp. 136-140. (in Hungarian)

Mezősi, G. (2008) **Magyarország környezetföldrajza (Environmental geography of Hungary)**. JATEPress, Szeged, pp. 21-56. (Földrajzi Tanulmányok/Geographical Papers 3) (in Hungarian)

Pálfai, I. (1988) Belvízi elöntések az Alföldön (Excess water in the Great Plain). **Alföldi Tanulmányok** 12, pp. 7-22 (in Hungarian)

Pálfai, I. (1994) Az Alföld belvív-veszélyeztetettség térképe (Excess water hazard map of the Great Plain). **Vízügyi Közlemények** 76(3), pp. 278-288.

Pálfai, I. (2000) Az Alföld belvízi veszélyeztetettsége és aszályérzékenysége (Excess water risk and drought sensitivity of the Great Plain). In **A víz szerepe és jelentősége (Role and significance of water in the Great Hungarian Plain)**. Pálfai, J. (ed.). Nagyalföld Alapítvány, Békéscsaba; pp. 85-95. (in Hungarian)

Pálfai, I. (2001) A belvív definíciói (Definitions of excess water). **Vízügyi Közlemények** 83(3), pp. 376-392. (in Hungarian)

Patton, P.C. and Baker, V.R. (1976) Morphometry and floods in small drainage basins subject to

diverse hydrogeomorphic controls. **Water Resour. Res.** 12, 941-952.

Rakonczai, J., Csató, Sz., Mucsi, L., Kovács, F. and Szatmári, J. (2003) Az 1999. és 2000. évi alföldi belvív-elöntések kiértékelésének gyakorlati tapasztalatai (Experience from the evaluation of the 1999 and 2000 excess water inundations in the Great Hungarian Plain). **Vízügyi Közlemények** Special Issue 4. pp. 317-336. (in Hungarian)

Ronczyk, L., Wilhelm, Z. (2006): Beneficial Use of the Stormwater in Pécs. In: **Grazer Schriften der Geographie und Raumforschung**, Band 40., pp. 135-144.

Schweitzer, F. (2001a) A magyarországi folyószabályozások geomorfológiai vonatkozásai (Geomorphological aspects of river flow regulation in Hungary). **Földrajzi Értesítő** 50(1-4), pp. 63-72. (in Hungarian)

Schweitzer, F. (2001b) Társadalom és a környezet: Gátépítés vagy hullámtérbővítés (Society and environment: dyke construction or active floodplain expansion). In **A táj megértése felé (Towards understanding the landscape)**. Keményfi R, Ilyés Z. (eds). University of Debrecen, Debrecen. pp. 95-103. (in Hungarian)

Simon, A. (1995) Adjustment and recovery of unstable alluvial channels: identification and approaches for engineering management. **Earth Surface Processes and Landforms** 20, pp. 611-628.

Sipos, Gy., Kiss, T. and Fiala, K. (2007) Morphological alterations due to channelization along the Lower Tisza and Maros rivers (Hungary). **Geografia fisica e dinamica Quaternaria** 30:(2), pp. 239-247.

Sipos Gy, Kiss T. 2009. Alluviális vízfolyások mederformálásának sebessége (Rate of channel formation in alluvial watercourses). In: Kiss T, Mezősi G. (eds.): **Recens geomorfológiai folyamatok sebessége Magyarországon (Rates of recent geomorphic processes in Hungary)**. Szegedi Egyetemi Kiadó, Juhász Gyula Felsőoktatási Kiadó, Szeged, pp. 17-27. (in Hungarian)

Somlyódy, L. (2000) A magyar vízgazdálkodás főbb stratégiai kérdései (Major strategic issues in Hungarian water management). In **Stratégiai kutatások a Magyar Tudományos Akadémián 4 (Strategic Research at the Hungarian Academy of Sciences 4)**. Somlyódy L. (ed.). Hungarian Academy of Sciences, Budapest. pp.3–10. (in Hungarian)

Somogyi S. (ed.) 2000. **A XIX. századi folyószabályozások és ármentesítések földrajzi és ökológiai hatásai (Geographical and ecological impacts of 19th century channelization and drainage measures in Hungary)**. Geographical Research Institute, Hungarian Academy of Sciences: Budapest. p. 302. (in Hungarian)

Szlávik, L. (2000) Az Alföld árvízi veszélyeztetettsége (Flood hazard in the Great Hungarian Plain). In **A víz szerepe és jelentősége (Role and significance of water in the Great Hungarian Plain)**, Pálfi J. (ed.). Nagyalföld Alapítvány: Békéscsaba; 64–84. (in Hungarian)

Szlávik, L. (2001) A Tisza-völgy árvízvédelme és fejlesztése (Flood control and development in the Tisza Valley). In **Proceedings of Geographical Conference**, Szeged, 25-27 October, 2001. Department of Physical Geography and Geoinformatics, University of Szeged, p.50 (in Hungarian)

Szlávik, L. (2003) Az elmúlt másfél évszázad jelentősebb Tisza-völgyi árvizei és az árvízvédelem szakaszos fejlesztése (Major floods over the past 150 years in the Tisza Valley and the gradual improvement of defences). **Vízügyi Közlemények** Special Issue 4, pp.31-43. (in Hungarian)

Szlávik, L., Bakonyi, P., Józsa, J., Kovács, L. and Krámer, T. (2003) Az új árvízvédelmi lokalizációs tervek kidolgozásának módszertani alapjai (Methodological bases of the new flood confinement plans). **Vízügyi Közlemények** Special Issue 4, pp.201-230. (in Hungarian)

Vágás, I. (1982) **A Tisza árvizei (Floods on the Tisza River)**. Manuscript report. Water

Management Documentation Centre (VÍZDOK), Budapest. (in Hungarian)

VITUKI (1976) **Magyarország folyóinak mértékadó árvizei (Design floods for the rivers of Hungary)**. Research Institute for Water Resources Management, Budapest. (in Hungarian)

VITUKI (1981) **Magyarország árvízvédelmi térképe, 1:500 000 (Flood-control map of Hungary)**. Research Institute for Water Resources Management, Budapest. (in Hungarian)

VITUKI (1990-2006) **Vízrajzi Évkönyvek (Hydrography Yearbooks) 1987-2003**. Research Institute for Water Resources Management, Budapest. (in Hungarian)

Wilhelm, Z. (2001): Contribution to the Analysis of the Development of Human Settlements in the Area of the Duna (Danube)-Drava National Park. In: **Pollution and Water Resources**. Columbia University Seminar Proceedings, 31, pp. 172-223.

Wilhelm, Z. (2005): Water and Economy – land use and hydrological coherences in the Lower Danube Region. In: **Geographical Review** (Földr. Közl.) CXXIX./LIII./ Volume Supplement, pp.9-18.

Zsuffa, I. (1999) **Árvizek okozta kockázatok (Flood risks)**. Magyar Tudomány 1999(1), 29-36. (in Hungarian)

Figures

Fig. 1 Consequences of the geographical location (by Ronczyk, L. – Wilhelm, Z.)

Fig. 2 Territory of Hungarian settlements affected by floods (by Ronczyk, L. – Wilhelm, Z.)

Fig. 3 Assessment of riverine flood hazard by the microregions of Hungary identified by Marosi, S. and Somogyi, S. (1990) (by Lóczy, D. from data by VITUKI 1990-2006). Continuous lines indicate the borders of macroregions, dashed lines the borders of units lower in the hierarchy (meso- and microregions). 1 = lowland macroregions; 2 = hilly macroregions; 3 = mountainous

macroregions; 4 = microregions with extensive active floodplain sections (regularly inundated); 5 = microregions with floodplains affected by the locally defined design flood; 6 = other potentially affected microregions

Fig. 4 Assessment of excess water hazard by microregions (by Lóczy, D. after Pálfai, I. 2000). For 1 to 3 see Fig. 3. 4 = microregions with

medium and locally serious hazard; 5 = predominantly medium hazard; 6 = predominantly moderate hazard locally with medium hazard

Fig. 5 Assessment of flash flood hazard (by Lóczy, D. after Czigány, Sz. et al. 2009). For 1 to 3 see Fig. 3. 4 = high; 5 = medium; 6 = low hazard.

(Professor (Dr.) habil Zoltan WILHELM, is the Head of Dept. General and Applied Environmental Geography & Director of the Asia Centre, University of Pecs, Faculty of Sciences, Institute of Geography, University of Pecs, Hungary,
Email: wilhelm@gamma.ttk.pte.hu)

TECHNICAL SESSIONS

SECTION I CONCEPTUAL ISSUES IN CARTOGRAPHY

Design of Maps for Disaster Management (Some Conceptual Cartographic Issues)

Vineeta John

Abstract

Disaster management efforts are generally grouped into five phases namely preparatory, mitigation, preparedness, response and recovery which are functionally related in a temporal sequence. Most of the required information at these phases relate to geosurface and is best presented in the two-dimensional map space. The paper will examine the types of maps required both general purpose and thematic maps at different levels of risk and crisis management at their different phases. Also it discusses the data needs, map design with its structural elements. The adequacy of the design concepts and their physical manifestations in map form in view of nature of data and user requirements, will be discussed in respect of their usability measured think aloud method and the method based on the ease and accuracy of information processing.

Introduction

The term 'disaster'(dis-astrum), means 'evil or bad star' in latin connoting misfortune, loss and ruin. Disaster events, in the current context, have been defined by a document of United Nations' International Strategy for Disaster Reduction (UN-ISDR) as 'a social crisis situation occurring when a physical phenomenon of natural, socio-natural or anthropogenic origin negatively impacts vulnerable populations and their livelihoods, production systems infrastructure and historical heritage, causing intense, serious and widespread disruption of the normal functioning of the affected social unit and in which the impacts and effects cannot be overcome with the resources autonomously available to the affected society'(UN-ISDR, 2004). These events have been an important part of man's experience since the evolution of human societies. From the earliest times people at risk from these events have made efforts to deal with the worst effects of these happenings at individual or small group levels. With the advance of times use of defense and police forces in these efforts became a common practice.

Creation and use of dedicated agencies and systems for disaster mitigation, saving life, providing relief and helping in reconstruction in a coordinated and organized manner is of recent origin and so is the use of the concept of

management in these efforts. The concept of management in this respect refers to the organization and coordination of the efforts and activities related to achievement of the above objectives and desired goals in accordance with certain policies using available resources efficiently and effectively. It also involves coordination and organization of the activities of institutions involved with these efforts because of a large number of different agencies working in different areas, and the need of coordination and cooperation between these agencies to enable them to take critical decisions related to operations in areas of their responsibilities.

The ultimate objective of all disaster management decisions and their execution is the reduction, to the maximum possible limits, of the extent to which a human community's destruction of people, their habitat and economy by a disaster event as compared to its pre-disaster conditions. These management efforts are usually treated as a cycle of certain efforts. Generally, the cycle is considered as consisting of five phases that are related functionally in a temporal cyclic sequence for all types of disasters (Fig.1). These interrelations exist even when each of these phases involve different types and levels of information, expertise and technological support. These phases are preparatory, mitigation, preparedness,

response, and recovery. This temporal cyclic sequence can also be seen as ordered in a linear sequence repeating itself following the completion of recovery phase on the basis of experience gained and lessons learned during the previous management efforts (Fig. 1B).

Disasters are basically geospatial events and their management efforts at these phases are principally based on geospatial-information from which knowledge is derived in terms of where, what, and how much for disaster management decision making. This information depends on the availability of data related to these questions and tools to present it. The availability of data in turn depends on the data storage systems, management and interconnectivity between different data sources.

Data needs

The geospatial data sets can be classified functionally into two groups as framework data, pre-event thematic data and post-event data. Framework or Basic data comprise the seven geographic bases that are most commonly used for providing a set of landmarks on the Earth's surface to which other data can be tied and located. Pre-event thematic data include ten themes that are necessary for maps both in risk and crisis management.

Framework data

1. Topographic or Basic maps at different scales of 1:1,000,000, 1:250, 000, and 1:50,000 and 1:25,000 including Geodetic control: the system of measurements used to establish and lay out the Earth's coordinate system.
2. Ortho-imagery: high-resolution images derived from aerial photographs or

satellites rectified to bring them into a proper orthogonal perspective.

3. Digital Elevation Models (DEMs) in different spatial resolutions
4. Hydrography: the locations and properties of rivers, lakes, and coastlines
5. Transportation: the locations and properties of streets, roads, railroads, and other transportation features
6. Administrative units: the locations and boundaries of administrative areas at different hierarchical administrative levels such as states, districts, tehsils, development blocks, and municipalities with ward boundaries.
7. Cadastral: the map of land ownership, showing the locations of property boundaries.

Pre-event thematic data

1. Geological maps: tectonic and lithological
2. Location of bridges and their load bearing capacity
3. Design and quality of buildings
4. Land cover
5. Past hazard occurrences and disaster damage extents

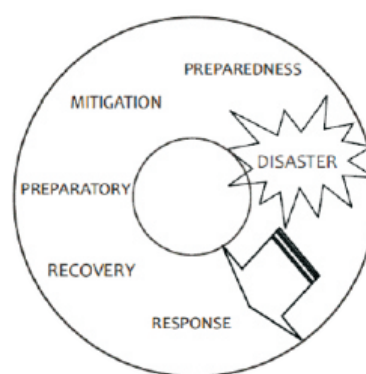


Fig.1 A Cycle of the Phases of Disaster Management



Figure 1.B Temporal Sequence of the Phases of Disaster Management

6. Location of hospitals and other medical facilities particularly trauma centres
7. Statistical and demographical data: Population distribution, density, number of households, age groups, occupational structure and income
8. Location of disaster management facilities, their capabilities and resources
9. Proposed evacuation routes, and traffic control points for the main state and county roads;
10. Location of weather and seismologic activity monitoring facilities

The presentation of this data, since it is related to three-dimensional geo-space, has to be in the form of sophisticated analytical maps disseminated electronically in soft copy format or hard copy formats on some stable medium. To be useful in cases of an emergency, such maps and the underlying data must be in place before the event occurs and much more these maps should be designed to be usable for the need for which these are intended at different phases of disaster management efforts.

Objective

The objective of the present paper is to recognise and present the principles and methods of designing two dimensional space which can be more useful in interpretation of patterns that eventually can lead to knowledge construction and decision making effectively. The basic tasks in this process of knowledge construction and decision making from such maps include: examining the spatial positions of attributes of interest in order to determine spatial proximities amongst different attributes; the interconnectivity between some of them and finding out their spatial density; and obtaining an overview of how a target value measured at one particular spatial location, or at different neighbouring locations, varies for various attributes of interest. These tasks can be extended to include identifying, locating, distinguishing, categorising, recognising clusters, and visualising distributions by:

ranking, comparing, finding associations, and correlations..

Information requirements in different phases of disaster management

The required information is identified in the context of each phase of disaster management. For the present purpose these phases are classified further in two parts: (1) Risk Management and (2) Crisis Management in a linear sequence (Fig. 1B).

Risk Management-includes the first three management phases and are supposed to be executed to reduce the extent of damage and preparation of response and relief in a quick and effective manner.

Preparatory Phase- involves the modelling of the probability of occurrence of hazards, vulnerability and risk assessment in terms of impacts on life, property, and the environment and their mapping. Such maps help in identifying and prioritizing areas for mitigation related actions aiming at to minimize the effects of natural hazards.

Mitigation Phase-During this phase potential disaster situations are identified, potential damage scenarios are created and evaluated. Relocation of facilities, properties, settlements, and wildlife are considered. Plans for minimising loss and destruction are executed. Emergency response facilities are planned and established. Such actions and needs are based on the expected magnitude of the hazard, vulnerability, and the involved risks modelled and mapped at the preparatory phases. At this stage appropriate combinations of spatial data and their visualisations in different map forms for various hazards for providing the possibility of making suitable mitigation policy and plan recommendations is a necessary requirement. Displaying of these information also helps in identifying sub-areas requiring more information, facilitates additional risk and vulnerability assessments. It also aids in identification of specific hazard reduction techniques, and making of land-use decisions. In

addition, this phase requires establishment of an early warning system for hazards.

Preparedness Phase- concerns with actions related to provision of facilities and services required for providing emergency response and relief in the event of a disaster taking place.

These actions for provision of facilities and services to answer the what, where and how much questions. The planning of evacuation routes, the design of centres for emergency operations, their location showing isochrones displaying response times in their possible coverage areas. The response services and facilities include location of fire stations, centres for providing evacuation, shelters for evacuees and displaced persons, paramedic units, emergency medical services and trauma centres, information on road networks with road types and their capacity to handle the emergency traffic, stores for emergency supplies. Their location requires decisions about the time available for responses in each case. In addition, during this phase actions are taken for examining and updating of the capabilities of the available early warning system for hazards. Graphic visualisations prepared during preparatory and mitigation phases and their overlaying in a GIS environment where their soft copies are available on desk top computers, or environments where only hard copies are available can provide answers to what, where and how-much related to facilities and services for emergency response and relief works. Information related to these questions can be shared and accessed through web linked GIS or hard copy maps by managers and field workers at different administrative scales.

Crisis Management- is related to two important phases after the onset of hazard. The mapped information's importance can be understood by the title of the report of U.S. National Research Council Report 'Successful Response Starts with a Map:' (2007). The graphic map form, to be efficiently 'usable', requires special design criteria in view of the user needs environment of use.

Response Phase- relates to operations for providing emergency help i.e. search and rescue, provision of temporary shelters, emergency medical care including transportation to primary trauma centers, and providing food to victims. It is also involved with the delivering of emergency response materials, equipment and routing disaster response units to reach the affected location within the earliest required time. This phase is also concerned with the reduction of secondary damage and speeding of recovery activities by damage assessment operations. Emergency responders have an urgent need for maps to organize search and rescue and initial and later response phases.

Recovery Phase- starts once the needs of emergency response in a disaster situation have been met. Efforts then start to bring back the habitat and economy to minimum required levels. Operations in this phase are divided in two sub phases (1) the short term and (2) the long term. The major aim of this phase is to bring back the normalcy. The former operations have a goal of restoration of basic vital systems related to habitat, and restoration of minimum operating standards of medical care, law and order, water supply and sanitary works. The latter stretched over a longer period of time and include habitat redevelopment monetary assistance, assistance for reconstruction of economy of the area, and community planning efforts. The early geospatial graphic information on damage, if integrated with GPS tools, works at this phase to identify and locate damaged buildings and other facilities, identify the type of damage and estimate the extent of damage. The system helps in making decisions about assigning priorities to needed restoring actions. In addition, such maps provide assistance in distribution of supplies from emergency supply centres to different disaster shelters in accordance with their needs. It also helps in reallocation of recovery operations to priority tasks and areas once the work on restoration of essential services has been completed in an area.

Map design

Map design is now understood as a structuring

process in the semiotic system of map graphics within a given set of rules. Implementation of a pre-mediated map design strategy towards well defined goals, like the present one, necessitates an understanding of the nature of map design. Such an appreciation will have to be made in terms of the bases from which map design rules derive and the nature of the medium through which the implemented design takes a corporeal form. The semiotic system of map graphics relates to a symbolism that takes the form of a map image. This symbolism has a unique place among the two major categories of symbolisms, described as 'discursive' and 'presentational' by Langer (1951), that man has been using for acquisition, organisation, storage and communication of knowledge. The map image form appears much closer to the presentational symbolism of one of the artificial languages. The signs used in this semiotic system are purely visual in nature. The visual forms of this sign system are the most effective lexical units of map graphics for creating eloquent statements of spatial reality.

Map design based on the notions of the structuring process in map symbolism, initially requires both an understanding of the characteristics of the semiotic system of map graphics and a distinction between other semiotic systems. This also entails the understanding of human cognitive visual information processing system that processes the presented information through map forms.

The structural elements of map design are: (1) selection of Map Projection and scales (2) verifying the location types of data and its required preamp data analysis (3) Symbolisation; (4) selection of graphic variable in symbolisation, particularly the colour dimensions in terms of their associativity, selectivity, and capability to produce gradients in the third dimension of depth in the map space; (5) graphic organisation of map image elements in map space with respect to the type of information thematic and locational, as well in terms of its visual importance - focal and peripheral realms in map space, and their layout

maintaining their positions in respect of required visual hierarchy in both realms of map space; (6) use of proper typography and its capability to produce differentiation and hierarchical gradients (7) aesthetic considerations in the choice and use of graphic variables.

Overview of human visual informing processing- is presently modelled as a two-staged hierarchical processing system. Following Neisser's (1967) initial formulations they are named as 'preattentive' and 'focal attentive'. The former are carried out over the map image space and simultaneously over all its feature dimensions and are very fast. These operations are 'global' or 'holistic'; they take place very early in the processing and are very rapid, effortless and automatic (Logan, 1992; Rensink and Enns, 1995). The latter operate in a serial and sequential mode. Focal attentive operations are performed selectively in the preattentively organized visual fields and in the contextual extents of the global properties already defined and organized during the earlier processing.

These earliest preattentive processes segment the visual input to the system into the figure and ground components on the basis of heterogeneity in the visual field. Subsequently the input is segregated into chunks that are organised in hierarchically arranged vertical planes along the dimension of depth. Such organisation are particular to processing of two dimensional images, and are primarily based on relations of similarity, texture and density gradients, surface contrast gradients which includes gradients of colour.

The position of objects in such a hierarchy is a function of those feature dimensions, among other things, produce relations of order along the dimension of depth or distance. Such relations are based on cues, which produce perceptual gradients. A gradient in this context has been defined as "an increase or decrease of something along a given axis or dimension" (Gibson, 1950).

These initial phases are seen to operate on the sensory properties for segmentation of the input. Experimental evidence suggests that such operations use easily discriminable physical properties (Beller 1970) that produce heterogeneity in the visual field (Wever, 1927; Forgus, 1966; Dent, 1972). These properties include luminosity, hue, texture, spatial extent and any bounding mechanism in the form of a contour. Dimensions of the stimulus which produce such heterogeneity are hue differences, differences of value and chroma, commonly described as brightness (Luke, 1996: 115) texture, differences in lower level shape features, spatial extent and any bounding mechanism in the form of a contour.

These early processes are seen to 'delineate units' which yield global properties and provide partial cues to guide shifts of attention. Wolfe (1992) and Wolfe et al. (1990) see the specific role of these processes in guiding the later serial processes in the second stage in selecting the elements of interest in the visual field for further processing. The extent of these functions is limited to the immediate present and to partial analysis of the input. The full analysis is dependent on the role of later stage of focal attention.

From the view point of map design it is here that the system responds markedly to systematic efforts in building the usability of map images in terms of their functional effectiveness and efficiency through deliberate and planned design efforts. This contention has support in Phillips (1984) and Gill's (1988) results who found a greater effect of map design improvement on the initial preattentive stage of processing.

The focal attentive processes at the second level are seen to be characterised by a more active involvement of the higher order central processes. These central process, here are taken to mean the functions which bring about an interaction between input data and stored knowledge on the one hand and on the other with such factors as expectations and preferences. The focal attentive processes at this

level are seen to follow preattentive processes and depend on them since they are resource limited and are serial. These are not capable of operating in parallel on the whole visual field. (Neisser, 1967:301, Wolfe, 1992). These processes are seen as those aspects of information processing which are involved with the selection and allocation of analysing resources to a limited part of the visual field. They are guided by monitoring of the unattended input by the processes that makes use of the whole array of the visual characteristics of the input as well the available semantic information in a complex two way interaction in which "...what is seen guides further seeing". (Neisser and Becklen, 1975:491). The time taken for each such selection and allocation i. e. Rapid Attentional Integration (RAI) can also be seen as an indicator of the ease with which the processing is taking place. Eastman and Castner (1983:129) are of the view that by speeding up this selection (RAI) by deliberate design efforts the ease and efficiency of processing of a map display can be improved significantly.

These two processes of visual information processing operate through the complementary 'bottom - up' and 'top-down' mechanisms. Palmer (1975) while elaborating this convergent and simultaneous sequence of operations suggests that in the initial phases of information processing from a scene or image display (such as maps) operations of segregation and feature extraction are performed on the input data by bottom-up mechanisms. These operations yield broadest global properties or visual primitives, which then act as probes to access a set of schema or frames for top down verification.

These initial data driven probes thus perform a function similar to contexts in the subsequent information processing sequence. Relying on Eastman's (1985) extension of Navon's (1977) findings to other visual displays, it can be surmised that, in case of maps too, the convergent operations of the visual information processing mechanisms begin with the broadest

global properties of map image and then move incrementally to local features or finer details(Fig. 2).

Design implementation

Disaster risk managers and crisis managers as well emergency task leaders and task forces perform their tasks under two different mental and time pressure environments i.e. during risk management phases and crisis management phases. The risk management phases have time to use their cognitive processes in using information tools particularly maps without time pressures constraints providing enough time spans to take into account alternative scenarios and use spatial decision support systems. Whereas during crisis management phases both at stationary and mobile command posts very short time spans are available for cognitive processing to have an overview of all operational information at a glance. The relevant operational information has to be displayed on maps using specific symbol sets which are visually enhanced and salient. The design of maps should particularly seek to maintain

minimal cognitive load with an aim to achieve an efficient and effective visualization of the relevant operational information as well easy interpretable symbol discrimination, identification and the segregation of target constituent structures.

The map design in these circumstances have to take into account the aspects of conspicuousness and saliency of map symbols in representations as well the question related to the limitation of human visual cognition as presented by the model human visual information processor (Akhtar and John) especially focussing on the visual requirements of preattentive processing and bottleneck of capacity constraint of the short-term memory of the visual cognition at preattentive level. Towards these ends the usability criteria should take into account the two map use environments i.e. risk management and crisis management as well the importance of the role of preattentive phase of visual information processing. In addition, a space-saving map representation, subject to required spatial resolution, would be particularly useful for displaying the relevant information for this kind of mapping.

Structural elements of map design-These will be discussed in view of the user/use specific needs, previous considerations of use environment and requirements of human visual information processing.

Selection of map projections and scale

The selection of map projections is generally made keeping in view the geometrical and visual requirements nature of data and demands of use on the one hand, and on the other the availability of required base cartographic data in the digital or analogue formats. Additionally, in the present ICT scenario another requirement has become necessary i.e. the compatibility of the projection on which remote sensed data is available for use, and updating, with the projection on which the maps exists or the projection being used for new maps. In case of India this base cartographic data as a topographic base is available on Polyconic projection for larger scales and for geographic

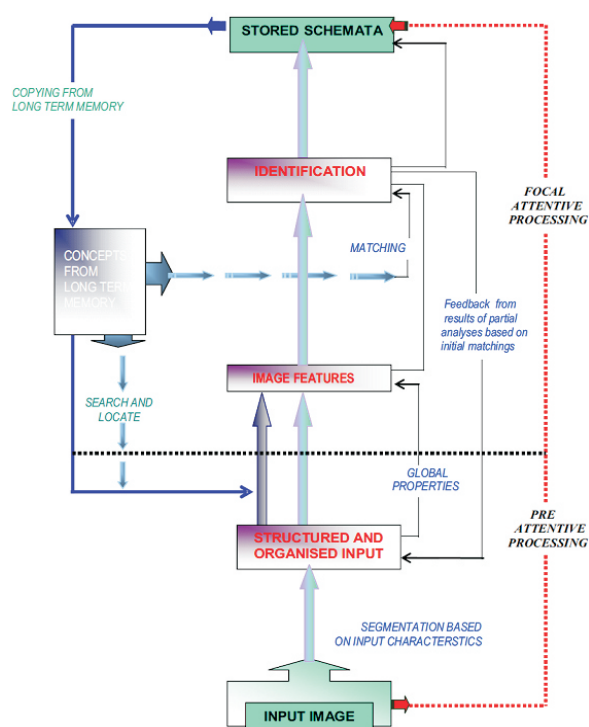


Figure 2 Bottom-up/Top-down convergent operations in visual map image processing.

base on relatively smaller scales on Lambert's Conformal Conic projection. However, efforts by SOI are under way to provide base data on Transverse Mercator's projection which will easily meet the third more important requirement too.

In case of selections of map scale, the consideration of the two factors namely (1) size of the maps in respect of its handling in use environments and (2) the spatial resolution requirements in spite of the needed simplifications, selection and elimination procedures during cartographic generalization phases. This will have to be a combined decision based on agreement between different levels of decision making and command levels.

Required pre-map data analysis

At this stage, in addition to routine premap data analyses like data conversion ratio, per cent, density and data classification, the most important part is related to modelling of hazard risks examples can be taken from the models used in environments of data limitations from the probabilistic model used by El Morjani and co-workers (2007) in case of seismic hazards and the work done by Islam and Sado (2000) in case of floods in Bangladesh to obtain data for mapping hazard risks..

Symbolisation and selection of graphic variables in symbolisation

The locational types of data involved in such mapping will be (1) place data both on nominal and interval or ratio scales (2) line data on

nominal and ordinal scales (3) area data on nominal scales, and (4) volume data on both interval and ratio scales. Volume data on both interval and ratio scales at places or points will be symbolised by graduated circles with redundant use of area fills, sectored circles for place or point data sets on interval/ratio scales. Mimicking pictorial point symbols will be used for nominal place data sets. Line symbols will be utilised for line data on nominal and ordinal scales. Area symbols will be employed for nominal scale data and area symbols will be used for volume data modelling a stepped statistical surface by choroplethic method. The required graphic variables that will be used in symbolisation will be size, and colour dimensions.

In view of the requirement of conspicuousness and saliency of map symbols certain changes will be made in symbol form by using redundant graphic variables. This will done in case of settlement size symbolisation by using conventional settlement symbols and overlaying them with graduated circles with coloured area fills, sectored circles where a redundant size variable will also be used with the use of colour for showing nominal categories of the thematic data being used. The conventional line symbols used for road transport network will also be modified. Similarly in case of colour dimensions larger least practical differences (LPDs) in place of just noticeable differences JNDs (Castner and Robinson, 1969) will be used for colour dimensions (Fig. 3 A, B and C).



Figure 3. Modified forms of (A) settlement size, (B) different road transport network symbolisation and, (C) sectored circles (Based on Robinson et. al)

Samples of colour schemes for use in different symbolisations

The following colour schemes were selected as samples for suggested use. The schemes have been selected on the basis their functional role as well to meet the aesthetic criteria in colour use in maps.

Usability testing of map designs

The maps in disaster management efforts should fulfill at least 'fit for use' criteria (Kraak, 2006) on basic map comprehension which lead to higher cognitive tasks. Since the themes under consideration will involve mapping of different types of geospatial data, these maps will employ different kinds of symbolisation and map design concepts solutions. In view of this, usability evaluation studies of map design concepts based on the notions of usability engineering borrowed from Human-Computer Interaction (HCI) area of computer software engineering.

In order to appraise the effectiveness and efficiency of a prototype map's design concept, a use and usability assessment has to be conducted to evaluate the designed map's capability to meet the user performance and satisfaction together fulfilling requirements of situation specific goals at different phases of management. The following visualization tasks have been identified that a map user will have to perform or carry out during both risk management and crisis management stages. These tasks have been selected from a general list of visualisation tasks (Wehrend, S. and Lewis, C., 2000).

Identify: to ascertain the characteristics by which an object is distinctly recognisable.

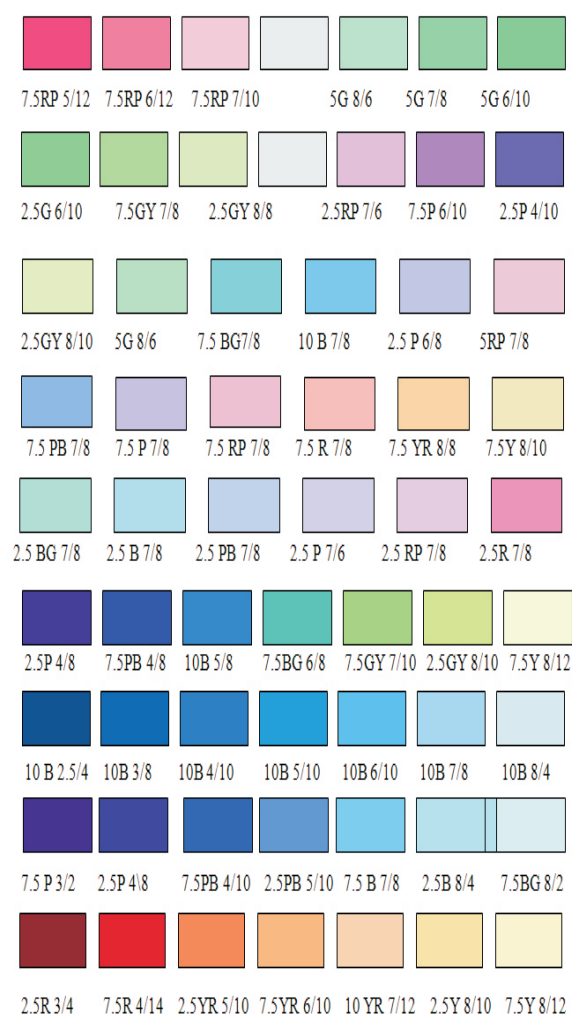
Locate: to determine the absolute or relative position.

Distinguish: to recognize as different or distinct by colour, position, or object's shape.

Rank: to give an order or position with respect to other objects of like type.

Compare: to examine so as to recognise similarities, differences, and order.

The following two methods: (1) thinking aloud (THA) method; and (2) the measurement of effectiveness and efficiency method. HA involves having a user involved with such map use continuously thinking out loud while using the designed map. The test users by verbalizing their thoughts enable the cartographers to understand how the test users view the maps view the map in reading and understanding the



map which makes it easier to identify the shortcomings or capabilities of the map design. (2) The effectiveness and efficiency measurement in respect of map design concepts used in map construction uses the in terms of ease of processing i.e. the visual cognitive processing speed from maps and accuracy i.e. number errors made in the responses of the visual processing.

References

- Akhtar, M. and John, V., 'How Thematic Maps are Read and Understood, Unpublished manuscript',
- Beller, H. K., (1970) Parallel and Serial Stages in Matching, **Journal of Experimental Psychology**, 84(2), pp.213-219
- Castner, H. W., Robinson, A. H., (1969), 'Dot Area Symbols in Cartography: The Influence of Pattern on their Perception', **ACSM Monographs in Cartography**, No.1, Washington, D.C.
- Dent, B. D., (1972), 'Visual Organization and Thematic Map Communication', **Annals, Association of American Geographer**, 62, pp.79-93
- Eastman, J. R., (1985), 'Cognitive Models and Cartographic Design Research', **Cartographic Journal**, 22,2, pp.95-101
- Eastman, J. R., Castner H. W., (1983), 'The Meaning of Experience in Task Specific Map Reading' In **Graphic Communication and Design in Contemporary Cartography**, D. R. Fraser Taylor (ed), John Wiley, New York, pp.115-147
- El Morjani, A. A. *et. al.* (2007) 'Modelling the spatial distribution of five natural hazards in the context of the WHO/EMRO atlas of disaster risk as a step towards the reduction of the health impact related to disasters', **International Journal of Health Geographics**, 6(8).
- Forgus, R.H., Melamed, L.E., (1976), **Perception: a Cognitive Stage Approach**, McGraw-Hill, New York
- Gibson, J. J. (1958), 'Perception of Distance and Space in the Open Air', In **Reading in Perception**, D. C. Beardslee and M. Wertheimer, (eds) Von Nostrand, Princeton (1958)
- Gill, Graham A., (1988), 'Experiments in the Ordered Perception of Coloured Cartographic Line Symbols', **Cartographica**, 25:4, pp.36-49
- Islam M.M., Sado K., (2000), 'Flood Hazard Assessment in Bangladesh Using NOAA AVHRR Data with Geographical Information System', **Hydrological Processes**, 14, pp.605-620
- Koua, E. L., *et. al.*, (2006), 'Evaluating the Usability of Visualization Methods in an Exploratory, Geovisualization Environment', **International Journal of Geographical Information Science**, 20(4), pp.425-448
- Kraak, Menno-Jan, (2006), 'Why Maps Matter in GI Sciences', **The Cartographic Journal**, Vol. 43-1, pp.82-89
- Langer, S. K., (1951), **Philosophy in a New Key**, New American Library, New York
- Logan, Gordon D., (1992), 'Attention and Preattention in theories of automaticity', **American Journal of Psychology**, 105:2, pp.317-339
- Luke, J. T., (1996), **The Munsell Colour System: A Language for Colour**, Fairchild Publications, New York
- Navon, D. (1977), 'Forest Before Trees: The Precedence of Global Features in Visual Perception', **Cognitive Psychology**, 9:3, pp.353-383
- Neisser, U. (1967), **Cognitive Psychology**, **Appleton Century-Crofts**, New York
- Neisser, U., Becklen, R., (1975), 'Selective Looking: Attending to Visually Specified Events', **Cognitive Psychology**, 7, pp.480-494
- Palmer, S. E., (1975), 'Visual Perception and World Knowledge: Notes on a Model of Sensory-cognitive Interaction', In **Explorations in Cognition**, D. A. Norman, D. E. Rumelhart (Ed) San Francisco: W.H. Freeman, pp.279-307
- Phillips, R. J., (1984), 'Experimental Method in Cartographic Communication Research on Relief Maps', **Cartographica**, 21:1, pp.120-128
- Rensink, R.A., Enns, J. T., (1995), 'Preemption Effects in Visual Search: Evidence for Low-Level Grouping', **Psychological Review**, 102:1, pp.101-103
- UN-ISDR (2004), 'Living with Risk: A Global Review of Disaster Risk Reduction Initiatives', United Nations' International Strategy for Disaster Reduction, Geneva

UNDRO (1991), 'Mitigating Natural Disasters Phenomena, Effects and Options', In **Manual for Policy Makers and Planners**, United Nations

Wattegama, C., (2007), **ICT for Disaster Management**, United Nations Development Programme– Asia-Pacific Development Information Programme (UNDP-APDIP) and Asian and Pacific Training Centre for Information and Communication Technology for Development, UNDP Regional Centre, Bangkok

Wehrend, S. and Lewis, C., (2000), 'A Problem-Oriented Classification of Visualization Techniques', **Proceedings of the 1st IEEE Conference on Visualization**, 1990, San Francisco, California

Wever, E., (1927), 'Figure and Ground in the Visual Perception of Form', **American Journal of Psychology**, 38, pp.194-226

Wolfe J. M., et. al., (1990), 'Limitation on the Parallel Guidance of Visual Search: Colour x Colour and Orientation x Orientation Conjunctions', **Journal of Experimental Psychology: Human Perception and Performance**, 16,4, pp.879-892

Wolfe, Jeremy M., (1992), 'The Parallel Guidance of Visual Attention', **Current Directions in Psychological Science**, 1,4, pp.124-128

(Dr. Vineeta John, Assistant Professor & Head Geography Department, Ewing Christian College, Allahabad-211003, Address: 812/28/537 Jamuna Christian Enclave, Mutthiganj, Allahabad-211003,

E-mail: vineetajohn@rediffmail.com)

Conceptualizing Cartographic Techniques for Disaster Management

Baisakhi Sarkar

Introduction

A hazard or unnatural incidence not affecting human society and environment is not normally considered as a disaster. Disaster Preparedness Training Manual, Philippine National Red Cross (1954) defined disasters as “phenomena that pose a threat to people, structures or economic assets and which may cause a disaster. They could be either manmade or naturally occurring in our environment.” The United Nations defines disaster as “...the occurrence of a sudden or major misfortune which disrupts the basic fabric and normal functioning of a society (or community).” The World Bank defines disaster as “an extraordinary event of limited duration which causes serious disruption of the economy of the country.”

To sum up, disaster is an event or a series of events that leads to casualties, damage or loss of property, infrastructure, essential services or means of livelihood on a scale that is beyond the average incidences affecting human community and environment.

Classification of disasters

Disasters could be natural or man-made. These are generally classified on the basis of their origin as tectonic (earthquake, volcanic eruption, tsunami), high altitude and slope related (landslide, avalanches, accidents during mountain expedition/trekking), meteorological (cyclones, tornados, forest fire, fire and electrocution from thunderbolt, flood, drought, heat wave, abnormal snow melt related to global warming, abnormal cold wave, etc), infection (health hazard like epidemic, locust invasion/viral infection to crop-fields) and man-made (industrial accident, rail traffic accidents, war related casualties, mining hazard, fire and short circuit, bombing, terrorist attack, nuclear explosion, etc).

Vulnerability from disasters

Natural disasters cover incidences of loss and extensive damage due to tsunami, volcanic eruption, severe earthquake, excessive rainfall/snowmelt and flood, avalanche, landslide, cyclonic storm and coastal surge, tidal bore, epidemic, forest fire, damage from fall of meteor etc. Man-made disasters are varied; like flooding due to sudden release of water from reservoir, massive rail accident, severe road accident, building collapse, ship wreck, evacuation due to socio-political reason, damage from war and bombing, industrial disaster in chemical factory, nuclear power plants, fire, short circuit and electrocution, oil spill in ocean/sea, environmental hazards from electronic wastes/satellite wastes in space etc.

People living in hazard prone areas are always in a threat to loss, damage and death. This vulnerable situation affects mental stability as well as health. Societal progress is adversely affected; efforts for physical survival consumes lion's share of human energy; for educational/technological progress little time is left.

Terms like flood prone, drought prone, cyclone prone areas denote frequent loss/damage over concerned areas due to natural calamities. Thus vulnerability is the term denoting super-sensitive situation of any region/ sub-region due to natural/ man-made calamities. National Institute of Disaster Management defines vulnerability as “the extent to which a community, structure, service or geographic area is likely to be damaged or disrupted by the impact of a particular hazard on account of either nature, construction and proximity to hazardous terrain or disaster prone area”.

Vulnerability incorporates both the intrinsic value of the elements concerned and their

functional value in contributing to communal well being in general and to emergency response and post-disaster recovery in particular. The concept of vulnerability therefore implies a measure of risk combined with the level of social and economic ability to cope with the resulting event in order to resist major disruption or loss.

Hazards in India

Because of the sub-continental dimension India experiences a variety of natural hazards like drought, flood, earthquake, tsunami, cyclone and consequent damages to life and wealth /property. Major hazards occurring in our country are flood, drought, cyclone and earthquake. During the same period different parts of the country might get affected by a variety of hazards—there may be flood in Damodar and Brahmaputra valleys, drought in Andhra Pradesh and Rajasthan, landslide in Uttarakhand, Sikkim and Mizoram, cyclonic storm and tidal bore in Sundarban of West Bengal and Orissa coast.

It has been estimated that 55 per cent of landmass of India is prone to earthquakes of various intensities (falling in zones III - IV), about 50 per cent of the net sown area is susceptible to drought, about 12 per cent of the net sown area is flood-prone and 8 per cent of the area is prone to cyclonic storm hazard (eastern coast and Gujarat coast); the south eastern coast and Andaman and Nicobar Islands are vulnerable to tsunami.

Further, there are socio-natural and man-made hazards affecting people fatally. For example massive rail-road accidents, terrorist attacks and bombing, flooding due to sudden release of water from reservoir, industrial disaster like Bhopal (Union Carbide) gas tragedy, disaster in mines (like Chasnala coal mine disaster), nuclear explosion and aftermath – all adversely affect the normal set up of our environment.

Cartography in Disaster Management

For disaster management not only funds but also proper planning from spatial perspective is essential. This would minimize calamities and associated loss in future. Hence, cartography

and thematic mapping and GIS have a lot of scope to serve.

Natural disaster mitigation and mapping

In case of natural disasters like river flood or coastal submergence, area that could get affected could be mapped from remote sensing data. Darker tone of the pixels would indicate the low-lying areas; 3D digital mapping with radar data/LIDAR data could indicate micro-relief and the most vulnerable zones. Micro-relief map with contour plan would serve the purpose.

For flood management suitable locations for constructing shelters in low-lying areas could be suggested from the study of aerial images. Flood-prone area mapping with respect to the population endangered would help to assess the amount of aid required for disaster mitigation. Cloud burst, torrential rain and associated heavy sheet flow and flooding (like the disaster in Leh on 6th August 2010) is an occasional phenomenon. However, drainage basin study at micro-level could indicate where runoff from different directions could coalesce to create deluge/flood/sheet flow. People could be alerted through media messages after meteorologists observe abnormal accumulation of low-level clouds over a particular area. Similar warning could be given for possible happening of tsunami after recording of sea-floor quake.

Because of slow but constant movement of Indian plate towards Asian/Tibetan plate, entire Himalayan region and the foothills are at constant threat from earthquakes. The jolt at Richter 6.8 that shook Eastern Himalaya (especially Sikkim) and much of the Indo-Gangetic plain on 18th September 2011 is not an exceptional event. The infamous Bihar earthquake of 1934 (magnitude 8.4) that perished 30,000 people had its epicenter at Sikkim. Darjeeling was badly hit by that earthquake. The Governor's House in Darjeeling was damaged. It had to get demolished and a new one was constructed. In 1993 Latur earthquake at magnitude 7.4 killed 20,000 people. The 26th January 2001 Kutch earthquake at magnitude 7.7 killed more than

20,000 people. The earthquake of 7.5 magnitudes happening on 8th October 2005 left 79,000 persons dead in Pakistan and 1,500 in Jammu & Kashmir. These statistics are indicators of a fragile tomorrow that we are going to deal with. For earthquake hazard management, seismic micro-zones map with epicenters of important previous earthquakes would be a good indicator. In high risk zones directives should be given for construction work. Similarly tsunami prone coasts could be mapped. The tsunami following the catastrophic earthquake of December 26th 2004 in Indonesia affected a vast stretch of this planet – from Indonesia to Africa.

Volcanoes (active as well as dormant) could be mapped showing the buffer zone that could get affected due to eruption of lava and ashes. Recent volcanic eruption during the first half of 2010 from Iceland affected atmospheric environment– aviation service from Europe to North America got disrupted. In these cases location of active volcanoes, amount of ash, particles erupted, along with atmospheric wind circulation system need to be studied for avoiding air-crash/plane accident.

Landslide affects transport system in hilly/mountainous areas. Sometimes severe landslide due to earthquake and heavy rainfall cause enormous damage to human life and property. Normally earthquake prone areas, areas composed of loose, fragile rocks, areas with degraded or no vegetal cover, areas where construction work has been done upon a fragile litho-base, roads lying over the flow direction of mountainous streams, deforested mountain slopes receiving heavy monsoon rain- all are prone to landslides. These are to be mapped in detail for mitigation of landslide disaster. Liquefaction potential of near-surface subsoil is to be studied for environmental impact assessment and management.

Bay of Bengal coast is frequently affected by cyclones. It has been observed that cyclones/tornadoes are often an aftermath of abnormally hot weather. Also, these are often associated with new moon and full moon days.

Recent hurricane of 27th and 28th August that affected the eastern coastal states of North America occurred on a new moon day. On the same day a severe typhoon devastated Philippine coast.

Tidal bores in Ganga estuary are frequent in the months of August and September. Special awareness is to be generated amongst the inhabitants about possibility of disaster season wise/lunar calendar wise.

Mangrove forests act as a natural barrier against cyclonic damage and coastal erosion. But deforestation has damaged this natural barrier. Coastal disaster management not only demand construction of artificial structures like embankment but also restoration of coastal forests too.

Man-made disaster mitigation and mapping

Major man made disasters are often related to poor maintenance of structures/factory and negligence/indifference towards man and environment of neighboring areas. Union Carbide gas tragedy in Bhopal, nuclear power plant disaster in Chernobil (Russia), etc caused massive disaster–the impacts are still recognizable in the crippled health condition of the population affected. Nuclear bombing in Hiroshima and Nagasaki (Japan) during Second World War caused havoc disaster for which compensation for the victims was next to impossible. Citizens of Japan still bear genetic physical deformity due to atomic explosion.

In this year severe earthquake caused tsunami as well as collapse of nuclear power plant at Fukushima Daiichi, Okuma, Japan (16th March 2011). Damage and death incurred was beyond anybody's assumption.

It is said that atomic explosion and atomic minerals are likely to spread cancer, anemia, nerve disorder and other physical deformities. Gas emitted from uranium plants causes fatal damage to lungs. Wastes from atomic reactors through soil and plants could penetrate human and other animal bodies; thus endangering our environment.

For installation of a nuclear power plant, management authority has to select a sparsely populated/ uninhabited site with at least 12 km radius, so that a buffer zone will remain to minimize the number of casualties if any accident occurs. Beyond this sterilization area there should remain an outlying area covering about 16 km radial distance. Township could remain at least 5 km away from the outlying area. The site should in a stable zone (in terms of frequency of earthquakes) and water bodies (for cooling the power plant). Moreover, the consumer area should not be far away. Cartographical research could do a lot towards recommending suitable sites of nuclear power plants.

Rail accidents are violent man-made disasters occurring frequently. The year 2011 started on an auspicious note with the Amritsar-Sealdah Akal Takth Express ramming into a truck near Jaunpur in Uttar Pradesh when its driver reportedly failed to notice the red signal at Babura railway crossing, probably due to intense fog. Within a couple of days, four wagons of a goods train derailed in Dadri area of Ghaziabad district of Uttar Pradesh, disrupting traffic on the Delhi-Howrah trunk route. While 2010 ended with 19 major train accidents involving the loss of human lives, the year 2011 has already had 13 so far, the one near Arakonam, Tamil Nadu being the latest.

Management of the railways is no rocket science. Solutions are needed that are pragmatic, easy to implement and cost effective. Collisions may cause loss of human lives and usually get much attention from the media, but these form less than five per cent of the total incidences. Almost 70 per cent of the accidents involve derailments that seldom get covered by the print or the electronic media, but are important indicator of the health of railways.

Flooding due to release of water from reservoirs is a serious threat to the inhabitants of Hugli and Howrah districts of West Bengal. If there is continuous heavy rain in Jharkhand and Bengal, reservoirs of DVC get full to the brim and to save the structures from overload of extra water,

irrigation department release water from dams. This storage water accompanied with rivers recharged with heavy rain cause extensive flooding. Cartographical approach towards this disaster management has to do a lot. Warning for heavy rainfall and possible inundation could be announced in advance using weather satellite data. Sites for constructing new reservoirs could be proposed. Areas where embankments are to be constructed, flood shelters to be built- up could be suggested. Mobile-based alert giving for natural hazards like flooding, cyclone, tsunami could be introduced.

Urban air pollution is a serious health hazard, SPM, SO₂, NO_x -all create respiratory problems. Ambient air quality mapping (zone-wise) for cities and identification of vulnerable areas are cartographers' job.

Town mapping showing location of old structures, congested areas, congested roads, buildings with wiring lines needing immediate replacement, etc would help to reduce damage from fire, short circuit, etc. Coalmines prone to collapse/ inundation could be marked and necessary precaution could be taken to avoid calamity. Another possible environmental threat in urban areas is likely to get generated from electronic industrial wastes. Persons who are associated with collection and recycling of electronic wastes are in a serious threat to health hazards related to carcinogenic diseases.

Vulnerability of environment is created also from lead mixed paints-especially the aquatic environment and fish are in a serious threat from painted (lead mixed) deities immersed in water bodies. It is learnt that after emersion of deities in lakes/ponds fish succumb to lead (Pb) mixed water. In densely populated areas water bodies should be carefully protected and use of lead (Pb) mixed paints and other harmful chemicals on deities have to be banned.

Geopolitical hazards, damage/loss due to terrorism are serious concerns in some states like Jammu & Kashmir, Manipur, etc. Metro cities like Mumbai, Pune and others had suffered repeatedly from terrorist attacks. Communal

disharmony, political rivalry, etc are the major social causes behind these calamities. Maoist extremist movements is a serious set back for the forested areas of Chhattisgarh, Andhra Pradesh, West Bengal, Jharkhand etc. Proper management of this vulnerable situation is need of the day for inhabitants as well as government personnel on duty in these areas.

Conclusion

The fields where cartography/GIS ought to work for safe environment planning are: disaster risk management schedule, preparedness and mitigation, baseline data collection and mapping, assessment of vulnerability, needs of victims, risk factor of a particular area, modeling (3D and 4D modeling) of disaster risks, spatial planning, housing and supply of essential commodities, disaster recovery and rehabilitation, infrastructure recovery, long term medical intervention (in case of epidemic

prone areas), monitoring and evaluation, development of knowledge base through GIS, knowledge management, awareness generation, tectonic-hydro-meteorological disaster mapping, tsunami/tidal wave prone area mapping, forest fire mapping, volcanic eruption study, biological disaster mapping, nuclear disaster mapping, chemical disaster mapping, social disaster mapping, multiple disaster mapping, formulation of awareness building program. Epidemic planning mapping is a new idea that involves mapping of areas where outbreak of a disease (like malaria or dengue) could occur; also location of hospitals for the treatment of the patients could be indicated through maps or through GIS based info files.

Briefly, the applied cartography and disaster mitigation plans would go hand in hand for minimizing risk, vulnerability and casualties due to disasters.

(Dr Baisakhi Sarkar, is a Research Officer at National Atlas & Thematic Mapping Organisation (NATMO), Salt Lake City, Kolkata-700064,
Email: baisakhisarkar2010@gmail.com)

Requirement of Orissa State Spatial Data Infrastructure for Managing Disasters in Orissa

P. K. DAS

Introduction

Orissa has a history of recurring natural disasters. The coastal districts of Orissa are exposed to floods and cyclones. Western Orissa is prone to acute droughts. A large part of the State is also prone to earthquakes. In addition, the State is also affected by disasters like heat waves, epidemics, forest fire, road accidents etc. The history of disasters substantiates the fact that about four-fifths of the State is prone to one or more forms of natural disasters. The two successive cyclones in October 1999, the severe cyclone which hit Ganjam coast and the Super Cyclone damaged the infrastructure in 14 districts of the state and disrupted public life. With millions of trees uprooted during the super cyclone, the state, especially the coastal belt has become extremely vulnerable.

With 80 % of annual rainfall concentrated over three months, the State is highly vulnerable to floods. High population density, encroachment on the flood plains, poor socio-economic condition, weak infrastructure and mud houses increase the vulnerability. Out of total geographical area of 15.751 lakh hectares, 1.40 lakh hectares is flood prone. There are 516 vulnerable locations in Orissa. Floods are the most recurrent disasters in the state. In the last 25 years, floods have occurred 12 times with varying severity.

Orissa is always vulnerable to cyclones in April-May and September-November. After a gap of few decades often a super cyclone strikes Orissa. Recent super cyclone that hit Orissa in the last century came in 1942, 1971 and 1999. The Super cyclone of 1999 killed about 10,000 and traumatized millions who survived its wrath. Over 15 million people were affected.

Now it is felt to have a State Spatial Data

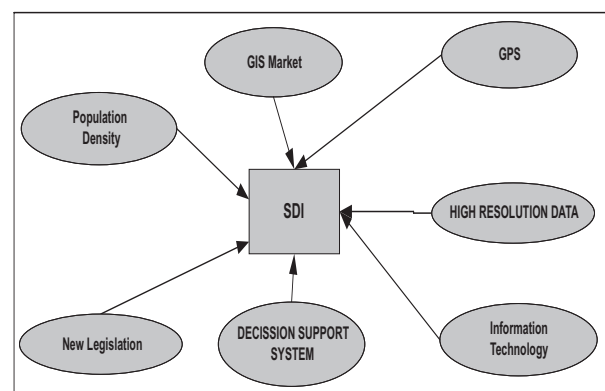
Infrastructure to provide necessary guide lines on all aspects of emergency management.

Stakeholders

- Some of the main stakeholders are
- Orissa State Disaster Mitigation Authority (OSDMA)
- Orissa Disaster Rapid Action Force (ODRFA)
- Special Relief Organisation
- Panchayati Raj Institutions and Urban Local Bodies
- Volunteer based organizations such as NSS, NCC, Indian Red Cross, Bharat Scouts and Guides, Nehru Yuva Kendra etc..
- Police, Home guards, Paramilitary forces
- District administration & many more

Key drivers for SDI.

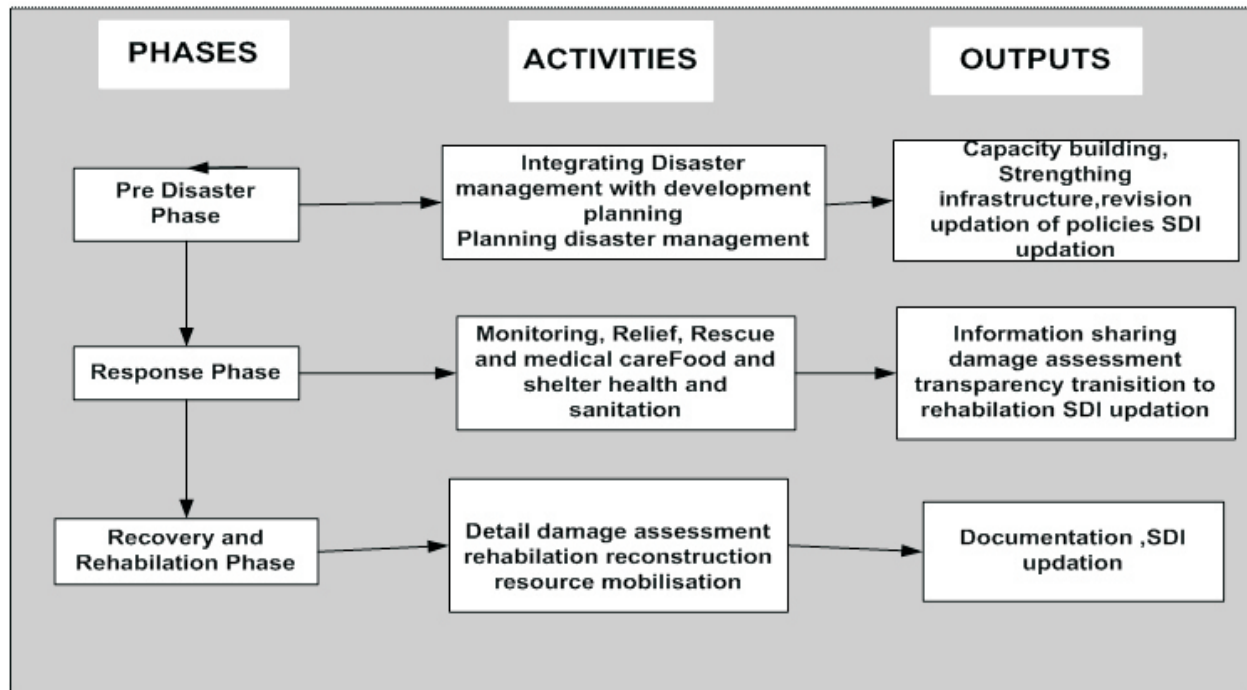
The factors like GIS market, GPS technology, high resolution data (Cartosat, Quickbird, IKONOS), Information and communication technology, decision support system and above all the people are the key drivers, which have given birth to SDI Fig.1).



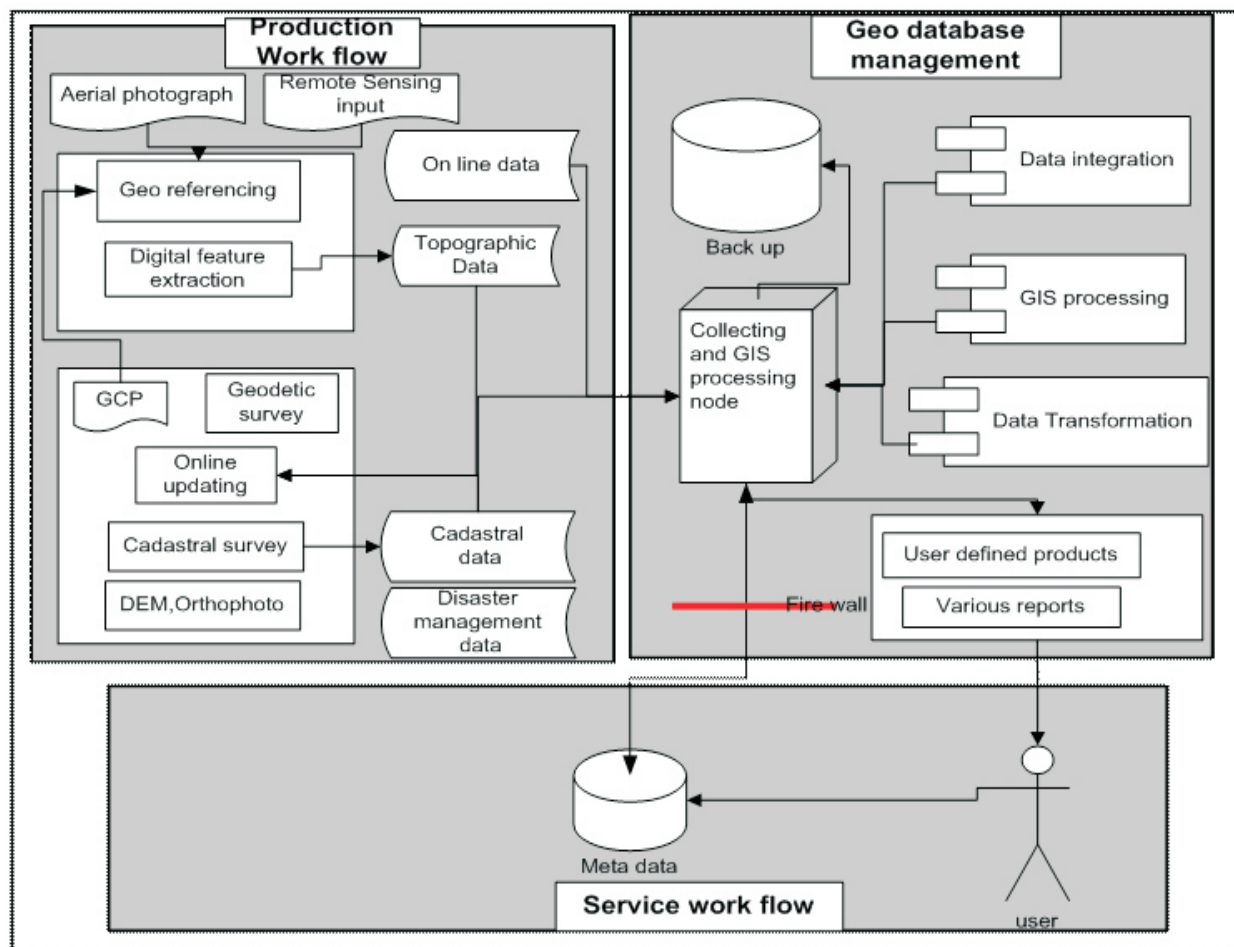
Disaster management cycle

Disaster Management will have an integrated approach covering the main three phases of disaster

Fig. 2 Steps in Disaster Management Methodology



SYSTEM ARCHITECTURE



- Pre disaster phase (Prevention, preparedness, Mitigation)
- The response phase
- The recovery and rehabilitation phase

Disaster management is a cycle of activities beginning with mitigating the vulnerability and negative impact of Disaster, preparedness in responding to operations, responding and providing relief in emergency situations such as search and rescue, fire fighting, etc, and aiding in recovery including reconstruction and providing a better quality of life.

The availability of recent advances in spatial data management including information and communication technologies (ICT) with the help of high resolution satellite data (RS), Geographical Information System (GIS) and Global Positioning System (GPS) have considerably improved disaster management through facilitating data capture, integration, and analysis. The integration of such technologies with each other and with other technologies such as Design Support System (DSS), the World Wide Web and simulation has created more effective disaster management spatial data and GIS has proven crucial in preparing for mitigating, detecting, responding, to and recovery from natural and technological disasters. Without spatial data one can not expect effective and efficient disaster management as spatial data are the initial input for GIS and emerging response modeling and simulation systems.

Organizational setup for disaster management

Disaster management concerns the development and management of tools and methods for collection, storage and processing of spatial data, and for the dissemination and use of these data and of services derived from such data (Fig. 2).

- This implies the development and application of concepts for spatial data modelling, for the information extraction from image data and for the processing, analysis, dissemination, presentation and use of spatial data.

- It also implies the development and implementation of concepts for the structuring, organization management and institutional arrangements of processes for spatial data production and the provision of geo-information services along with attribute data.

Figure below shows (see Fig. 3) the adjustment strategies. Now SDI has to take care of derived strategies to fit to achieve the goal of producing a large scale data base. This is only possible with the support provided by Information and Communication Technology (ICT). Due to the development of Internet, wireless system for data transfer, Global Positioning system (GPS) for point determination, high resolution satellites for providing input data, image processing software, geodatabase for data storage & dissemination through portals would provide the efficient and effective technology for the achievement of the objectives.

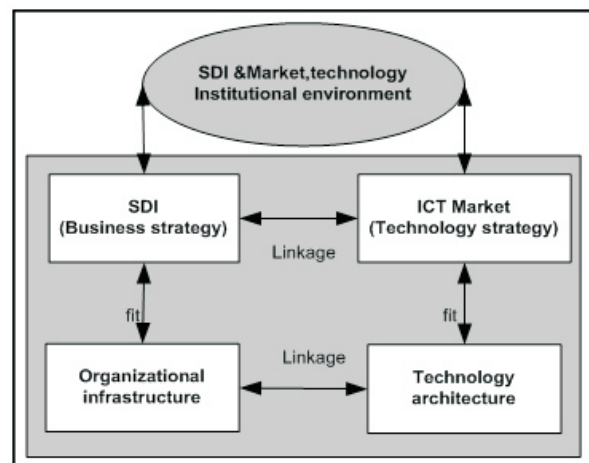


Fig.3

Standardisation

Contents: The database will contain all essential standard topographic information in accordance to the scale. All geographical names, street names and all types of names will appear. All the well identifiable topographic objects and hedges and fences will also appear. Data will be stored in database on seamless basis. As such the usable range for presentation can starts from 1:1000 for township and 1:5000 for rural areas. Point accuracy in the map can be 50cm in urban

and 2.5 meters in rural areas. A reference guide will be prepared for this purpose.

Structures: There are mainly three types of data model, like CAD data model, coverage data model and geodatabase data model. It is proposed to have geodatabase data model for large scale data base. Given guidelines for a uniform structure and contents of the map with the correct software, users can develop a map as per their choice.

Access and dissemination

It is paramount that information is efficiently collected, and user friendly systems are put in place to access and disseminate information. The main challenge lies in accessing and communicating information appropriately -

- Responsible usage
- Redistributing the spatial data where required
- Timely dissemination
- Identification of high and low level risk and the definition of dissemination accordingly

Updating and maintenance:

Data maintenance and updating is the next important step to satisfy the needs of disaster managers (Fig. 4). The responsibility with the various organizations must be fixed. Data may be updated using high resolution imageries. It is suggested that help from all village heads and primary school teachers may be taken for gathering information about change occurrences. They may notify the nearest surveyor so that all new and modified details can be incorporated. After the database is updated it should be available to other users. The main server should take care and deliver to various nodes.

In the above figure SDI Server is the owner of topographic database. It distributes say user1, user2 and user3. Suppose user2 has notified some changes and SDI has agreed upon. Then this is SDI server who distributes to all other user1, user2 etc after up dating.

Metadata and catalogue services

TC 211 with respect to the contents and

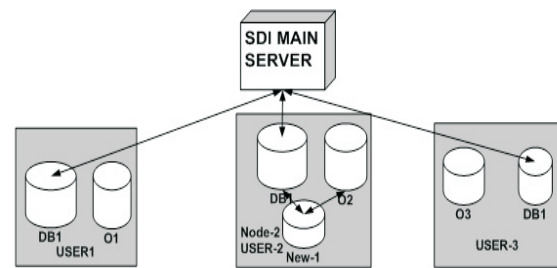


Fig. 4 Update Control in a distributed environment

structure of the metadata which will be followed for SDI. Metadata must contain description of spatial and non-spatial aspects. Cataloguing services will access the data and make query and find the result.

Web GIS

Metadata and catalogue services are the activities in the area of Internet GIS Called Web Mapping. This consists of Web map server, Web feature server, and Web coverage server. Web feature server interface can be used for updating information and has functions for locking and committing transactions whereas web map server can be used for query aspects using functions like GetMap, GetCapabilities, and GetFeatureInfo. For vector data transfer Geography Markup Language (GML) (Open GIS Consortium, 2000C).

Conclusion

SDI along with communication/dissemination system are the important elements, which will enhance the capability and capacity of disaster management with multi-participation within decision supported environment.

With the above points in consideration, the paper first addressed the role of SDI as a framework for disaster management and its stakeholders. Thereafter we addressed valuable outputs of various activities in different phases of disaster management cycle to propose a Spatial Decision Support Systems (SDSS) generated from SDI.

This also includes the proposed architecture of SDI which is highly scalable and interoperable at various levels of organization set up. We also discussed the standardization and

interoperability of Web GIS with updation, access policies and metadata.

Disaster managers requires adoption of a suitable framework of hazard mitigation modeling, GIS-based SDSS, well defined

communication protocols for various emergency responder groups both at the government and community levels, stating well defined multi-level responsibilities of the participating agencies.

(**Shri P.K.Das** is working as a Superintending Surveyor, Bihar, Geo Spatial Data Centre, Patna Survey of India

Email: pkdsti@yahoo.co.in)

Planimetric Accuracy Evaluation of ETM Orthoimages for Indian Landmass

K.S.S.Sekhar, Bankim Shah, B.Kartikeyan

Abstract

Several RS and GIS related projects including urban and rural planning applications in India and other parts of the globe use Enhanced Thematic Mapper (ETM) mosaic products for reference. The imagery collected by the space-borne sensors has to be accurately registered to ground coordinates in a suitable map projection before use in any analysis or application. This entails availability of well distributed as well as dense control points in a form suitable for automation in registration. Geometric control in the form of geometrically corrected RS imagery fulfills this requirement to a large extent. USGS has produced a dataset covering the entire globe using imagery from Landsat TM and ETM. This dataset was released for public use in 2000.

During the last two decades ISRO has come up as a leading supplier of RS data products with a wide range of spatial, spectral and radiometric resolutions suited for specific application objectives. During this period ISRO has also worked for better geometric ground control generation along with making efforts towards producing reference image data for the Indian landmass and organizing the same in a well structured database for internal consumption.

Under IRS-P5 (CARTOSAT-1) data processing a project named CARTODEM has been operationalized to generate Ortho-images and Digital Elevation Model (DEM) covering Indian landmass. GPS measured precise ground control points have been used for generating the Orthoimages and DEM.

For verification of the correctness of the reference images the data sets provided by USGS in the public domain a comparison was made between ETM ortho-image data for Indian landmass and the latest Indian reference data – the CartoDEM-Ortho-Images. This paper attempts a detailed analysis of the results, indicating the accuracy of the ETM products is not uniform across the Indian landmass. The data needs to be used cautiously.

Introduction

Remote sensing imagery is for a wide variety of natural resource monitoring and anthropological activity planning applications. The imagery collected by the space-borne sensors had error due to alignment of optics, attitude, ephemeris and drift. These errors have to be rectified by interior and exterior orientation using well qualified ground control points (Friedmann *et al.* 1983), before use for any analysis or application. This entails availability of well distributed dense control points in a form suitable for automation in registration. Geometric control in the form of geometrically corrected remote sensing

imagery would fulfill this requirement to a large extent. The combination of an accurate orthomosaic and a DTM represent a viable source of control in the geometric processing of high resolution satellite imagery (Dare *et al.*, 2002). Accurate elevation information is crucial for national mapping projects (Li, 1998). For the Landsat Coverage, NASA has sponsored creation of an ortho-rectified and geodetically accurate global land data set of Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper (ETM) data, from the 1970s, circa 1990, and circa 2000, respectively. (Tucker *et al.*, 2004). Later on Landsat-7 derived circa year 2000, orthorectified mosaics and color

balanced digital image dataset covering the entire land area of the Earth except the high latitude polar regions, generated in natural color composites by the NaturalVue 2000. They consist of 800 tiles each 5x6 degree tiles with a resolution of .05 arc sec (approximately 15m) produced in a UTM projection. (NaturalVue 2000 A Global Landsat Image Dataset by Jon Dykstra, 2002)

ISRO launched IRS satellites to create its own importance in the domain of remote sensing imagery with a wide range of spatial, spectral and radiometric resolutions suited for specific application objectives. In the last two decades ISRO has also created large geometric ground control database and also in producing reference image data for the Indian landmass.

As the ETM images are widely used by the Indian remote sensing community because of the free availability through websites. This made us interested in evaluating the ETM ortho-image data for Indian landmass with respect to the latest Indian reference data – the CartoDEM-Ortho-Image. The details of the comparison analysis and results are reported in this note.

Datasets

The ETM datasets: ETM orthorectified tiles generation was sponsored by NASA to support a variety of scientific studies and educational purposes. First time a geodetically accurate global compendium of orthorectified multi-epoch digital satellite data at the 30- to 80-m spatial scale spanning 30 years have been produced for use by the international scientific and educational communities.

The first step in the ETM orthorectification process is to assemble the satellite data in large blocks comprising 400 to 1,500 Landsat 4 and 5 scenes. A photogrammetric program called “Mospoly” (Earth Satellite Corporation patent number 6125329) is used to perform a pixel-to-pixel correlation to accurately acquire tie-points within the overlap between adjacent TM scenes for the block in question. A six parameter affine transformation was used to “tie” the images together in all areas of overlap. This included

translation, rotation, differential scale, and affinity or “skew. Once the images are “tied” together at common overlapping points in all overlapping areas, geodetic control points were located manually in the TM scenes, where they occurred. The next step is to associate the respective digital elevation model data with the satellite data block by matching geodetic coordinates. The digital terrain elevation data sets have a spatial resolution ranging between 1.0 and 30.0 arc seconds (30 m and 1 km, respectively). A typical block of data will contain over 300,000 tie points and over 300 ground control points (Tucker *et al.* 2004).

In the present study ETM ortho-imagery of bands 2, 4, 7 are availed from <http://glcf.umiacs.umd.edu>. These data are available in UTM map projection, WGS-84 in vertical and horizontal datum with an extent of roughly of 5deg latitude X 6deg longitude tiles with 14.25m spatial resolution.

ISRO reference image earlier initiatives:-After the launch of IRS 1C & 1D systematic acquisition of LISS-3 was available at 23m resolution. An inter-centre activity was taken up to develop a reference image data for Indian landmass. The basic approach was to use system level corrected standard product as input, use control points from 1:50000 topo maps to improve location accuracy and produce Geo-referenced scenes in Polyconic projection and Everest datum. Similar approach was followed for the PAN sensor having 5.8m resolution for specific pockets taking control from 1:25000 scale topo maps. The dataset is in the form of path-row based products and have been extensively used for Geometric Data Quality Evaluation(GDQE).

After the launch of Resourcesat-1 (IRS-P6) the AWiFS camera having combined swath of 720km and spatial resolution 56m, for upgrading the reference images. The control used was from GCPL, having better than 1m accuracy and spatially consistent (mosaicable) dataset covering Indian landmass were generated. These were 1degX1deg extent precision products in LCC projection on WGS84 datum.

CartoDEM Ortho-image:- This is the latest dataset having a spatial resolution of 1/12 arc-sec (~2.5m) covering Indian landmass derived from Cartosat-1 stereo image pairs and GCPL – ISRO's high accurate Ground Control Point Library (GCPL).

GCPL is a library of high accuracy control points distributed over Indian landmass. More than 5000 points are available in this library. These are based on GPS measurements on ground supplemented with satellite and on-ground image chips and description, useful for 1:5000 scale image corrections.

Cartosat-1 launched in 2005 produces along-track stereo imagery having one camera in off nadir and another in near-nadir looking. Long strips of stereo pair (500km) covering about 10 GCPs have been used to update the model and attitude using the new concept of SSTS- Stereo Strip Triangulation System.

Novel approaches to robust and dense image matching were developed under the CartoDEM project along with SSTS to generate one of the best quality DEM and Ortho-image which are seamlessly mosaicable.

Evaluation of ETM

We now present the approach and results of evaluation of ETM data with respect to the CartoDEM Ortho-image dataset for Indian landmass. The Indian landmass is covered by 6 UTM zones 42-47, and in terms of tiles it is covered by 21 ETM tiles out of this 13 tiles are taken to analyze accuracy of the ETM orthomosaics (see Fig.1).

The CartoDEM ortho-images are available in units of 7.5' X 7.5' in geographic projection at 1/12 arc-sec resolution and 10bit information stored in unsigned 16bit. These are first mosaiced to ETM tile extents, re-projected to UTM and down-sampled for 15m.

Evaluation of orthoimages is a process done based on ground control points, whose coordinates are known in both land and image. The selected points may indicate either measured points in the field or/and can be

designated as visible points in images. These points may represent; building corner, road cross, panting objects, etc.

Earlier studies have shown that internal accuracy of CartoDEM Ortho-image is very good and less than three a pixel in both easting and northing for most of the images. This product type, however, has the lowest accuracy specification (RMS positional accuracy of 10m), good enough to evaluate the ETM ortho mosaics.

In each ETM-tile a number of well distributed and precise common features are identified in CartoDEM generated orthoimages. Kadota and Takagi (2002) used above mentioned method in acquisition of GCPs for geometric correction of high resolution satellite image from reference images. This common feature identified in the



Fig. 1 Indian landmass overlaid with ETM tiles extents and number of feature points in each tile.



Fig. 2

ETM and CartoDEM generated orthoimages are pictorially represented in Fig. 2 for each tile; for the number of points identified on each tile see Fig. 1.

For each feature, the difference in easting and northing are determined and attached to the

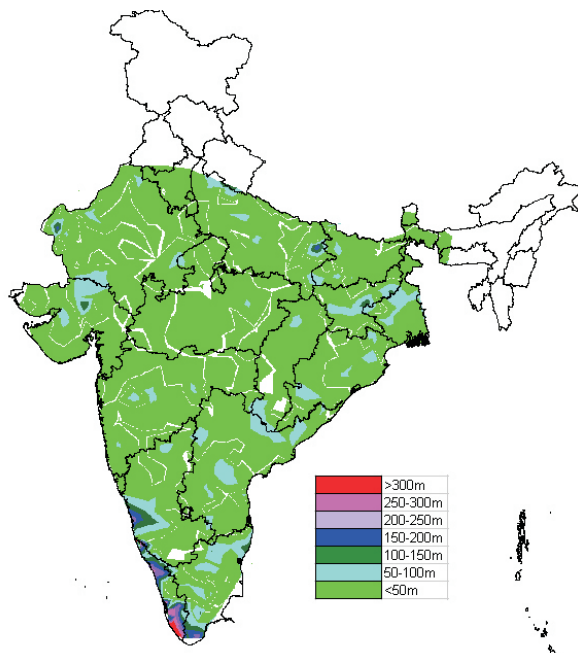


Fig. 3 (a) Northing error surface

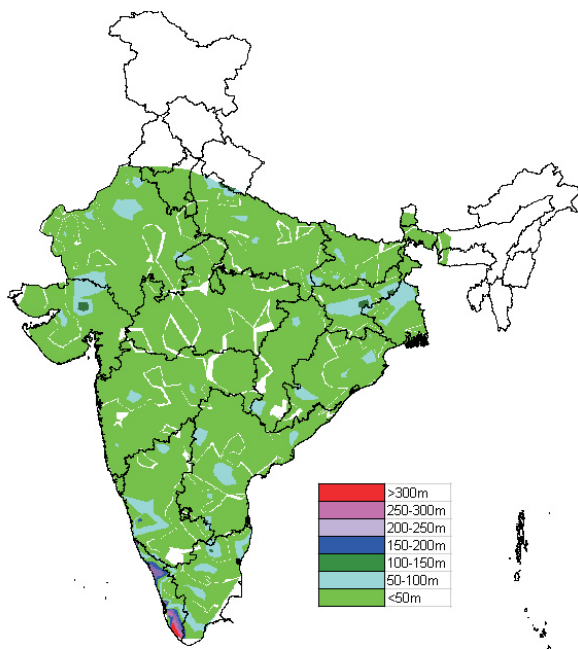


Fig. 3 (b) Easting error surfaces

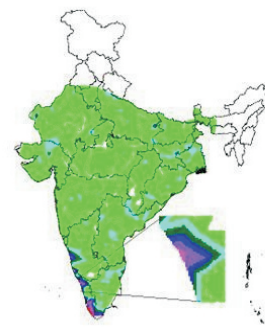


Fig 3c North Kerala area error profile

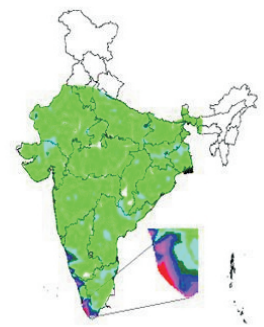


Fig 3d South Kerala area error profile

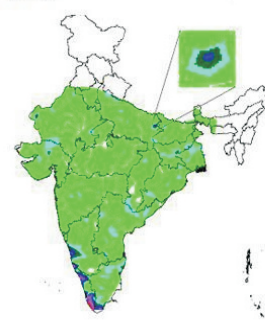


Fig 3e Eastern UP area error profile

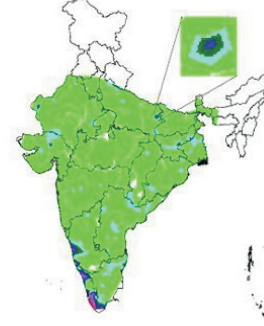


Fig 3e Eastern UP area error profile

Fig. 3 (c) Northing error surface



Fig 3g Rajasthan area error profile

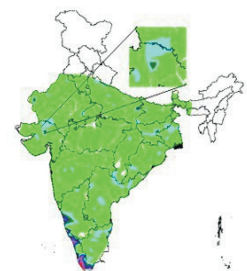


Fig 3h Gujarat area error profile

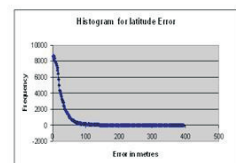


Fig 4: (a) Northing error histogram

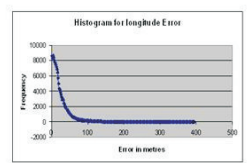


Fig 4: (b) Easting error histogram

Fig. 4

point as attributes. A trend surface for each component of error is then constructed (See Fig. 3). The northing error varies from 0m to 350m, and the easting from 0m to 300m. The maximum error seems to occur in South India–Kerala (see Fig. 3c). The statistical variation in the errors is shown as histogram in Fig. 4.

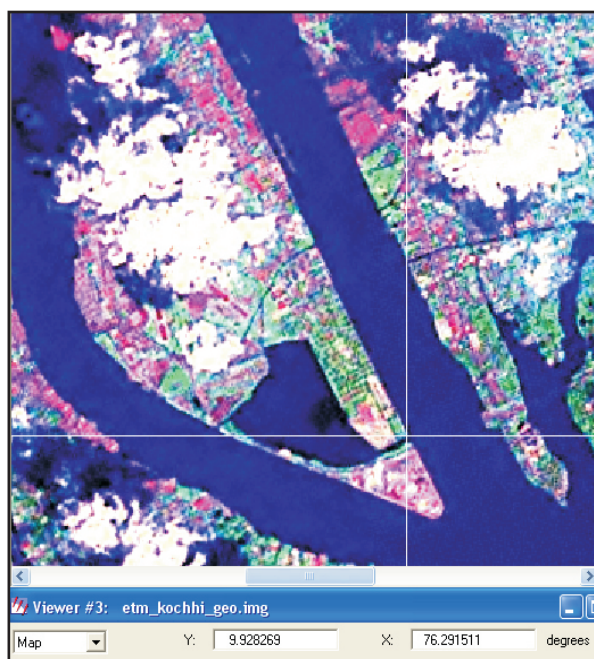


Fig. 5a CartoDEM and Google chip position locator

Both histograms show similar distribution where significant portion of the land mass reveal deviation of about 50m. However, a number of points also show deviation of the order of 100 to 300m and these occur in pockets (see Fig. 3-c-h). To compare with an independent source, a small portion in Cochin-Kerala is considered, having high degree of error. The Google imagery was

also examined. Figures 5a and 5b show three chips of the same feature along with their coordinates from ETM, CartoDEM ortho, and Google Earth. It is evidently clear that the ETM image has high planimetric error (300m) in this region, showing difference in latitude and longitude direction in third decimal with CartoDEM generated orthoimages and Google chip shown in figure 5a and 5b, produced with old and limited control.

Conclusion

ETM mosaic products are as reference in several RS and GIS related projects including urban and rural planning applications in India and other parts of the globe. The work done to generate ETM mosaic images are worth appreciating. For studying the behavior of the ETM products by UTM zones using 500 uniformly distributed ground control reference points for the Indian land mass regions, the present study took 13 ETM mosaics projected in four UTM zones using CartoDEM project generated orthoimages for evaluation. The error in the ETM+ products mostly varying in the range of 50m except in some scattered parts of India including Kerala, where the Error is more than 300 m. In addition, error is moderate between 50 and 200 m at some places in Gujarat, Rajasthan, eastern UP and Jharkhand; and moderately high in West Bengal. Even though the errors are less than 50 m most parts of the peninsula, but in some



Fig. 5b ETM chip position locator

regions errors above 50 m can cause internal distortions while evaluating or generating the above 1:50000 scale products using these ETM mosaics. The errors in the Kerala regions, which are in order of 300 m, can result severe impact in block adjustments leading to huge problems in the urban mapping applications. The histogram figures show that errors are beyond 50 m, a matter of serious concern. We conclude that the use of the ETM mosaics images for the urban applications for the regions shown in the figure-3c to 3-h is not recommended. Other ETM mosaics are good for 1:50000 and less than this scale mapping products for the Indian regions.

References

Li, R. (1998), "Potential of high-resolution satellite imagery for national mapping products." **Photogrammetric Engineering and Remote Sensing**, 64(2), pp.1165-1169

Daniel, E. Et al. (1983), 'Multiple scene precision rectification of spaceborne imagery with very few ground control points', **Photogrammetric**

Engineering and Remote Sensing, 49(12), pp.1657-1667.

Jon Dykstra (2002), Earth Sat Natural Vue2000™., **2002 A Global Landsat Image Dataset**

Kadota, T. and Takagi, M.(2002), "Acquisition method of ground control points for high-resolution satellite imagery", **Proceedings of the 23rd Asian Conference on Remote Sensing**, No. 173, November 25-29, Kathmandu, Nepal.

Dare, P. et al. (2002), "Digital Orthomosaics as a source of control for geometrically correction high resolution satellite imagery", **Proceedings of the 23rd Asian Conference on Remote Sensing**, No. 173, November, 25-29, Kathmandu, Nepal.

Compton J. et al. (2004), NASA's Global Orthorectified Landsat Data Set, **Photogrammetric Engineering & Remote Sensing**, 70 (3), pp.313-322.

(**K.S.S.Sekhar, Bankim Shah**, and **B.Kartikeyan** are working as Scientist/ Engineer, IAQD/SIPA, Space Applications Centre Ahmedabad-380015
Emails:sekhark@ sac.isro.gov.in)

Disaster Mapping and Management (A Participatory Approach)

B.K Ramprasad

Abstract

Any event may it be a road mishap or floods due to heavy rains or an earthquake or a building collapse could not be treated as a disaster unless it affects the life and property of the community to the extent that it is not possible to cope with it without outside help. Struggle for existence is a natural/biological property of living organisms on the earth. For example, if there is a life threat to a particular species, it increases its productivity for survival. Similarly human beings and their communities have own mechanism to protect their lives and property in case of any eventuality. Looking for an external help from the administrative authorities by ignoring local community strengths or natural resistance to overcome such situation is meaningless when disaster occurs. Generally, the local people reacted first in the rescue operations prior to arrival of help and aids from government agencies when a disaster does occur. The present paper focuses on the role and importance of community participation to implement any disaster mitigation programmes for sustainable development. The indigenous knowledge provides us valuable information especially when data/information to use sophisticated technology based models used to generate inundation models of flood prone areas. This was clearly evident when the Tsunami took place in Andaman & Nicobar Islands in 2004; the survival rate was much higher in localities resided by the tribals than by the modern society. Certainly the local information from the community is the main source besides the other key sources viz. satellite imageries, relief, slope, land use, drainage, and demographic maps along with meteorological information and tidal records in case of coastal regions. Preparation of vulnerable maps for the respective localities through public participation will help the administration for an easy access to the site. Cartography plays an important role in preparing maps based on relevant data/information for better management to mitigate the loss.

Introduction

Disasters whether natural or man-made, cannot be predicted fully. But scientific evidences and study results can help us to mitigate the loss caused by the Event. "Hazard is the probability of occurrence of a damaging phenomenon within a specified period of time and within a given area. Natural disasters of various types are linked with each other. The frictional forces developed in the subsurface of the earth due to plate movement causes earthquake on land. If the same disturbance happened beneath the ocean, we call it as Tsunami. The heavy rains, whether it is a cyclone, tornado or a Katrina leads to floods in such regions. The monsoons of 2008 and 2011 caused devastating floods in Bihar, West Bengal, Andhra Pradesh, Punjab, Orissa, and Gujarat states.

Besides natural disasters, the human activities like construction of roads, bridges and dams as a part of infrastructure development also do cause disasters. For example, under the construction flyovers collapsed in Hyderabad and Delhi during 2008, causing a huge loss of property and life. The 2008 Bihar flood is an example of engineering failure. The toxic cloud that struck Bhopal 20 years ago provoked the sudden death of 7000 persons. Since then, another 15,000 persons died from diseases related to that accident. Worldwide, today more than 100,000 persons suffer from chronic diseases (Amnesty International Report 2004).

Government of India took steps by setting up disaster management departments in each and every State, besides carrying out public

awareness programs. The policies have been formulated with the help of experts from various fields. Some examples are the establishment of cyclone warning centers, and installation of Earth Quake and Tsunami warning systems. The Indian Meteorological Department has been promulgating temporal variations of climate to the public through its network of observatories all over India.

People are central to any program of sustainable development. In this context, administrative authorities alone can't handle the situation. Hence the participation of local people and their indigenous knowledge must be taken into consideration while formulating and implementing mitigation measures.

Public participation

Public participation is a generic term identifying, on the one hand, an ethical and democratic value, and on the other hand, a series of technical procedures, also called participatory processes. The basis of developing public participation is that every individual, or citizen, has the democratic right to take part in public decision-making processes affecting life. According to Iskoyan (1999), "in issues pertaining to the environment, the improvement of access to information and public participation in decision-making increases the quality of decisions made and of their implementation, contributes to the awareness of the public regarding environmental problems, [presents] the public [with] an opportunity to express its concerns, and ensures adequate consideration of such interests by public authorities".

In the last few decades, authorities have been indeed increasingly confronted with NIMBY ("not-in-my-backyard") syndrome situations. Such a local protest is likely to take place when inhabitants neighboring a project challenge or reject the change that it causes, arguing that it would induce negative consequences (negative social "externalities"), regarding their quality of life and living conditions. Such conflicts were likely to produce impacts at national level in

terms of public opinion and to have country-wide political costs. These conflicts also usually dealt with environmental issues (development of transport infrastructures threatening valuable biosphere areas, installation of industrial facilities, noise in dwellings close to airport areas) and often involved active and/or legal response from environmental non-governmental organizations (NGOs) and similar citizen-based networks. Such reactions, at both local and national levels, to public projects that had been designed, approved and implemented by elected and/or appointed authorities, confronted governments with a concept increasingly shared by the public. This concept dealt with the limits of centralized decision-making in democratic countries. Whether this non-compliance comes from a wrong definition and identification of the public expectations or from the lack of solutions and options for the public to choose from, would need to be analyzed in each case. The idea remains that the "voice of the people" (Fishkin, 1995) was neither listened to nor taken enough into account in several public decision-making processes. In this context, and before we consider what might be the added-value of public participation in public decision making processes, we need to identify who (or what) the public is. Still, the definition of the public may be somehow different for two reasons. When dealing with natural hazards and with water-related disasters, we may need to distinguish "the public concerned" (e.g. citizens nation-wide caring for their co-citizens confronting a disaster threat or suffering from it, or in other words "national solidarity and empathy") from "the public at risk", that is communities directly experiencing natural risks and hazards, as well as disasters and emergencies. Secondly, it may sometimes not be relevant, to consider "the public at risk" as a homogeneous entity, e.g. because of socio-economic differences, as well as differences in cultures and beliefs, and in geographical distribution and settlement. As a consequence, such "sociological mapping" of the public at risk may enable authorities to identify distinct "

(social) vulnerability levels” to hazards and disasters, in order to design and implement tailored community-based, or target-oriented, mitigation policies, strategies, and plans of action(Affeltranger,2001).

Community based hazard mapping

For better management one should have an idea about the geography, demographic details, infrastructural facilities available, contacts of responsible local administrative authorities, livestock details, road and rail network, means of transport and the details of rehabilitation shelters in a particular region. For putting all the information available at one place a map is required. The affective way of preparing these maps is the participatory approach, which helps to incorporate the indigenous knowledge and the historical background of the area though the public opinion.

A group of people representing all the sections of the society can participate in the preparation of these vulnerable maps.

The inputs from the local public will play vital role to map that particular region. The foremost important is the field survey, involving the representatives from various stake holders to collect the information from problematic areas by questioning the local residents, through conversation and visual observations. Secondly this field data will be plotted on a paper by all the representatives jointly. Finally this information will be analyzed and discussed within the local groups and responsibilities allocated for further course of action towards implementing mitigation measures. The output is the community based vulnerability map. Discussions on flood forecasting methods are discussed by the community. To carry out these activities the local self help groups should have some financial assistance that can be generated through public donations, from state government, general public, from the industries etc. This fund can be utilized for hazard protection structures, post hazard rehabilitation activities and to procure life saving drugs in case

of emergency for the local communities.

Indigenous Knowledge- an abundant resource

In spite of increased investments in the area of disaster management in recent decades the losses continue to mount. There is an evident gap between practice and policy. There is an urgent need to bridge this gap with adequate recognition of the domain of indigenous knowledge and local coping capacities. There is a strong need to recognize the potential of community knowledge and actions, and of switching to a bottom-up approach that uses appropriate community practice as the base for policy formulation. It was evident in the past, ‘indigenous knowledge’ is the basis of community coping practices that have helped vibrant community survive natural calamities over centuries. The Asia Pacific region is particularly rich in such bodies of knowledge. Ancient civilizations, a multi hazard content, frequent disasters, diverse geo-cultural communities and large population dependent on scarce resources, have all led to the evolution of very low cost ways of life that include indigenous knowledge and disaster risk reduction in a very strong yet inconspicuous way.

While such local practices are based on sound principles of interaction between humans and nature, the policy content for disaster management in most countries in the region has evolved from the governance domain. Most countries have tended to work with relief codes for delivering calamity relief. The emergency response systems based disaster management models adopted from the west have generally overshadowed the Disaster Risk Reduction aspects of disaster management and particularly indigenous knowledge within Disaster Risk Reduction. The recent initiatives for development plans in many countries in the region have recognized this limitation, but have so far been able to address it on a limited scale. Transfer of this knowledge to the next generations is the need of the hour. Experts

recommended the following criteria for transferable indigenous knowledge:

- Understandable to users,
- Implementable,
- Originated within communities, based on local needs, and specific to culture and context (environment and economy),
- Provides core knowledge with flexibility for local adaptation for implementation,
- Uses local knowledge and skills and materials based on local economy,
- Has been proven to be time tested and useful in disasters, and
- Is applied or applicable in other communities or generations,

Environmental conservation and natural disaster management are important in the livelihoods of indigenous people, living in hazard-prone areas and have built up, through thousands of years of experience and intimate contact with the environment, a vast body of knowledge on disastrous events. This knowledge is a precious resource to contribute to environmental conservation and natural disaster management in these regions.

To mark the International Day of the World's Indigenous People, the UNEP announced a unique programme drawing upon indigenous knowledge to deal with natural disasters. The project is implemented in the Nenets Autonomous Okrug and Kamchatka regions of the Russian Federation to document indigenous knowledge about early warning signs of natural disasters and cope with to lessen their impacts. The project is intended to raise awareness and enhance understanding of the application and use of traditional knowledge in natural disaster management. Similar initiatives are required in India where the indigenous knowledge is abundant.

The hunters, gatherers and herders interviewed in this study described how careful observation of the behaviour of animals, and of the appearance and colour of the sky, is used as early

warning of natural disasters. "When the dogs start rolling on their backs on the snow and the crows circle in flocks and then hide, a blizzard is coming," explained a hunter from Kamchatka. "If old reindeer run in the evening, it's a bad sign. They must be testing their legs before danger," said a reindeer herder from Nenets. Another reindeer herder, from Kamchatka, told the interviewers: "Last year birds predicted volcano ash, which is dangerous for reindeer. They say the cleverest bird is the crow.

Concluding remarks

India has a rich cultural heritage and indigenous knowledge which has been carried forward through generations. In good olden days there was no communication system to the interior places to provide weather forecast. The people had enough knowledge to forecast the weather for agricultural work, whether to fix time for sowing seeds, harvesting crop etc. They had traditional medicines to prevent the seasonal diseases. A study from Rajasthan revealed that the tribes in this desert region face many natural hazards, however, the people have developed a variety of measures to contend with these situations, such as growing drought resistant and early maturing indigenous crop varieties gathering a diversity of wild fruits and vegetables, wetlands cultivation, livestock diversifying and splitting, that have enabled them to survive climatic hazards independently, with little or no support from the outside world (Aparna Pareek *et. al.* 2011). The people are well aware of the disasters they face and in most cases had the knowledge and administrative structures, or social institutions to cope with them. Some of the predictions in climate using indigenous knowledge are as below:

Ficus species: flowering and generation of new leaves indicates near rainfall onset.

Butterfly: appearing many butterflies indicate early rainfall onset and also gives a prospect of good season.

Ants: appearance of ants indicate imminent rainfall onset and signifies a prospect for good

season.

Termites: appearance of many termites indicates near rainfall onset.

Frogs: when frogs start to make a lot noise, it indicates near rainfall onset.

Change in wind direction and temperature signifies imminent rainfall.

The similar beliefs and predictions observed in the African tribal communities as well. Not only in predictions but also in the use of medicinal plants for chronological diseases are similar with Indian practices. For example use of Cardammom, Tamarindus species, Lippia javanica, leaves of Melia azedaach and Aloe saponaria to cure various health disorders.

With the disruption of traditional lifestyles and settlement in permanent communities, it is a challenge to maintain the continuity of traditional knowledge through its transmission from generation to generation. One solution is to find new ways to ensure that this knowledge is not lost, including the development of products to preserve and disseminate traditional knowledge and incorporation of this knowledge into school curricula. The scientific results should be correlated with indigenous knowledge towards a better and sustainable management practice to mitigate the loss while disaster happening.

The design and the implementation of disaster mitigation strategies at local level is a complex task for appointed or elected authorities, for they have to cope with a high diversity of stakeholders. These stakeholders indeed show different perceptions and relationships to natural hazards, and reflect different socio-economic and socio-psychological backgrounds. This diversity and complexity also very often characterize urban areas indeed, where socioeconomic and cultural heterogeneity may be even more tangible than in rural areas. Implementing public participation in disaster mitigation decision-making processes may thus help local authorities to develop mitigation

strategies that will both fit into the local context and answer the social expectations of differing population subgroups as regards disaster mitigation. Urban areas appear to be systems with a complex “social morphology”, and cities often turn out to be places where socio-cultural and socio-economic differences, changes and conflicts are exacerbated and developed. Implementing public participation in disaster-related decision-making processes may thus help local authorities to develop mitigation strategies that will both fit into the local context and meet the value system of the people. This may also improve the level of capacity-building and the response capacity of communities confronting natural disasters.

Communities often confronted with natural hazards may have developed over the years a so-called “culture of disasters”. Public participation is expected to turn this culture into a culture of risk, making individuals rationally aware of risks and ways to mitigate them. A culture of risk may then lead to a culture of prevention/mitigation, enabling community members to take part to their own disaster capacity building processes at local level, or in a more efficient and coherent way.

In India, the National Disaster Management Authority (NDMA), a national level professional and technical body of experts, should work in the direction so that policies are made in a manner that government agencies work together with the people towards sustainable development rather than working for the people. Besides scientific studies and experiments, the indigenously knowledgeable people should be taken into consideration and correlate their experiences and ways and means of risk management to be formulated by conducting project studies in the disaster prone regions whether the issues of rural or urban concern.

References

1. Affeltranger, (2001), “Public participation in the design of local strategies for flood mitigation and control.

2. Aparna Pareek and P.C. Thrived (2011), "Cultural values and indigenous knowledge of climate change disaster prediction in Rajasthan, India", **Indian Journal of Traditional Knowledge**, 10(1), pp 183-189.
3. Fishkin, J.S. (1995), **The Voice of the People**, Yale University Press, New Havens.
4. Iskoyan, A. (1999), **Manual on Public Participation in Environmental Decision-Making**", EPAC, ABA/CEELI Project, Yerevan, Armenia, p.67.
5. RAIPON- Russian Association of Indigenous Peoples of the North <http://www.raipon.org/>

(**Dr. B.K.Ramprasad** is working as Principal Civil Hydrographic Officer, National Hydrographic Office, Dehradun-248001

E-mail:bkp1972@yahoo.com; inho@dataone.in)

Cartographic Applications and the Disaster Management

Dharam Singh

Abstract

Cartography, generally considered to be the science and art of designing, constructing, and producing maps, has emerged as an essential tool for a wide range of application areas. Among others, disaster management is one of the fields, where maps have enormous relevance and utility. In disaster management cycle the phases of response, relief, recovery, reconstruction and rehabilitation are greatly facilitated with the help of maps.

India is vulnerable to various types of disasters and hazards can be gauged from the following statement that more than 12 per cent of the total geographical area is prone to floods, 68 per cent of the net sown area is susceptible to droughts, 59 per cent is vulnerable to moderate to severe seismic activity (Zone III to Zone V) and the eastern coast as well as Gujarat coast are exposed to cyclone risk. Also, the sub-Himalayan and Western Ghats are vulnerable to landslides. In the present paper an attempt has been made to use conventional dynamic flood frequency analysis techniques to quantify flood hazards over the past fifty years.

Key words: *Cartographic Applications, Disaster Managements, Vulnerability*

Introduction

Today cartography, its cartographical products and techniques have the wide application in disaster management. In fact, it would not be an overstatement to say that disaster management cannot be undertaken without the use of cartography. Before proceeding further, it is important to discuss what is cartography? Cartography is generally considered to be the science and art of designing, constructing, and producing maps. It is also treated as a science of human communication. Map is the most potent cartographic tool. Map is defined as a representation of a portion of earth's surface in a two-dimensional depiction. Accordingly, mapping denotes the making of a map i.e. setting out various physical geographical features on a map. The mapping of disasters for their effective management is greatly helped by cartography.

According to International Federation of Red Cross and Red Crescent Society, "Disaster management can be defined as the organization and management of resources and responsibilities for dealing with all

humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters".

Disaster management is a process or strategy that is implemented when any type of catastrophic event takes place. Sometimes referred to as disaster recovery management, the process may be initiated when anything threatens to disrupt normal operations or puts the lives of human beings at risk. Governments at all levels as well as many businesses create some sort of disaster plan that make it possible to overcome the catastrophe and return to normal function as quickly as possible.

Objectives

The main objectives of the present study are to-

- (i) analyze disaster vulnerability of India,
- (ii) understand the types of disaster mapping techniques used in India, and
- (iii) provide a greater insight into relationship between cartography and disaster management.

Methodology

Methodology in simple words refers to the research techniques of a discipline itself. The philosophy of the discipline changes with time; its research technologies also undergo a change so as to meet the requirements of the widened subject matter.

For the purpose of this paper data, pertaining to different aspects and requirements of the theme, were picked up from the government agencies viz. National Disaster Management Authority (NDMA), New Delhi, works of different scholars academicians and research journals.

Disaster vulnerability and risk in India

The seismo-tectonics of India is unique. The Indian plate is colliding with Eurasian plate in north at Main Central Thrust (MCT) and Main Boundary Thrust (MBT). The Himalayan range is still rising due to thrust imparted by Indian plate moving towards north. This makes the northern part of India from Jammu & Kashmir to north-eastern India highly prone to seismic waves. India's climate has all extreme conditions, such as lowest temperatures in Ladakh and highest temperature in Thar, driest weather in Thar and wettest weather in northeast. The long Indian coast line is prone to the severe weather arising from ocean such as cyclones, tsunami etc. The dust storms and squalls are most prevailing severe weather phenomena in northern and north-eastern regions. The heavy rainfall during southwest and northeast monsoon seasons causes flooding. Thus, Indian landmass is prone to multiple (natural) disasters including seismological, meteorological, hydrological and geo-hydrological rising due to its typical topographical, geographical and geological features. Earthquakes, cyclones, floods and droughts are the major natural hazards faced in India. More than 12.0 per cent of the total geographical area is flood prone, 68 per cent of the net sown area is susceptible to drought and 59 per cent is vulnerable to moderate to severe seismic activity (Zone III to Zone V) and the eastern coast as well as Gujarat coast is exposed to cyclone risk. Also, the sub-Himalayan and Western Ghats are vulnerable to landslides.

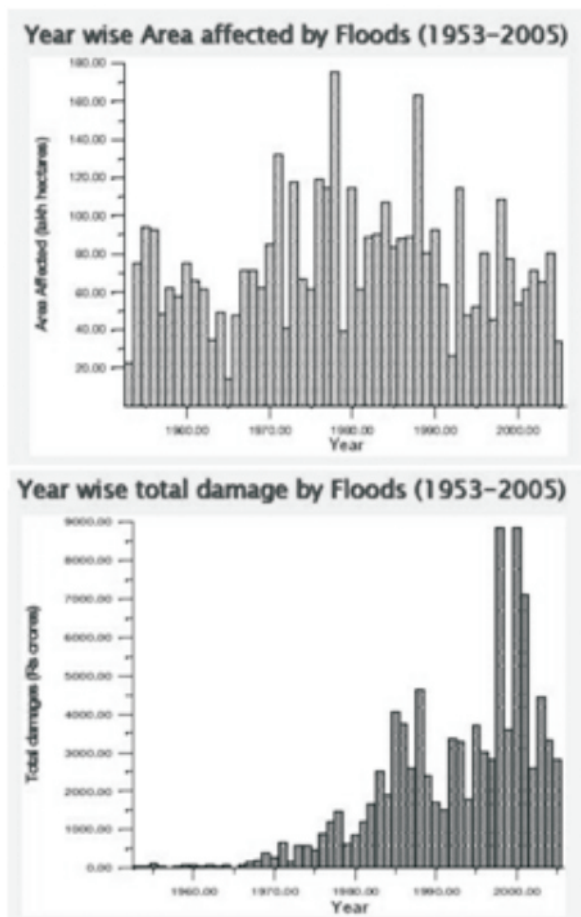
Geology-related disasters, such as earthquakes, tsunamis and volcanic eruptions, are generally among the most destructive in terms of human lives and property. In a global survey covering the period 1970-1997 prepared by the Swiss Reassurance Company, published in 1998 of the forty worst catastrophes in terms of fatalities listed, having caused over a million deaths, 48 per cent were inflicted by earthquakes. The fact that three-fourths of such catastrophes occurred in the ESCAP region (Economic and Social Commission for Asia and the Pacific) (and 87 per cent of the casualties) highlights the importance of this issue for the countries of this region.

Information on Disaster Mapping in India

In a country like India, natural disasters like floods and cyclones are fairly frequent. Earthquakes also occur time and again. The occurrences of such disasters, their intensity, the area of their occurrences and their impact has to be assessed, so as to have information/ data about the damages caused by them to the area/population specific or probable damages or impact likely to be caused. Proper mapping will be helpful not only for pre-disaster preparedness but also in rescue and relief operations with greater accuracy and speed. With the data/information collection, storage, retrieval becoming highly technical and scientific, new specialized techniques like geographical information system (GIS) are increasingly used for disaster mapping and these are proving to be very useful.

Techniques to read and interpret maps

Traditionally, maps have been prepared based on physical surveying. These maps are then presented as hard copies, i.e., they are printed on paper, using colours, symbols, labels and other drawing elements, to represent geographic facts. Such a map is on 'scale', which means that its dimensions are proportionate to the actual area it represents. A typical town may be conveniently represented on a scale of 1:20,000, meaning that one unit length on the map represents 20,000 unit lengths in reality. In other words, a distance of one cm shown on the



Figs. 1 & 2: Yearly flood affected area and damage caused by floods, 1953-2005

map represents 20,000 cm, or 200 m, of actual distance on ground. Various land uses, activities, zones etc., are shown with different colours, the colour code being explained in a legend, or key, on the map itself. Different structures or specific locations are shown using various symbols, which again are explained in the legend. A compilation or collection of maps is called atlas.

The usual problem with such maps is that they are tedious and time consuming to prepare, difficult to update and inconvenient to maintain. Therefore, now-a-days remote sensing is becoming popular as a means of collecting data for map preparation, and Geographical Information Systems (GIS) is being used for storage, analysis and retrieval. Under remote sensing techniques, maps are prepared.

We can use satellite data or aerial photographs, and then digitise and store these on computers using GIS software. Once this is done, they can be retrieved and viewed on the computer any time. They can easily be enlarged or reduced, and even printed in multicolour format.

Disaster maps usually show risk zones or disaster impact zones. These could include flood zone maps, seismic zone maps, industrial risk zone maps etc. A number of such maps may be overlaid on a base map of the area to give a composite disaster map that covers the risk of a number of types of disasters because many geographical areas are prone to more than one type of disasters. The vulnerability atlases of India contain useful maps of this type covering various disasters.

Explanation of flood hazards

Floods

Flood simply means inundation of land area with water for several days in continuation. Generally, floods are considered to be associated with rivers and people conceive floods as the outcome of accumulation of huge volume of water coming out of rivers through overtopping of river banks during peak discharge period. In fact, flood is an attribute of physical environment and thus is a component of hydrological cycle of a drainage basin. This shows that flood is a natural phenomena but it is also important to mention here that floods are also aggravated by anthropogenic activities. And as a matter of fact, today floods have become a human induced phenomenon.

Floods in India

Fig.1 shows the year- wise area affected by floods in India. During the recent years, both the frequency and intensity of floods have increased significantly which has further increased the average loss from floods. According to Fig.2, the country suffered an estimated loss of more than Rs. 9000 crores due to damage caused by floods in year 2000.

Flood hazard mapping

For flood hazard mapping, different types flood maps can be prepared.

A flood hazard map provides information about the return period associated with the areal extent of inundation for a reach of a river (Fig.3). The flood hazard maps are prepared delineating areas subjected to inundation by floods of various magnitudes and frequencies. These maps may serve as important tools in proper flood plain management. It is necessary that the area flooded by a particular flood is shown by suitable color scheme or designs on the map. In addition, explanatory notes, tables and graphs may also be provided with flood hazard maps to facilitate their use.

Flood inundation map

A flood inundation map provides information about areal extent of inundation for a reach of a river during a flood event when the flood water in the river overflows its banks and leads to the flooding of adjoining areas or flood plains. The flood inundation map for a reach of river may be prepared by demarcation with physical inputs i.e. by demarcating the various locations of the flood plains which get inundated during a particular flood, by hydraulic/hydrologic modeling and using the satellite data.

Flood risk zonation map

A flood risk zone map provides information about the risk associated with the damages caused or losses resulting from a flood event in a particular area or flood risk zone. Preparation of flood risk zone map incorporates the financial aspects and provides the actual inputs for flood insurance plans and for other purposes.

Flood plain zonation map

A flood plain zoning map categorizes various zones based on administrative legislations for planning and development of the flood plains for various purposes such as agricultural activities, play fields, industrial areas and residential areas etc. Preparation of flood plain zoning maps takes into consideration the inputs from flood

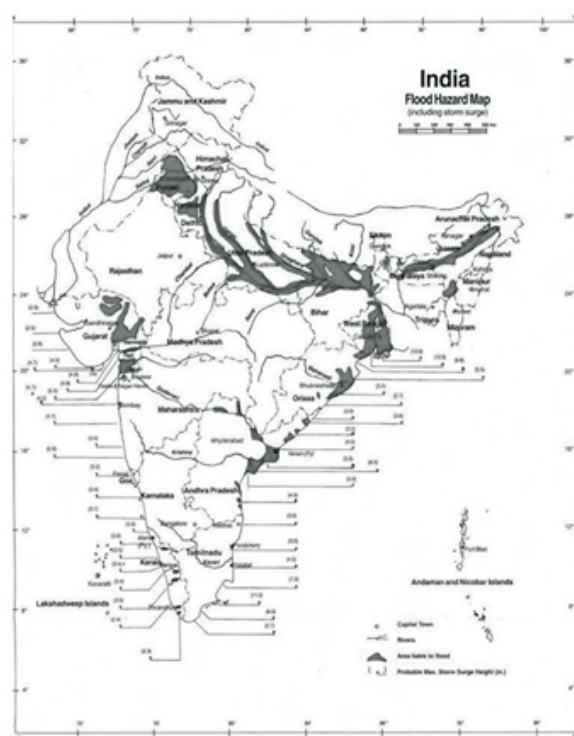


Fig. 3. Flood prone areas in India

inundation, flood hazard and flood risk zone maps.

Traditional techniques of floodplain mapping

Conventional dynamic flood frequency analysis techniques have been developed to quantitatively assess flood hazards over the past half century. These traditional techniques yield dynamic historical flood data which, when available, is used to accurately map floodplains. In addition to a record of peak flows over a period of years (frequency analysis), a detailed survey (cross sections, slopes and contour maps) along with hydraulic roughness estimates is required before the extent of flooding for an expected recurrence interval can be determined. This kind of dynamic approach requires extensive field surveys, with a network of gauging stations that can develop the data needed for precise risk assessments. Such extensive long term information is seldom available for river systems in less developed countries. To obtain hydrologic data, one must contact to the appropriate hydro-meteorological

agencies of government to secure available data and maps. Soils maps and geological maps often delineate floodplains. Topographic maps at suitable scales for the project should be available within the country. What is more readily available is information derived from static techniques which are capable of yielding information on flood hazard assessment.

Actions required

1. Flood data record to be collected for different river basins and flood returns period analysis and flood intensity analysis to be done.
2. The river cross-section and river hydraulic maps to be worked out (Fig-3).
3. The flood inundation map for different river gauge levels, flood return period and flood intensity analysis to be converted into flood hazards maps.
4. The flood hazards maps to be calibrated with actual flood records to arrive at flood hazard zonation map.
5. The early warning can be generated 72 hrs prior to actual event based on inundation and risk maps.

Conclusion

While concluding it can be stated that cartographic products are so useful that just a glance over them can easily reveal the extent and intensity of the disaster and also provide as insight for disaster preparedness and risk mitigation. Disaster maps usually show risk zones or disaster impact zones. These could include flood zone maps, seismic zone maps, industrial risk zone maps etc. A number of such maps may be overlain on a base map of the area to give a composite disaster map that covers the risk of different types of disasters because many geographical areas are prone to more than one type of disasters. The vulnerability atlases of India are useful maps of this type covering various disasters.

Bibliography

1. Misra, R.P., and Ramesh, A. (1969), **Fundamentals of Cartography**, Concept, New Delhi.
2. Govt of India (1997), **Vulnerability Atlas of Himachal Pradesh**, published from Building Materials & Technology Promotion Council, Ministry of Urban Development, New Delhi.

(**Dr. Dharam Singh**, Associate Professor & Head at PG Department of Geography, SCD Government College, Ludhiana (Punjab)
Email: dharamsandhu@gmail.com)

Evaluation of Indian National DEM from Cartosat-1 Data

S. Muralikrishnan, Abhijit Pillai, B. Narender,
V. Raghu Venkataraman, V.K. Dadhwal

Abstract

Cartosat-1 satellite was launched in 2005 with the payload comprising of a pair of along track panchromatic cameras with near-nadir viewing and forward viewing telescopes providing stereoscopic imaging capability with a base-to-height ratio of about 0.63 and spatial resolution of 2.5 m. CartoDEM is the National Digital Elevation Model (DEM) generated by the Indian Space Research Organization (ISRO) from the Cartosat-1 stereo data. The methodology used to produce the CartoDEM involved stereo-strip triangulation of 500 km strip pairs using precise GPS derived Ground Control Points (GCPs). This paper analyses the quality of CartoDEM in terms of absolute accuracy and comparison with other globally available DEMs like ASTER and SRTM in terms of drainage delineation.

Introduction

On May 05, 2005, the Indian Space Research Organization (ISRO) launched CARTOSAT-1 into orbit from its launch facility in Sriharikota, India. This satellite, the eleventh in ISRO's Indian Remote Sensing (IRS) series, is meant for stereo imaging for cartographic applications while offering improved spatial and radiometric resolution over its predecessors. The CARTOSAT-1 payload includes two imaging sensors: fore and aft, with a ground sampling distance (GSD) of 2.5 meters (see details in Table I); Both before and After sensors are push broom sensors tilted in along track direction by 26 and -5 so that each scene from the two cameras forms a stereo pair (Muralikrishnan, et. al., 2006).

Methodology-DEM generation

The methodology adopted to produce the CartoDEM involved stereo-strip triangulation of 500km strip stereo pairs using high precise ground control points, interactive cloud-masking, automatic dense conjugate pair generation using matching approach (Radhika et. al., 2007). Seamless homogeneous DEM is produced by TIN modeling of irregular DEM, interpolation for regular DEM generation and automatic strip to strip mosaicing. These automatically generated DEM tiles are further evaluated for quality and tile editing to remove

anomalies. The primary output unit is a tile of 7.5' X 7.5' extents with DEM spacing of 1/3 arc-sec, and co-registered ortho-image of resolution 1/12 arc-sec. However data sets are available at 1 and 3 arc-sec.i.e. 30m and 90m spacing at equator that are generated by sub sampling the original 1/3 arc-sec data. The CartoDEM is a surface model of elevation and covers land surfaces of India. It is comprised of tiles that contain at least 0.01% of Indian landmass are included. As per the design of CartoDEM, the DEM accuracy is 8m at LE90 and 15m at CE90 for ortho data.

Validation approach and methodologies

The DEM was validated with two approaches viz. absolute accuracy and 2. Drainage delineation in

Parameter Name	Fore (+26 deg)	Aft (-5 deg)
GSD (m)	2.5	2.5
Spectral Sensitivity	500 - 850 nm	500 - 850 nm
Quantization	10 bits	10 bits
Swath Width	29.42 km	26.24
Num of detectors	12000	12000
Detector size	7 x 7 μ m	7 x 7 μ m
Focal length	1945 mm	1945 mm
Field of View	± 1.08 deg.	
Integration time	0.366 ms	0.366 ms

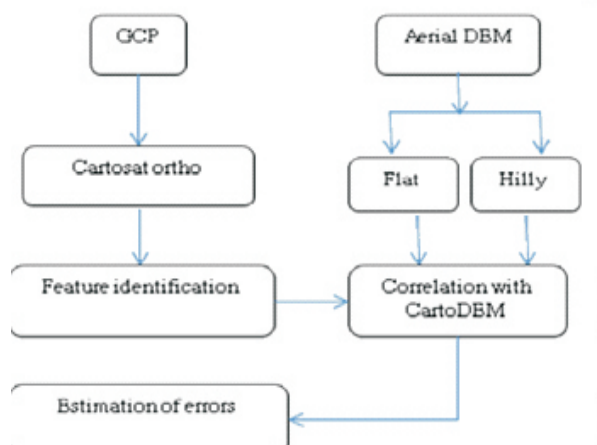


Fig. 1

comparison with ASTER (Kääb, 2002) and SRTM data sets (Van Zyl, 2001). The SRTM data was downloaded from USGS EROS centre and ASTER from Earth Remote Sensing Data Analysis Center (ERSDAC). The following section briefly describes the methodology adopted in evaluating data with the two approaches.

Absolute Accuracy: To study the absolute vertical accuracy of DEM's, three test areas were chosen in such way that it comprises topography of flat (coast), hilly and mixed area. The precise ground control points acquired from dual frequency geodetic survey grade GPS receivers have been used in relative positioning mode. The GCPs have the vertical accuracy of better than 50cm. For one test site i.e. Alwar, aerial DEM with vertical accuracy of 50cm is used as reference. The flow chart of validation is given in Fig.1.

Test Area: Jagathsinghpur, Orissa: The terrain is mostly flat, with the elevation ranges from 0 to 25m above MSL. The DEM at 30m and 90m is validated by comparing it with the elevations of ground control points. A total of 15 points were used for the present study (see Fig.2). The RMSE of CartoDEM30 and CartoDEM90 is 3.4 and 3.44m respectively and Linear Error (LE 90) is 4.7m (see Table-II)

Test Area: Dharmasala, Himachalpradesh: The study area is part of Dhamashala, Himachal Pradesh. The elevation in the study area varies from 650m to 4850m above WGS-84 ellipsoid. The DEM at 30 m and 90 m is validated by

comparing with elevations of ground control points. A total of 8 points were used in the present study (see Fig.3). The RMSE of CartoDEM30 and CartoDEM90 is 4.72m and 4.79m respectively. The LE 90 of CartoDEM30 and CartoDEM90 is 7m and 8m respectively (see Table III).

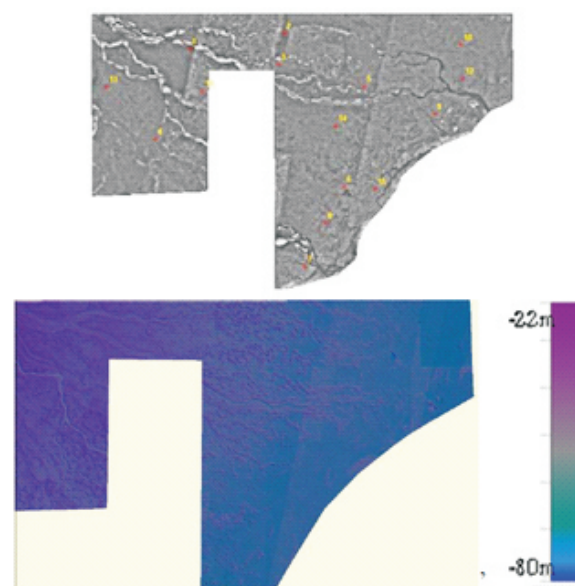


Fig.2. Distribution of control points and shaded relief of CartoDEM- Test Site: Jagathsinghpur

Test Area: Alwar, Rajasthan: The study area includes part of Alwar district, Rajasthan. It comprises both plain and hilly terrain. The elevation range in the study area varies from 150 m to 650 m above WGS-84 ellipsoid. For comparison purpose, DEM generated from aerial photograph is used as reference whose vertical accuracy is better than 50cm. The aerial DEM was generated at 30 and 90m postings. The DEMs are validated by taking independent checkpoints (ICP) on reference and CartoDEMs (see Fig.4). A total of 59 ICPs are used for validation of CartoDEM30 and CartoDEM90 postings. The RMSE of CartoDEM30 and CartoDEM90 is 4.7m and 5.5m respectively and LE 90 for CartoDEM30 and CartoDEM90 is 7.3 and 8.0 m respectively (see Fig. 5).

Drainage Delineation: Drainage delineation analysis has been carried out in comparison

Table 2
Elevation error with respect to GCPs

Sl.No	Residual (m) on CartoDEM 30 (control point elevation – DEM)	Residual (m) on Carto DEM90 (control point elevation – DEM)
1	-3.69	-3.69
2	-3.63	-2.63
3	-0.29	1.71
4	-0.78	0.22
5	-4.04	-3.04
6	-2.47	-0.47
7	-5.10	-7.10
8	-2.27	-2.27
9	-1.45	-2.45
10	-3.71	-2.71
11	-3.68	-1.68
12	-4.76	-4.76
13	-3.96	-3.96
14	-1.21	-1.21
15	-4.83	-5.83

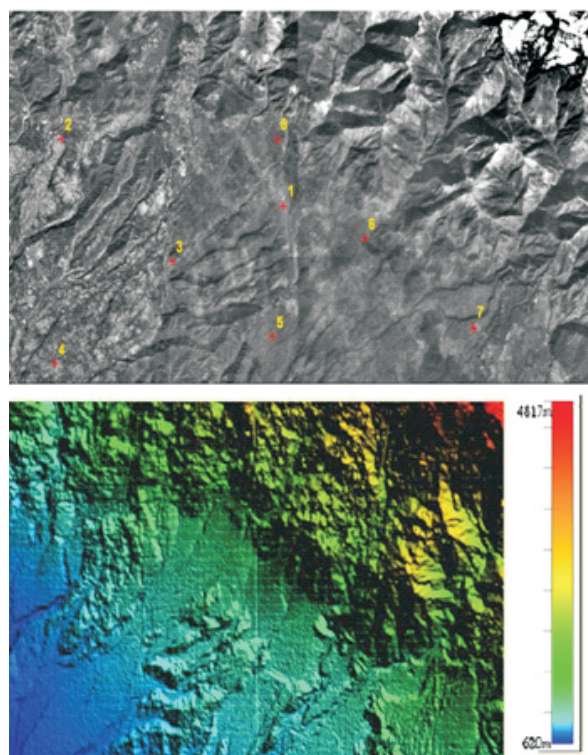


Fig.3. Distribution of Check points and shaded relief of CartoDEM – Test site: Dharamshala

with ASTER and SRTM for hilly data since hilly terrain allows easy understanding of flow

Table 3
Elevation error With Respect to GCPs

S.No	Residual (m) on CartoDEM30 (control point elevation – DEM)	Residual (m) on CartoDEM90 (control point elevation – DEM)
1	-6.14	-3.69
2	2.43	-2.63
3	-1.02	1.71
4	2.53	0.22
5	-10.55	-3.04
6	6.12	-0.47
7	3.41	-7.10
8	8.03	-2.27

direction. Primary objective of this study is to show the demarcation capability of CartoDEM. ArcHydro tool is used to demarcate watershed (both varying catchment and river flow) from the digital elevation data. By the stream definition factor, it is possible to reduce or increase the density of the streams. By this factor, streams have been classified as primary (minimum) flow, secondary (medium) flow and

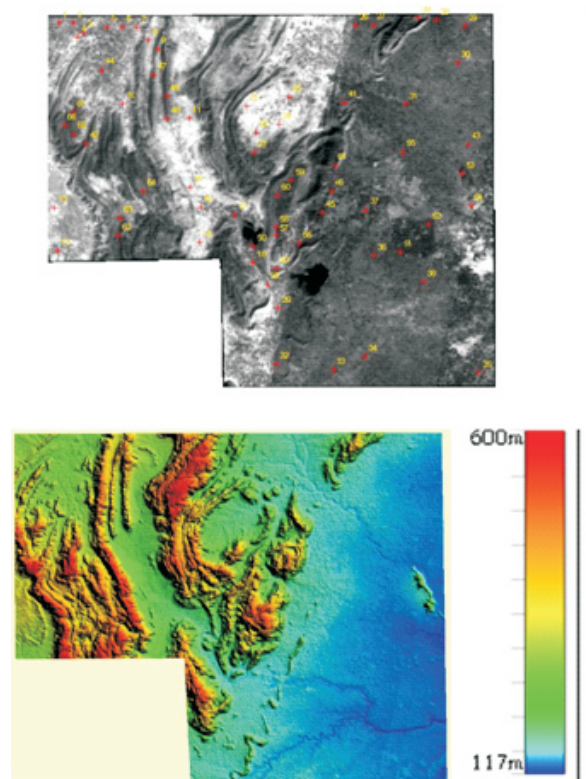


Fig.4. Distribution of Check points and shaded relief of CartoDEM – Test site: Alwar

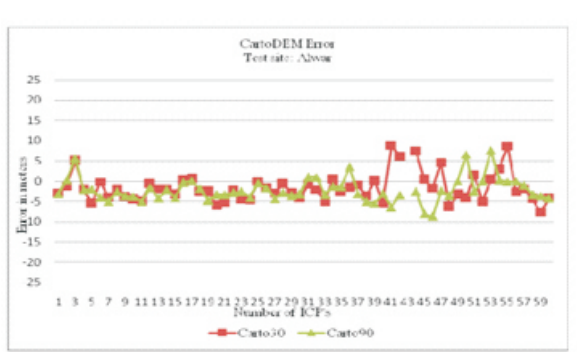


Fig.5. Elevation error With Respect To Aerial DEM-
Test site: Alwar

tertiary (maximum) flow. The results for SRTM (90m), ASTER (30m) and CartoDEM (30m, 90m) are separately derived using MSL (WGS-84 converted to EGM) as a common height reference and compared to understand demarcation results.

1) *CartoDEM Vs ASTER (30m spacing)*: From the Fig.6a&6b, it is observed that CartoDEM shows a clear demarcation of the catchment ridgeline. CartoDEM further shows a good demarcation of secondary flows while ASTER fails to demarcate the secondary flow direction. The smaller catchments obtained from CartoDEM are better demarcated and the tertiary flow shows a natural pattern whereas straightening of flow is observed in case of ASTER data with flow densely packed together that did not represent a natural flow. The statistical representation of drainage flow is given in Fig. 7a&7b. It is observed that the delineation of drainage length is more in CartoDEM compared to ASTER where shortening of drainage is present. The similar

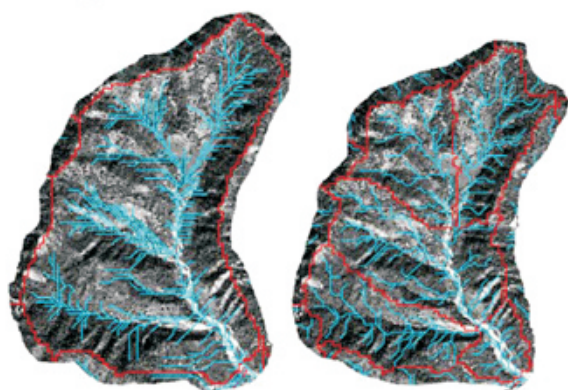


Fig. 6a. ASTER 30

Fig. 6b. CartoDEM 30m

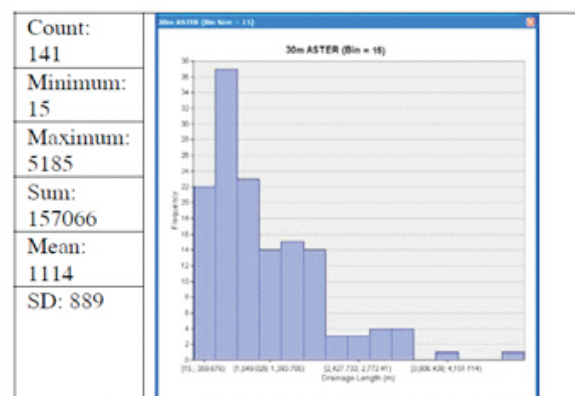


Fig. 7. Statistical representation of drainage flow –
ASTER

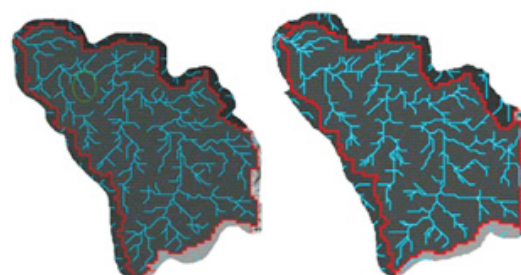


Fig. 8a. SRTM 90

Fig. 8b. CartoDEM 90

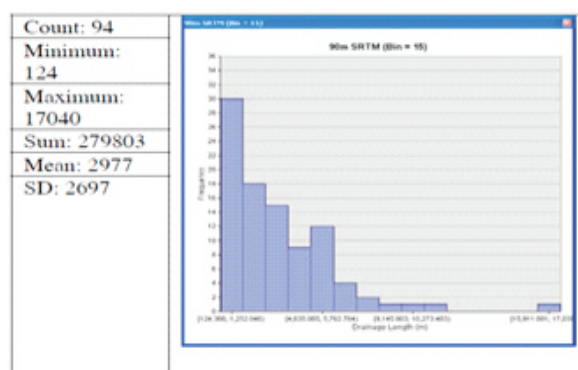


Fig. 9a. Statistical representation of drainage flow –
SRTM

pattern is observed in primary and secondary flow also.

2) *CartoDEM Vs SRTM (90m spacing)*: From the Fig.8a&8b, it is observed that both SRTM and CartoDEM 90m spacing is closely matching in terms of catchment delineation and flow depiction. The same result is observed and shown as statistics in Fig. 9a&9b.

Quality issues

The CartoDEM was generated with fully automatic s/w and hence the typical DEM errors

that occur in automatic algorithm like match point failure in hill top and large triangles formation in plain area were exists. Apart from this, mosaic errors across tiles due to local vertical error are also observed.

Related studies

ISPRS-ISRO Cartosat-1 Scientific Assessment Programme (C-SAP) provides more details about Cartosat-1 capability and its application potential (Jacobsen, 2006).

Summary and conclusions

Statistically, the CartoDEM meet its specification of vertical accuracy i.e. 8m at 90% confidence. Most of the tiles have substantially better than 5m accuracy at 1σ (67%). The CartoDEM contain anomalies and artifacts that may reduce its usability for certain applications, because they can introduce large elevation errors on local scales. However, for the generation of drainage pattern, 3-D perspective views, viewshed

analysis and vertical control points for further processing of various satellite data as well as reference for evaluation of coarser DEM's, this data would be useful. The DEM is complimented with corresponding ortho data and hence this will become a unique data set available for the user community.

Acknowledgement

The authors acknowledge with thanks the help received from Mr. A. S. Manjunath, Project Director, NRSC and Dr. B. Karthikeyan, Associate Project Director, SAC, Ahmeddabad, CartoDEM project.

References

- S. Muralikrishnan, *et. al.* (2006), **Geometric Quality Assessment of Cartosat-1 Data Products**, ISPRS commission IV, WG iv/9,
- Radhika, V.N, *et. al.* (2007), Robust Stereo Image Matching for Spaceborne Imagery, **IEEE Transactions on Geoscience and Remote Sensing**, 45 (8),
- Kääb, A., (2002), Monitoring high-mountain terrain deformation from air and spaceborne optical data: Examples using digital aerial imagery and ASTER data. **ISPRS J. Photogrammetry and Remote Sensing**, 57 (1-2), pp.39-52.
- Van Zyl, J., (2001), The shuttle radar topography mission (SRTM): A breakthrough in remote sensing of topography. **Acta Astronautica**, 48(5-12), pp.559-565.

K. Jacobsen (2006) ISPRS-ISRO Cartosat-1 Scientific Assessment Programme (C-SAP) Report– Test Area Mausanne and Warsaw – **ISPRS Commission IV**

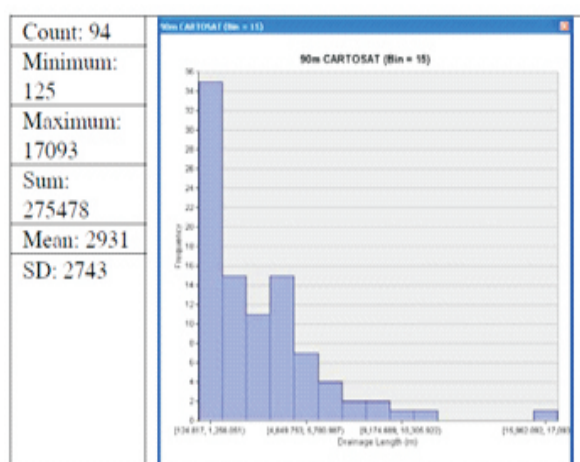


Fig. 9b. Statistical representation of drainage flow - CartoDEM

(Drs. S.Muralikrishnan, Abhijit Pillai, B.Narender, V. Raghu Venkataraman and V.K.Dadhwal are associated with the National Remote Sensing Centre, Indian Space Research Organization Hyderabad, India.

Emails: muralikrishnan_s@nrsc.gov.in, abhijitmadhusudan_p@nrsc.gov.in, naren_br@nrsc.gov.in, raghu_vv@nrsc.gov.in, director;@nrsc.gov.in)

SECTION II

MAPPING DISASTERS

Sikkim 2011 Earthquake: Lessons to Learn

Smita Bhutani, Tarun Vats

Abstract

Sikkim, landlocked, second smallest Indian state situated in the Himalayas experienced an earthquake of 6.9 moment magnitude scale (Mw) on September 18, 2011. The earthquake was felt not only in Nepal, Bhutan, Tibet, Bangladesh but also across the parts of north-east India. Sikkim was the worst-hit by this earthquake. In the present study an attempt is made not only to map the location of Sikkim in the context of vulnerability of the region to earthquakes; to give a brief estimate of the loss of life and infrastructure in the state; to know the timely aid and services provided by the government; to understand the participation of community in relief and rescue operations but also to examine the role played by human intervention in instigating natural disasters in geologically fragile areas of north-east India.

Introduction

An earthquake is defined as a motion of the ground surface ranging from a faint tremor to a wild motion capable of shaking buildings apart. The trembling of the ground is produced by the passage of seismic waves (term seismic means pertaining to earthquake). These waves move outward in widening circles from a point of sudden energy release known as focus. A large amount of energy is released in the form of seismic waves which shake the ground. Seismic waves usually lose energy as they move outward in all directions.

Earthquakes occur without warning and cause a loss of millions of dollars in destruction and numerous deaths. Earthquakes are the most unpredictable and devastating disasters.

Aims and objectives

In the present study, an attempt is made to map the location of Sikkim in the context of vulnerability of the region to earthquakes as well as to examine the responsibility of human actions in stirring up natural disasters in geologically fragile areas of north-east India. A brief account follows of the loss of life and infrastructure in the state and the timely aid and services provided by the Government, NGOs, and local community in relief and rescue operations.

Methodology

The study relates to the earthquake that shook the state of Sikkim on Sept. 18, 2011. Details of the disaster were collected from various sources like Government websites (mainly the website of Indian Meteorological Department (IMD), non-Government websites and newspapers published during the period 18th September 2011 to 14th October 2011.

Seismic Zones of India

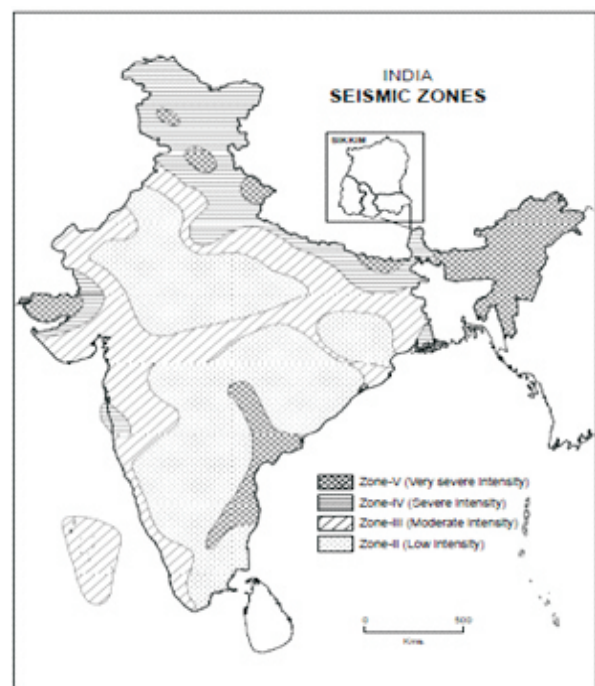


Fig. 1

Indian and Eurasian Plate Margin

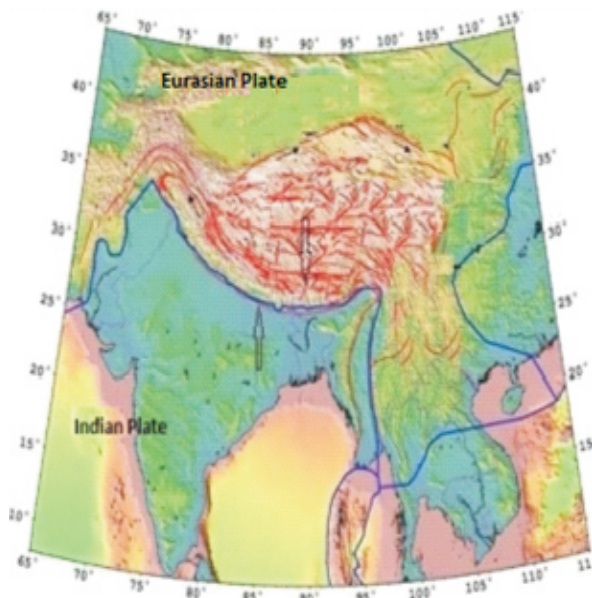


Fig. 2

Convergence of Plates in North-East India



Fig. 3

Vulnerability of the Region

In respect of vulnerability to earthquakes, the whole of Indian Territory falls into one or the other of the four seismic zones, (Fig 1) viz. Zone II (low intensity), Zone III (moderate intensity), Zone IV (severe intensity) and Zone V (very severe intensity). Sikkim itself lies in Zone IV.

Table 1

India: Major earthquakes in North-East

	Place of Occurrence	Date of Occurrence	Intensity of Earthquake
1	Cachar	10.01.1869	7.5
2	Shillong Plateau	12.06.1897	8.7
3	Dhubri	02.07.1930	7.1
4	Bihar-Nepal Border	15.01.1934	8.3
5	Arunachal Pradesh	15.08.1950	8.5
6	Nepal-India Border	21.08.1988	6.4
7	Sikkim	14.02.2006	5.7
8	Bhutan	21.09.2009	6.2
9	Sikkim-Nepal Border	18.09.2011	6.8

Source: Indian Meteorological Department Report 2011



Fig. 4

Source: Sustainable Economic and Educational Development Society Report 26.09.2011 (SEEDS) (www.seedsindia.org/ accessed on Sept. 26, 2011)

The Modified Mercalli (MM) intensity, which measures the impact of earthquakes on the surface, is the highest in Zone V.

The North east region of the country has experienced the largest number of severe earthquakes in the country. This region lies on the convergence of Eurasian plate and the Indian plate (Figs 2 & 3).

Geological structure of this region is fragile, tectonically active and seismically very sensitive, which makes it prone to earthquakes. This region is also characterised by some other important geological features like Tista lineament, Kunchenjunga lineament, Purnea-Everest lineament, Arun lineament and Dhubri fault in the southeast.

Some of the earthquakes experienced by this region are mentioned in Table 1. Three of these great earthquakes were with a magnitude of above 8 on the Richter scale.

Sikkim Earthquake: September 18, 2011

An earthquake of 6.8 magnitude (followed by three quick after shocks measuring between 4.6 and 5.7 on the Richter scale) struck the Sikkim-

Table 2
Sikkim Earthquake 2011: Deaths and Damage to Houses and Buildings

	Deaths	Estimated Homeless People	Number of Houses/ Buildings Damaged			
	Number	Number	Destroyed	Severely Damaged	Partially Damaged	Slightly Damaged
North Sikkim	59	20160	6000	Un	Un	Un
South Sikkim	01	2755	820	Un	446	1582
East Sikkim	13	20160	6000	Un	9000	Un
West Sikkim	04	18170	1679	5327	8342	Un
Total	77	61245	14499	5327	17788	1582

**Un - Unknown*

Nepal border area on September 18, 2011 (Fig 4). This earthquake caused widespread damage to people and buildings (Table 2).

The epicentre, located in Kanchenjunga conservation area was 19.6 kilometre in depth and 64 kilometres north from Gangtok, the capital of Sikkim. Sikkim was the worst-hit by this earthquake though earthquake was also felt in Nepal, Bhutan, Tibet, Bangladesh and parts of north-east India.

Casualties and Damage in Sikkim Earthquake

The total number of deaths occurring in Sikkim due to the Sept 18, 2011 earthquake was 77 and the North district was marked by the highest number of deaths and in South district, only one death was recorded (Table 2).

Table 3
Sikkim Earthquake 2011: Damage to Schools and Hospitals

District	Schools			Hospitals	
	Destroyed	Partially Damaged	Slightly Damaged	Destroyed	Damaged
North Sikkim	Un	Un	Un	7	Un
South Sikkim	21	41	68	Un	Un
East Sikkim	201	Un	Un	23	Un
West Sikkim	64	Un	Un	Un	Un
Total	286	41	68	30	-

**Un – Unknown*
State Government of Sikkim Report (26 Sept, 2011).

Rescue and Relief Operations

Rescue and relief operations were strenuously carried out by National Disaster Relief Force (NDRF), under the direct control of National Disaster Management Authority (NDMA);

Indian Air force; Indian Army; Border Road Organization (BRO); ITBP; State Administration; State Police; NGOs and local people. Ten teams of NDRF were involved in rescue operations. Out of ten, five teams were from Delhi in which 176 rescue officers, 21 section officers, 2 medical officers were included. Five rescue teams were from Kolkata including 181 rescue officers, 15 section officers and 1 medical officer. To provide better health facilities a team of 20 specialized doctors, 7 anaesthesia, 4 surgeons, 5 neurosurgeons was also sent on the affected/target areas. Indian army and air force sent their 5500 army persons, 927 ITBP, 5 cargo planes and 18 helicopters (Microfinance Monitor Global News, 2011). Ninety affected villages were served by these rescue teams. Two women officers were leading the air force rescue operations (IANS, 2011). State Government of Sikkim opened 11 relief camps in which 2700 people were sheltered in army camps and 550 people were provided shelter in ITBP camp (Pengong).

Rescue and relief operations started with the efforts of BRO which repaired Siliguri-Gangtok NH 31 A and cleared it from landslides. Indian Army personnel contributed significantly by restoring electricity and communication links. Women pilots of the IAF worked actively for rescue operations. Essential services and commodities including arrangements for shelters, medicines, doctors, torch lights, gumboots, blankets, tents, stoves, tarpaulins etc. were delivered to most of the villages affected by the earthquake. The affected people were also provided with food, water and medical treatment. NDRF, ITBP personnel reached remote areas to disburse relief measures. Medical teams, comprising doctors, medicines, were deployed by the government of India. Food packets were air-dropped. Ex gratia grants were announced for the families of the dead and injured. A grant of Rs 50 crore was announced by the government (Sikkim Special, 2011).

Inclement weather, heavy rains, landslides, falling boulders, hostile terrain, lack of infrastructure, however, hampered the search

and rescue operations in the earthquake affected areas.

Delayed Rescue of Stranded People in Upper Reaches

Thousands of people and workers remained stranded in the upper reaches of the Himalayas for days. Relief did not reach many villages even after weeks of the tragedy. Important roads like Chungthang- Lachen (22kms), Chungthang- Lachung (24 kms) remained blocked even five days after of the earthquake. About forty foreigners were reported to be missing/ stranded even after 3 days of the tragedy.

Government had come under severe criticism for lack of preparedness and clumsy handling of relief efforts.. National media gave a lukewarm response to this tragedy while other less important news items were given more importance. The aid provided was late and not sufficient.

Human Actions and Disaster Losses

i) Interference and Exploitation of Nature: Disaster Management Act 2005 had a vision of building a safe and disaster resilient India by developing a holistic, proactive multi-disaster resistant country with technology-driven strategy through a culture of prevention, mitigation, preparedness and response. Complying with the guidelines of the Disaster Management Act, 2005, a State Disaster Management Authority for the state of Sikkim and District Disaster Management Authority for each district of the state were constituted.

In view of the strategic location of the state in the high risk zone of seismicity, the Disaster Management System of the state assumes special significance. Unfortunately, it still needs to be strengthened intensively. Construction of hydel power projects and high buildings; absence/lack of basic infrastructure; unplanned urban development have contributed largely not only to inducing or accelerating natural disasters like earthquakes but also impeding relief and rescue operations in the event of a disaster.

ii) Construction of dams and projects: The Central Government's "Master Vision" identified north eastern region of India, where Sikkim is located, as India's "future powerhouse" by building approximately 170 dams in the region. Teesta river in Sikkim is used extensively for dam building. As the Himalayas form a chain of young mountains as a result of the collision of the Indian plate with Eurasian plate, the government of West Bengal Committee on Landslides conducted a study of the movements of the tectonic plates in 2000 (Hindustan Times Darjeeling, Sept 21, 2011). The Government Committee of Experts made strong recommendations. As the river Teesta originating in Sikkim flows in north-south direction and the Himalayan fault lines lie in the east-west direction, it was strongly recommended by the Government Expert Committee that the presence of multiple dams on the river Teesta and its tributaries could either induce or accelerate earthquakes. It further recommends that no constructions should be allowed on the rivers and a study should be conducted by geologists into the recent quake and on the dams which induced seismicity. Under Teesta Low Dam (TLD) around 35 hydel power projects have been identified for creating a capacity of 332 MW power in four stages. The first two stages with 100mw capacity are in Sikkim. The recommendations of the land slide expert committee 1998 included, "more devastation can happen any day. It is time the public woke up and pressurized the government to act more reasonably. Electricity in lieu of lives is not a very human option", (Hindustan Times Darjeeling, Sept 21, 2011). Ironically, Lower Subansiri Project (2000MW), the country's biggest hydro-power project in Arunachal Pradesh, at a distance of less than 600 kms from Gangtok, is already under construction. Many expert committees have already raised issues of threat from Lower Subansiri Project due to its location in seismic Zone V. In view of the expert opinion on the subject, due caution needs to be taken in the matter after thorough investigations.

iii) Absence of earthquake-resistant buildings: People in the hills live close to Nature, close to Nature's bounty but also to its boundless fury. In the Indian Himalayas, the danger is stark. The north-east region falls in Zone V which is seismically most active. In the last 100 years, this region experienced hundreds of tremors of varying intensity. More than 150 were with more than 6 magnitude on Richter scale. Nothing was learnt from these events as building and construction in such towns seems unmindful of the risks. National Disaster Management Authority has however, mandated all new constructions to be earthquake-resistant especially in seismic zone cities. The fundamental building code for earthquake prone regions is that (i) all structures should remain undamaged under minor to moderate earthquakes with a magnitude from 3 to 5.9; (ii) all structures should be without significant damage to the structure under a moderate to major earthquake of a magnitude from 6 to 7.9 and (iii) all structures should be immune against collapse under severe earthquake with a magnitude of above 8.

In Sikkim, permissible building height rules and degree slopes are flouted. No proper building laws are followed. None of the buildings in Gangtok, which draws lakhs of tourists every year, are earthquake resistant. Gangtok, the capital of Sikkim, had a clutter of concrete buildings situated on steep mountain slopes. In the earthquake, these buildings turned into concrete jungles. More than 90 per cent buildings in Gangtok suffered structural damage (Table 3). Legislation should be followed strictly. Earthquake resistance policy should be followed by private buildings also. Safety essentially lies in ensuring construction of quake-resistant buildings. Actually "quakes do not kill people, buildings do!"

iv) Inadequate infrastructure: Inadequate infrastructure in the context of roads, airfields, hospitals, primary health centres did not allow the relief measures to reach the interior areas of the tiny state of Sikkim even after weeks of the

earthquake. More than 20 villages remained cut off and more than 10,000 people stayed marooned (Daily Bhaskar, 2011). The availability of roads, airports, and rail heads in Sikkim is meagre because of its terrain.

Two National Highways, NH 31 and NH 31A, which connect Gangtok with Siliguri in West Bengal were damaged badly and thus severely affected rescue operations. The infrastructure handicap includes the absence of a landing site for larger planes that could have carried more material and evacuated more people. Advanced landing grounds and roads had not been developed in Sikkim perhaps for 'strategic' reasons. Strategic road from Gangtok to Nathu La Mountain Pass (above 14000 feet) connecting Sikkim with Tibet Autonomous Region of China remains physically cut off from the rest of the country. Air fields were missing particularly close to Mangan, Chungthang and Lachung, the worst-hit places. Mobilization of resources was poor. Men and equipment could not be moved to the worst affected areas. Local hospitals struggled to treat the critically injured. The hospitals lacked adequate facilities for medical investigations. Electricity in hospitals remained cut off for 48 hours after the earthquake (BBC News, 2011). Mangan, headquarter of North Sikkim, owned one hospital which was like a primary health centre. The nearest hospital, Singtham Hospital, was in East Sikkim, about 50 kms away. Such was the sorry state of affairs!

v) Unplanned urban development: The nature of hills in the region is fragile. These are vulnerable to landslides and earthquakes. Man-made drains in the mountains further weakened the hills. Many constructions are illegal and are of poor quality.

Main findings and suggestions

North east region of the country is prone to earthquakes as it is geologically fragile, tectonically active and seismically very sensitive. Sikkim, located in seismic zone IV with severe intensity was shaken on September 18, 2011 by an earthquake of 6.8 magnitude. Location of hydel power projects with 100 mw

under Teesta Low Dam (TLD); nearness to the country's biggest hydro power project i.e. Lower Subansiri Project (2000 mw); absence of earthquake resistant buildings; flouting of building height rules and building laws; inadequate infrastructure; unplanned urban development contributed not only to accelerating earthquake but also impeding relief rescue operations.

In the end, it may be mentioned that natural disasters which take a huge toll of life and leave thousands of people homeless and injured need to be managed properly. Construction and development activities in the regions which are vulnerable to earth quakes should be well-planned and well-executed. Human interference in geologically fragile environment needs to be monitored. Basic infrastructure needs to be developed according to rules and regulations not only for the development of the region but also to be properly utilized at the time of such disaster. NDMA and other relevant bodies need to play more meaningful role not only in providing relief and rescue operations and in handling such grave situations but also how better steps can be taken to avert such tragedies.

References

BBC News (2011), Anger Over Lethargic Response to India Sikkim Quake, September 22.

CATDAT (2011), Nepal/Sikkim Himalaya Earthquake-Extended September 27 Overview-Slow Rescue Due to Bad Weather, September 27.

Daily Bhaskar (2011), Sikkim Earthquake: Hundreds Still Stuck in Remote Village, Sept. 22.

Disaster Management Act (2005), **The Gazette of India**, pp. 7-10. Government of Sikkim Report (2011), State Government Sikkim, September 26.

Hindustan Times, Darjeeling (2011), Sikkim Quake May Have Been Induced by Dams Across Teesta, September 21.

Indian Meteorological Department Report (2011), Indian Meteorological Department, September 18.

Indo-Asian News Service (2011), Women IAP Pilots Shine in Sikkim Relief, September 24.

Manipurhab (2011), Earthquake Toll Rises to 92; 3000 Rescued in Sikkim, September 20.

Microfinance Monitor- Global News (2011), Sikkim Earthquake, 2011 Update as of 1P.M. Friday, September 23.

Sikkim Special (2011), Complete Coverage of

the Sikkim Earthquake and Aftermath, September 28.

Sustainable Economic and Educational Development Society Report (2011), Sustainable Economic and Educational Development Society, September 26, www.seedsindia.org/

Lee, R.V. (2010), "Darwin's Earthquake", **Articulo Especial**, p. 900.

(**Dr. Smita Bhutani** is a Professor and **Mr. Tarun Vats** is a research fellow at Department of Geography, Panjab University, Chandigarh.

E mail. pb6757@yahoo.com)

Flood Proneness and Agriculture Development in Kannur District, Kerala

(A Study based on GIS Technology)

M. Sulfikkar, O. Nadheer Bin Haneef, B. Sukumar and Ahalya Sukumar

Abstract

Flood, one of the most common hazards, occurs suddenly and unpredictably. Flood destroys crops, land, plantations and houses in a short time. It is a state of inundation or water logging along the river course, coastal area and other low lying areas during rainy days. The present study attempts to analyse panchayat wise flood prone area and its impacts on agriculture with reference to Kannur district, Kerala. The district stands second in terms of total cropped area in the state and third in net sown area in the state. Agriculture in Kannur is controlled by terrain, water availability and soil type. Since it is an undulating terrain, flood prone area analysis is very useful for agricultural planning. Data were derived from topographic maps, LANDSAT ETM satellite data, CESS publications and other sources. Maps prepared in GIS environment are of relief, drainage, soil, slope, drainage density, rainfall, temperature, land use/land cover, flood prone area and Panchayat boundaries. It emerged from data analysis that more than one-tenth of total area is flood prone. These areas are in valley fills, paddy fields and coastal low lands. Panchayats affected by flood prone areas are Cherukunnu, Ezhome, Kalliassery, Narath, Kannapuram, Pattuvum, Mattool, Cheruthazham, Kuchimangalam, Erancholi, Pinarayi and Dharmadom.

Introduction

Flood, one of the most common hazards, occurs suddenly and impossible to predict. Flood destroys crops, land, plantations and houses in a short time. It is a state of inundation or water logging along the river course, coastal area and other low lying areas during rainy days. In Kerala, riverine flooding is a recurring event consequent to heavy or continuous rainfall exceeding the absorptive capacity of soil and flow capacity of streams and rivers. This causes a water course to overflow its banks into flood plains.

Research Objectives

The main objective of the study is to conduct Panchayat level analysis of flood prone areas and its impacts on agriculture in Kannur district of Kerala with the use of GSI Technology.

Materials and Methods

Maps of relief, drainage, soil, slope, drainage density, rainfall, temperature, land use/cover,

flood prone area and Panchayat boundaries were digitized. Land use/cover map was prepared using Survey of India topographic maps and landsat ETM digital data. Digital image processing was used to prepare Land use/cover map. Digital maps were integrated in GIS environment for analysis

Study Area

Kannur district, lying between 11° 40' to 12° 48' N. and 74° 52' to 76° 07' E, is bound by the Western Ghats in east (Coorg district of Karnataka State), Kozhikkode and Wayanad districts in south, Lakshadweep Sea in the west and Kasaragod, the northern most district of Kerala, in the north. The district is divided into three geographical units: highlands, midlands and lowlands. The highland region, mostly mountainous, has major plantations agriculture in coffee, rubber, tea, cardamom and other spices. Timber trees like teak and veetty are grown in plenty. The midland region, lying between the mountains and the low lands, made

up of undulating hills and valleys, is an area of intense agricultural activity. The lowland is comparatively narrow and comprises of rivers, deltas and seashore. The Ezhimala peak (259.69 m) with characteristic N-S alignment is a distinct physiographic unit in the coastal plains. This is a region of coconut and paddy cultivation. The district has a humid climate with an oppressive hot season from March to the end of May, followed by the S-W monsoon that continues till September end. October and November form the post-monsoon or retreating monsoon season. The N-E monsoon extends up to the end of February, although the rains generally ceases after December. During the months of April and May, the mean daily maximum temperature is about 35°C. Temperature is low in December and January about 20°C. On certain days the night temperature may go down to 16°C. The annual average rainfall is 3438 mm and more than 80 percent of it occurs during the period of SW monsoon. The rainfall during July is heavy, district receiving 68 per cent of the annual rainfall during this season.

Analysis and Discussion

The study shows that 339.18 sq.km (11.45%) of the total area of the district is prone to floods. Among the 81 Panchayats and 6 Municipalities in the district, 75 Panchayats and 6 Municipalities are included in the flood prone areas. Major parts of Cheruthazham, Kalliassery, Madayi, Mayyil, Mattool, Narath, Ezhome, Kuchimangalam, Pinarayi, Kadannapalli-Panapuzha, Pariyaram, Chelora, Pappinisseri, Karivellur-Peralam Panchayats and Payyannur, Thaliparamba and Thalasseri Municipalities are identified as high flood prone areas (see Table 1 and Fig. 1). High flood prone areas are concentrated in valley fills, paddy fields and coastal low lands. Low flood prone areas are concentrated in high elevated portions.

Conclusion

Kannur district ranks second and third in total cropped area and net sown area in Kerala,

Table 1
Panchayats having maximum flood prone area

Sl No.	Panchayat/Municipality	Area in sq.km
1	Payyannur(M)	21.85
2	Cheruthazham	9.435
3	Taliparamba(M)	8.631
4	Kalliassery	8.254
5	Madayi	7.918

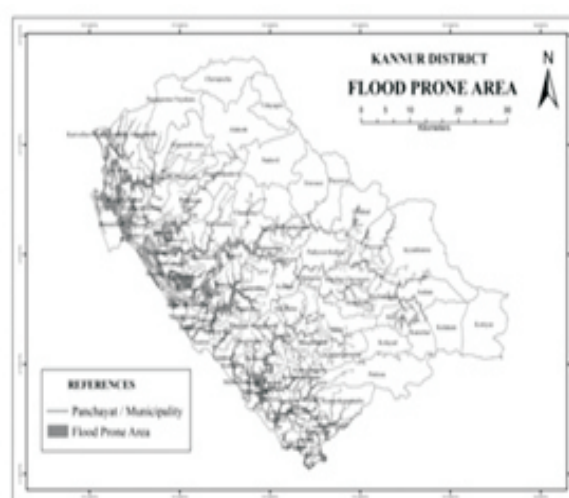


Fig. 1

respectively. Agriculture in the district is controlled by terrain, water availability and quality of soils. The soils get leached due to flood, leading to low yield of crops mainly, paddy, coconut, and areca nut. Due to flooding, the cashew plants are prone to insects during the flowering season. The study recommends for flood prone area mapping analysis for agricultural planning.

References

- CESS (2009), **District level Natural Hazard Zonation Maps of Kerala**, Centre for Earth Science Studies Trivandrum, India.
- CESS (2008) **Natural Resources and Environmental Atlas of Kerala**, Kerala State Remote Sensing and Environment Center, Trivandrum.

CESS (1984), **Resource Atlas of Kerala**, Centre for Earth Science Studies, Trivandrum.

ICAR (1997), **Resource Inventory, Cannanore District**, Indian Council of Agricultural Research, New Delhi.

Ahmed, Shaik Iftikkar (2009), "Consequences of Natural Disaster", **Asian Journal of Water, Environment and Pollution**,

Sukumar B & Ahalya Sukumar (2009), "Mapping the Disaster-Prone Areas for Mitigation: A GIS Solution for Kannur District, Kerala", In Reddy, K.R. et al. *eds. Natural Hazards and Disasters: Essays on Impact and Management*, Dept. Of Geography, Sri. Krishnadevaraya University, Anantapur, Andhra Pradesh, pp. 100-110.

(Sulfikkar. M, Nadheer Bin Haneef. O, Sukumar. B and Ahalya Sukumar are associated with Resources Analysis Division, Centre for Earth Science Studies, Akkulam, Thiruvananthapuram-695 031

E-Mail: sulfikkarm@gmail.com)

Forest Fire – a Boon or Bane?

Asim Kumar Goswami

Abstract

Forests cover about one third of our planet earth providing not only valuable raw materials, maintain biodiversity, protect land and water resources but also play a vital role in climate change mitigation. India has some 76.4million hectares of forestland with a variety of plant communities in different climato-vegetative zones. The ever increasing population in the tropics is creating intense pressure on forest land due to land conversion for agricultural and settlement purposes. Also a huge amount of the forest gets depleted due to shifting agriculture and the long term effects of repeated and uncontrolled wildfires. Although often harmful and destructive to the society, naturally occurring forest fires (wild fire) also play a useful role in the nature. They return nutrients to the soil by burning dead and decaying organic matters. They also act as a disinfectant, removing disease-ridden plants and harmful insects from forest ecosystem. Animals too in their dependence on vegetation for food and cover are variously affected by fire. The dichotomy in this respect need be properly addressed and perceived in an appropriate manner has been addressed in this paper.

Introduction

Forests cover about one third of our planet earth and provide us not only valuable raw materials, maintain biodiversity, protect land and water resources but also play a vital role in climate change mitigation also. India has some 76.4million hectares of forestland having a variety of plant communities in different climato-vegetative zones, ranging from tropical evergreen forests in the West Coast and Northeast to alpine forests in the Himalayas in the North. In between, there are semi-evergreen forests, deciduous forests, sub-tropical broad-leaved hill forests, sub-tropical pine forests, and sub-tropical montane temperate forests. The ever increasing population in the tropics is creating intense pressure on forest land for its conversion to agricultural and settlement purposes. In addition, a large amount of this forest deplete due to shifting agriculture (slash and burn techniques) and the long term effects of repeated and uncontrolled wildfires which accompany fuel wood collection, grazing and the harvest of minor forest products.

Although often harmful and destructive to the society, naturally occurring forest fires (wild fire) also play a useful role in the nature. They return nutrients to the soil by burning dead and

decaying organic matter. They also act as a disinfectant, removing disease-ridden plants and harmful insects from forest ecosystem. Canopy fire together with brushy undergrowth allows sun light to reach the forest floor and help grow new generation of seedlings.



Fig.1 A wild fire in Almora region, Uttarakhand.

But, in India, 99 per cent of wild fires are caused due to anthropogenic factors. Grazing, shifting cultivation and collection of minor forest products by villagers are the major causes of the forest fire. In the tropics and sub-tropics in particular dry weather and pro-long draught condition convert the whole cover of vegetation into highly flammable fuel stock; very high temperature associated with gusty winds up-hill

during day time set the entire forest stretch at a steady state, now what is needed is a spark – in the form of a lightning, arson or even a mere fag-end. Wild fire is a fire that's beyond control and thus is undesirable from the point of view of the forest managers. A prescribed fire is very much desirable as it fulfils requisite forest management objectives.

It's important to note that fire behaves differently in different ecosystems. This is due to the fact that forest fire follows a complex nature of interaction between fire and ecosystem. Flammable plants (containing oil and fat) burn more readily even if other factors are not so favourable, because natural selection has led to the development of such characteristics. The same can be proved by igniting the different litters of eucalyptus, pine and tropical hardwood leaves in the laboratory. Fuel chemistry is essentially more important- the more the crude fat content the more flammable the plants to fire. Certain plant communities require periodic fire to maintain themselves in the ecosystems and thus fire is considered as an essential and integral part of forest management practice especially in areas having dominant species like chir pine, long-leaf pine, teak, eucalyptus etc.

The use of prescribed fire for land-management purposes and the incidence of wildfire have increased substantially in the past 15 years (Neary *et. al.*, 1999). Frequent or seasonal fires, as a management tool, have been shown to have inconclusive results. Although some have suggested that repeated use of fire increases nutrient availability (Woodmansee and Wallach, 1981) others state that this practice can cause long-term cumulative negative effects on critical ecosystem processes. Frequent or regular burning can decrease surface OM and soil OM, alter C allocations in plants, reduced nitrogen (N) mineralization rates, decrease total N, change species composition of above- and belowground, and alter plant succession and evapo-transpiration rates (see Biederback *et. al.*, 1980; Blair, 1997; Daubenmire, 1968; Ojima, *et. al.*, 1994; Towne and Owensby, 1984)



Fig.2 Flammable fuel stocks, Kaziranga N.P. (May, 2010)

Fire produces a spectrum of severities that depends on the interactions of burning, intensity, duration, fuel loading (i.e. live and dead materials), combustion type and degree of oxidation, vegetation type, fire climate, slope, topography, soil texture and moisture, soil OM content, time since last burned, and area burned (Neary *et. al.*, 1999).

Fuel loading, referring to the aboveground plant biomass and the OM build-up range from <1 Mg ha per year in grasslands to >400 Mg ha per year in woodland and forest stands. Fire severity is determined by the interactions of climate conditions such as temperature, relative humidity, antecedent rainfall, and wind that affect the combustion process.

Effect of Fire on Soil and its Properties

The role of fire in increasing erosion and surface run off, and in changing soil moisture characteristics is a widely studied subject. Burned soils also show increased fertility. It has also been found that heating of soil to 96° C accelerated the growth and vigour of plants, while heating to 175° C delay germination, retard growth, and increase susceptibility to disease. Also, it is reported that heating soil increased germination by eliminating certain fungi pathogenic to seeds and seedlings. One very important factor controlling soil productivity is the available nitrogen; and there is little doubt that in most cases fire affects the quantity available. At the same time, fire may cause changes in other soil conditions which in turn stimulate or inhibit the nitrification process

carried on by soil and nodule bacteria and soil fungi.

Effect of fire on living organisms

The lower organisms are the most frequent living components of the forest floor, their destruction or increase as a result of fire is important. In some cases, fire may help in the control of plant diseases. It has been pointed out the value of fire in purging the forest of insect and fungus enemies, and in restoring vigorous, fast growing species. But contrary to this, fire may also favour the increase of disease by producing thick stands of the host plant and thereby induce multiplication and spread of the pathogen (Ahlgren and Ahlgren, 1960).

A change in soil bacterial population with burning would be expected, since burning frequently raises the soil pH, a factor critical in bacterial growth. Indirect evidence of an increase in bacteria is contained in the reports described earlier, that nitrification- a process largely dependent upon soil bacteria- often increases after fires.

Animals in their dependence on vegetation for food and cover are variously affected by fire. Deer, for example, are usually associated with post fire vegetation. Leopold (1950) pointed out that deer are most frequently found on the sub-climax forest characteristic of burned over areas, and that a climax forest does not favour their existence. Tiger habitat in India and fire management is intertwined because "the only apparent requisites of tigers for survival are some form of plant cover, water supply, and sufficient prey". Fire management is important because the habitat upon which tiger prey depend can be fire dependent in itself. The Indian one horned Rhinoceros depends primarily upon grasslands for forage. Management of these grasslands for rhinoceros often entails the use of fire (Landsberg and Lehmkuhl, 1997).

In India, Srivastava (1985) reports that almost one-third of the *Shorea robusta* forests, one-half of other forests (miscellaneous) are burnt every year. Forest utilisation is another important

reason behind fire occurrence, and especially the permanent presence of people travelling and living through the forested lands itself provokes a high probability of accidental wildfires (Goldammer, 1988) but the major threat of uncontrolled wildfires is caused by the widespread use of fire for facilitating and/or improving the harvest of the NWFPs (Non Wood Forest Product). In India, the most important example being the collection of "tendu" leaves used for cigarette wrapping. Generally this tree develops new shoots and tender leaves after being injured artificially or by setting the bush on fire, considered as a very old practice for providing better flush and more tender leaves early in the plucking season. The costs are also significantly lower than those of mechanical treatment for stimulation of coppicing.



Fig.3. Mahua forest, Padamdungri, Vyara Forest Division, Gujarat

Besides, the collectors of leaves and graziers, the collectors of edible fruits like "mahua" or *Madhuca indica*, are setting fires for removing the forest litter in order to make the freshly fallen fruits visible and also to facilitate collection. The use of fire by honey and wax collectors is yet another traditional practice widely used by the aboriginals or tribals of all continents. Annual low intensity fire is a conspicuous management strategy in virtually all floodplain grassland of protected areas in India, while it is primarily used to reduce fuel levels and to facilitate regeneration of desired species for wild ungulate communities.



Fig.4. Prescribed fire in parched grassland of Kaziranga N.P. (May, 2010)

Fire management capability

Fire management in India is supported in federal policy by the National Forest Policy of 1988 which lays down a strategy for protection of the forests including protection from the fire, and allows for the use of prescribed fire. A UN Development Programme project from 1984 to 1990 in "Modern Forest Fire Control" began the process of installing fire suppression in two Indian states. Fire management in India is receiving new attention under the 1995 UN Technical Cooperation Programme (FAO, 1995). Under this programme, a training course in forest fire management planning was formulated and regularly given to the Indian Forest Service Officers.

Joint Forest Management (JFM) Committees have been established at the village level to involve people in forest protection and conservation. At present there are about 36,165 JFM committees throughout the country, covering an area more than 10.24 million hectares (see Bahuguna and Singh, 2001; Kumar, 2001). These committees also take the responsibilities of protecting the forest from fires. For this purpose a Modern Forest Fire Control Plan is being revised and JFM is made integral component of the forest fire prevention strategy. The government of India has issued national forest fire prevention and control guidelines which include steps like identification of vulnerable areas on maps, creation of a database on forest fires, establishment of a fire forecasting system,

provisions for a crisis management group, involvement of JFM committees and efficient enforcement of legal provisions.

Observations and suggestions

The Indian subcontinent has a rich and diverse flora and fauna. The appropriate use of prescribed fire to enhance and preserve these natural systems is beneficial. Though the fire management system has been institutionalised at the state level with strategic inputs and cooperation from the Central government in the form of training, research, awareness etc, still availability of forest fire statistics in terms of area burned, value and volume are not appropriately maintained because of the fear of accountability. However FSI in 1995 estimated about 1.45 million hectares of forest lands are affected by fire annually. Another assessment put forwarded by Forest Protection Division under the Ministry of Environment & Forest, Government of India, is 3.73 million hectares, annually. The author suggest for effective mitigation of such disastrous wildfire. It is necessary to build up forest-division level comprehensive GIS data base. And the same data base to be used for generation of requisite maps - large scale aspect and morphological maps, soil types, soil moisture regimes, infiltration and run-off patterns, vegetation types (trees, bushes, grass etc), canopy density, fuel load, persistent and seasonal wind speed and direction, wildlife population, location of forest dwellings and nearby rural and urban settlements and so on. By overlaying the different ignition parameters (map layers) in efficient GIS environment potential fire-prone zonation maps can be prepared. Thus, GIS and satellite technology would be of great help in controlling forest fires through monitoring and early warning. But like other dynamic fields this data base too has to be updated continuously. As no single department can do this job efficiently, an integrated approach may be undertaken by involving the following major institutions in this process.

- Department of Space
- State Forest Departments
- Forest Survey of India

- Indian Meteorological Department
- Local Weather Stations
- Forest Research Institute
- National Bureau of Soil Surveys and Land Use Planning
- Survey of India
- University Departments
- PRIs and Tribal Councils
- Wildlife Institute of India
- Ministry of Environment and Forest
- State and District Informatics Centre

Acknowledgement

The author acknowledges with thanks the help from Ms Shinjini Goswami, M.Sc Student, European Forestry, University of Joensuu, Finland & University of BOKU, Vienna to write this paper and special thanks are also due to family members for their moral support.

References

1. Ahlgren, I. F. and Ahlgren, C. E. (1960), Ecological effects of forest fires. **The Botanical Review**, 26, pp. 483-533.
2. Bahuguna, V.K., and Singh, S. (2001), The forest fire situation in India. **International Forest Fire News** No. 26: 23-27.
3. Biederback, V.O. *et. al.* (1980), Effects of burning cereal straw on soil properties in and grain yields in Saskatchewan. **Soil Sci. Soc. Am. J.** 44, pp. 103-111.
4. Blair, J. (1997), Fire, N availability, and plant responses in grasslands: a test of the transient maxima hypothesis. **Ecology**, 78, pp. 2359-2368.
5. Chapman, H. H. (1936), Effect of fire in the preparation of seedbed for longleaf pine seedlings. **Jour. Forestry**, 34(9), pp. 852-854.
6. Daubenmire, R. (1968), Ecology of fire in grasslands. **Adv. Ecol. Res.** 5, pp. 209-266.
7. F.A.O. (1995), **Tropical Forestry Action Plan**. Rome, p. 159.
8. Goldammer, J. G. (1986), Technical and vocational forestry and forest industries training, Burma. **Forest Fire Management**. FAO Rome, p. 60.
9. Goldammer, J. G. (1988), Rural land use and wildland fires in the tropics. **Agro forestry Systems** 6, pp. 235-252.
10. Kumar, C. (2001), Community involvement in forest fire prevention and control: lessons from Joint Forest Management (JFM), India. **International Forest Fire News** No. 26: 28-31.
11. Landsberg, J. D. and Lehmkuhl, J. F. (1997), Tigers, Rhinos, and fire management in India. **Fire effects on Rare and Endangered Species and Habitats Conference**, 1995.
12. Leopold, A. (1950), Deer on sub-climax vegetational stages. **Trans. North Amer. Wildlife Conf.** 15: 571-580.
13. Neary, D. G. *et. al.* (1999), Fire effects on belowground sustainability: a review and synthesis. **Forest Ecology and Management** 122, pp. 51-71.
14. Ojima, D.S. *et. al.* (1994), Long- and short-term effects of fire on nitrogen cycling in tall grass prairie. **Biogeochem.** 24, 67-84.
15. Srivastava, P. C. (1985), **Work Plan for the Modern Forest Fire Control, Uttar Pradesh (1985-1989)**. Haldwani, p. 203.
16. Towne, G., and Owensby, C.E. (1984), Long-term effects of annual burning at different dates in ungrazed Kansas tall grass prairie. **J. Range Manage.** 37, pp. 392-397.
17. Woodmansee, R.G., and Wallach, L.S. (1981), Effects of fire regimes on biogeochemical cycles. In: Mooney, H.A. *et al.* (Technical Coordinators), **Proceedings of the Conference on Fire Regimes and Ecosystem Properties**, December 11-15, 1978, Honolulu, HA. pp. 379-400.

Dr. Asim Kumar Goswami, Ex-Research Officer, NATMO, DST, Kolkata, Address: Flat-4, Apt- Krishnakali, 356/35, S.K.B. Sarani, Kalindi (West), Kolkata-700 030,
Email: natmo.asim@gmail.com

SECTION III

MAPPING VULNERABILITY

Hazard Mitigation-Socio-Political Dimension

Rajbala, Dinkar Srivastava, P. S. Dhote

Abstract

The process of formulation of a policy on hazard mitigation is undeniably more socio-political than scientific. Socio-political condition of the region not only plays a vital role in formulation but is insidious even during adoption and implementation of hazard mitigation measures. Consideration of this aspect is imperative, as human civilized society is a socio political system and an effective hazard management programme has to recognize this fact and factor it into any technical plan of hazard mitigation. In addition, we here discussed the various issues and requirements involving affected stakeholders in formulation of policy of hazards mitigation and to end with a socio-political model suitable in conditions like Indian society if policies of hazards mitigation are to be implemented effectively by government agencies.

Introduction

Natural disasters are nature's revenge on man is an expression after used in meetings on environment and hazard management. It is a partly expression and may also be a reflection at the anguish of the speaker at the same times indiscriminate exploitation of mother earth however natural disasters have been taking place even before man came into the framework. He may have added to the list of disasters or what we call man-made disasters. Examples of man-made disaster that really come to mind are the nuclear bursting of Hiroshima and Nagasaki, Chernobyl nuclear leakage and Bhopal Gas tragedy. Relief or lack of it in all the cases was looked with the socio-political set up at that time and was country specific. Even in a developed country like U.S.A. politics is on the forefront. The destruction of more than 53,000 houses in Dale Country, Florida by a hurricane the country enacted strict building codes.

This episode sharply illustrates the intensely socio-political nature of natural hazard risk reduction. Socio-political conflicts arise because there are multiple social classes of peoples affected by hazards mitigation policies that disagree about standards such as building codes, state involvement, and having different social and economic preferences such as short-term profit. The foremost amongst them in any hazard mitigation preparation are homeowners,

business owners like developers, builders, insurers and, legislators and bureaucrats. Another bottleneck in hazard mitigation planning are multiple layers of government working nearly independent of each other and sometimes at cross purposes. Central Government makes policies which after limits the maneuverability of the State Governments. The State Governments in turn listening to even lower level of governance with their own ideology and local pressures, and social conditions pressurize the central authority to adjust its programmes to suit local conditions as to give them space so that they can react at least partly independent of central guidelines. Firstly the growing awareness of citizens has lead to their active association in policy preparation and acceptance. The classic examples being the agitation against construction of Teri Dam and problems regarding Narmada Dam ouster rehabilitation. We now have gathered a lot of information about natural hazard risk reduction despite of its erratic nature. The above discussion indicates that environmental hazards mitigation is a function of the following elements (Burton *et. al.*, 1978):

- (1) the physical environment;
- (2) the human environment; and
- (3) the adjustments we make to cope with the hazard.

In turn, hazard adjustments can be classified according to the four phases of emergency management (Pratar and Lindell, 2000): (1) mitigation; (2) preparedness; (3) response; and (4) recovery.

Hazard mitigation has a passive protection against the impact of anticipated hazards and measures include land use and building construction practices that prevent assets damage; however hazard preparedness entails proactive response after impact which include warning systems and emergency response plans (Lindell and Perry, 2000). Pre-disaster measures are undeniably most helpful, but governments are often reluctant to adopt risk reduction policies for repetitive hazards such as floods, draughts, landslides, earthquakes etc. (Burby and French, 1981; Lindell and Perry, 2000) mainly because the risks involved in developing hazardous areas are often ignored as public memory is short and the damage caused is forgotten against other socio-economic problems like crime and education which generally receive more attention, time, and money. Last but not the least, hazard-prone areas are often beautiful locales which makes them prime real estate which in turn creates pressures for more intensive use of land that already is developed and development of undeveloped more hazard prone areas. As development continues, hazard mitigation becomes increasingly difficult and costly (Pratar and Lindell, 2000). In spite, of all these impediments, successful adoption and implementation of hazard mitigation policies is possible if the right organizations are involved and they understand the political process well enough to implement effective policy. Local governments which are often neglected are the key to successful hazard mitigation policy because disasters strike at the local level. Natural disasters destroy property that is located in hazard-prone areas that have not been adequately designed and constructed to withstand extreme wind water, or seismic forces as the specific case may be. The key to reducing disaster losses is therefore a change in land use

and building construction practices. New structures ideally should avoid hazard areas and wherever it is not possible they must adhere to design parameters that can withstand extreme forces of nature. As the percentage of new but damage added each year is low hence it is important to strengthen existing structures and if that is not possible they should be removed. National governments are generally keen to reduce disaster losses because the disasters at macro level disasters are certainly but at the local level only a statistical probability that may as may not occur. The central government and its departments however own only a small fraction of the nation's investment in buildings and infrastructure, which are largely with the local government households and private sector organizations hence regulations governing land use and building construction practices should and might be established at the local level, in consultation with the central agencies as the state hazard mitigation policy can only be carried out at the local level. Many a time good hazard mitigation policies have proved ineffective because they were poorly implemented. Institutions and groups involved in policy adoption are often also are involved in policy implementation, but their roles may change as the policy process progress. Mahatma Gandhi was one of the first to recognize the importance of a singular community and he used to empower it for all activities pertaining to it – including hazard mitigation. He used a village as a model cohesive community and the need to use its dynamics in all development work. The presumptions of Mahatma Gandhi are probably were valid today than when he propounded them due to greater enlargement of society. For hazard mitigation this dimension can only be ignored at the cost of effectiveness of any proposed model of hazard mitigation.

Hazards mitigation: convergence of multiple issues

- i) Government-citizen interrelationship: Citizens have access to many points in policy-making processes in democratic political system. Elected people

As individuals, citizens can express their opinions by traditional media such as voting, letter writing, telephoning, and face-to-face meetings, as well as through more recent technologies such as faxing and e-mailing. In a democratic set up numbers count even at the cost of articulate scientific argument hence it is vital to involve large and politically active groups in policy processes. Like-minded stakeholders such as neighborhood associations, environmental action groups, social workers religious organizations and others need to be involved in the development and adoption of hazard mitigation policy. These groups can be mobilized for various forms of action: letter-writing or e-mail campaigns, sponsoring of petitions, and door-to-door canvassing on issues. Unfortunately, mobilization on hazards-related issues is infrequent. A recent survey of resident communities in earthquake hazards prone areas found very few respondents had taken any political action and only three per

Hazard mitigation policies and political will: The problem is thus how to get out the political agenda and remain there. One method could be to focus on a major disaster that has attracted public attention. An experienced disaster or a disaster within a neighboring community or country can be a powerful tool to start policy processes. The only commendably needed is perceived similarity in hazard vulnerability. In the case of hazard mitigation policy, this window is in the immediate aftermath of a disaster when the community is most receptive to policy changes as any delay causes shifting to other issues as it has repeatedly been proved that people's attention span is short. For example, Gujarat's and especially Kachchh resident's frequency of thought and discussion about seismic hazard virtually disappeared within three months of the Bhuj earthquake. Thus, by the time that disaster recovery is well under way, the policy makers are less likely to risk promoting any specific policies that could produce identifiable winners and losers. This is particularly important because the benefits of hazard mitigation can't be quantified and only show results when the next disaster occurs and are distributed across the either community whereas the costs of hazard mitigation are immediate easy to calculate, and are borne by a relatively small number of stakeholders. If a critical mass of stakeholders reaches consensus on a policy before a disaster, it will be easier to gain support for its passage when a disaster occurs. This well-developed policy alternatives and a clear strategy of action before the event takes place. In a survey regarding nature of the

type of shift that can occur in support for hazard mitigation policy, tabulated as a hypothetical distribution of stakeholder opinion before, during and a disaster, it is observed that, political support for hazard mitigation before a disaster is exactly balanced by political opposition, and most people are neutral (because they are inattentive, or uninformed or ambivalent about the issue). Immediately after the disaster, public opinion shifts in support of hazard mitigation, with twice as many strong proponents than before, however, there are no dramatic conversions to the cause of hazard mitigation. The additional strong proponents came from the ranks of the neutrals. Moreover, some of those who now are neutrals came from the ranks of the weak opponents, while the strong opponents have not changed their opinions at all. Long after the disaster there are slightly more weak proponents than weak opponents, but these generally will not have no significant impact because so few of them will take the time to pressurize the government or other policy making bodies. Strong opponents now exactly offset strong proponents, and a plurality of voters will be apathetic bystanders to the policy debate.

Hypothetical changes over time in stakeholder opinions about hazard mitigation policy

Table-1

Time (months)	Strong proponents	Weak proponents	Neutrals (%)	Weak opponents	Strong opponents
Before disaster	5	20	50	20	5
Immediately after disaster	10	40	35	10	5
6 months after disaster	5	25	50	15	5

Policy advocate

Political institutional agenda depends on many factors, but one of the most important factors is

whether or not there is a policy advocate for the agenda. This advocate sponsors an issue, make sure it stays on the agenda, and mobilizes community support for the relevant policies. The advocate may be an elected official looking for an issue to gain attention, build name recognition, and win reelection, or it may be that someone in a government agency or a relevant profession with a long-term interest in an issue.

The ideal hazard mitigation policy advocate should combine technical expertise in hazards with political expertise and personal commitment such as a geologist for seismic hazard policy. In Utah, America a professional geologist was elected to the Utah House of Representatives for the establishment of the Utah Seismic Safety Advisory Council (USSAC). Finding individuals with a combination of all the skills is rare. Therefore, successful hazard mitigation policy advocates must build coalitions to compensate for the areas in which their knowledge is meager. At the local level, city council, village panchayats might launch a crusade to make their community more hazard resistant by utilizing technical assistance from architects, engineers, planners and scientific associations.

A community should have emergency managers with the necessary knowledge and be must make an effort to link mitigation policies not only to urban development but also rural development and focus on environmental issues that are of interest to the neighborhood. In this he can take the help of associates that have become active in the aftermath of a disaster. In this way, technical specialists can exert upward influence upon policymakers by mobilizing a political constituency for more farsighted hazard policies.

It is important to recognize that there may be powerful interest groups who are antithetical to hazard mitigation. These groups will work actively to keep hazard mitigation off the agenda altogether. In some cases, there may be personal self interests even an opposition to any governmental activity affecting private land-use

decisions. A part of the reason for the demise of the any organization working properly for the cause of hazards mitigation is the changing political culture of the legislature. These groups disturb the hazard mitigation agenda after resort to an insider strategy i.e. they will get their work done in various government departments so that the other group is presented with a fact accomplice. An example of such insider strategy could be development of colonies in environmentally fragile areas where the developers get their plans passed by the involved agencies quietly as it generally involves local agencies. When state or central agencies are involved insider strategies became difficult because in this case there is a period of public notice during with period an aware group can file its objection.

News media is an important element in keeping an issue on the informal systemic agenda. Media attention that is oriented toward serious mitigation measures rather than sensationalism is necessary to the adoption of hazard mitigation policies. Such attention serves to bring the issue to the forefront and helps provide a political atmosphere favourable to the adoption of mitigation measures.

Policy advocates can help by using the media to put hazard mitigation on the agenda however they should use non-technical language as far as possible because most reporters and the constituency they are addressing are generally non-technical persons. An organization after its failure uses the media to mobilize relevant interest groups. While using the media, policy advocates should be aware of differences between electronic and print media, as well as the ways in which local media differ from their regional and national counterparts. In television reportage visually arresting images with brief explanations is most effective while the print media often provides more depth and analysis in their coverage. Local media generally tends to concentrate on personal reactions to events and the maintenance of community cohesion. Regional and national media on the other hand seek to inform the public by documenting

events, disseminating scientific explanations, and articulating opposing points of view in policy controversies. If long-term contacts are maintained, it is possible to get stories about hazard mitigation into the local media even during the period between disasters by connecting the issue to national and international as a disaster is occurs somewhere every day. Policy advocates can draw upon these events to emphasize the fact that a similar event can occur in the local area also. Unless such a connections is made hazard mitigation will be shoved off the agenda by other important issues and eventually die of neglect.

Mobilizing concerns

Mobilizing concerns depends on who is talking about them. For many years, emergency management in the India was framed in terms of the insurgency and confrontation with the neighbouring countries. Only recently have we shifted from Civil Defense to Comprehensive Emergency Management with hazard mitigation being on the systemic agenda. National disasters for many years have been referred to as “acts of God” i.e. events that are impossible to predict, let alone to prevent. The idea that disasters are at least partly a result of vulnerability created by human actions is being increasingly accepted and this has increased the prominence of hazard mitigation on the governmental agenda.

Political issues may not be immediately identifiable as political problems. Rather, but may exist as problems for sometime before the feasible strategies for coping with them moves them into the realm of public discussions as problems that are amenable to solutions. Thus, the first stakeholder group to frame an issue may seize a significant political advantage, especially if he is successful in linking the proposed policy with widely shared public values. As an example we can use the dispute between private land rights and publics (read government) rights to acquire its far common good. Those who support land-use regulations, as a means of promoting hazard mitigation must overcome the apprehensions regarding taking over by

reframing the issue of land-use regulation as one of balancing property rights with responsibilities that also must be accepted.

A variation on this strategy focuses on the externalities that are unfairly imposed on others when upstream development of private land creates risks for downstream property owners who may be forced to seek relief when disaster strikes. More forcefully, hazard mitigation advocates can frame the issue as one of ending public handouts to the few who are endangering their own property and that of their neighbours through unbridled development by documenting the problem of repetitive losses due to flood as a result of improper land use.

Framing Policy

Hazard mitigation policy advocates must have a set of policy proposals on hand before they attempt to shape the agenda, otherwise they run the risk that policy makers will find the issue too overwhelming and ignore it on the assumption that they cannot do anything about it. As the framing of an issue from arising out of a problem becomes widespread, different stakeholders will propose solutions giving rise to many policy alternatives at this critical stage policy formulation is a more technically demanding process than setting an agenda. Drafting of legislation is crucial to the success of the policy because laws that are hastily drafted and poorly worded can have negative effects on the implementation and the eventual effectiveness of the policy for this the first thing a community must do is to identify the hazards to which the community is vulnerable and assess the severity of each threat. Here, a substantial investment in hazard mapping can payoff in the long run by giving decision makers adequate facts to work with.

The next important step is that policies must be developed within the local socio political framework. It is crucial to define clearly the targets of a policy (i.e. what types of households and businesses), what activities are to be regulated (i.e. land-use practices and building construction practices), and what influence

mechanisms are to be used (i.e. social information, economic incentives, and legal penalties). With regard to the activities to be regulated, government may seek to avoid the construction of residential, commercial, or industrial structures in frequently flooded wetlands. Such wetlands serve important hazard mitigation functions by absorbing wave energy during hurricanes and retaining excess water during recovering floods or the policy may be directed toward ensuring that houses within floodplains are elevated, those near the coast have adequate wind resistance, and those near fault lines have seismic safety features.

To achieve the desired land-use and building construction practices, governments can use hazard awareness campaigns to make households and businesses aware of the risks they face and the suitable hazard adjustments for reducing their vulnerability. Information campaigns based upon voluntary compliance tend to be politically acceptable but have had limited success (Lindell et al., 1997). Alternatively, governments can motivate the adoption of hazard-resistant land-use and construction practices by providing economic incentives such as low interest loans or tax credits. Of course, the money for such incentives must come from somewhere and cash-strapped local jurisdictions may not be able to provide it. Finally, governments can require hazard-resistant land-use and construction practices as a condition for construction permits. Of course, verification of compliance requires on-site inspections, and the problems with such inspections are extremely well known.

A combination of risk communication, land-use planning, building codes, and hazard insurance can be an excellent way to address natural hazards (Burby, 1998). Whatever the combination selected, successful implementation requires that the policy be consistent with the community's capacity (e.g. tax base, agency capabilities) and commitment (especially the community values articulated in issue framing).

Activating community for hazard mitigation: When developing any public policy, care should be taken to include members of politically active stakeholder groups to ensure that their interests are considered. This is especially important in the case of hazard mitigation, because these policies cost the community either investment i.e. allocation of budgets or in terms of cost either in the form of opportunity in terms of land development projects, in order to obtain an uncertain future benefit in terms of reduced disaster losses. The typical groups that should be considered at the local level are those that have been mentioned already business leaders, elected officials, government agency staff, civic groups, religious leaders, and neighborhood association. All of these groups have a role to play in providing for community hazard mitigation. For example, business leaders may need to change their plans for expansion if it would mean encroaching on a floodplain and perhaps putting the community at risk from toxic spills during flooding. Their cooperation with the community's hazard mitigation program may be facilitated by information about the risks they are taking and, perhaps, economic incentives such as tax credits to help them finance mitigation measures such as structural elevation or relocation to a less hazard-prone area.

Considerations other than economics should be addressed as well. Agencies such as the public works department may be accustomed to dealing with hazards, but feel threatened when the decision-making process is expanded to include meeting with neighborhood groups. As anonymous bureaucrats, they may not be accustomed to being held personally accountable for technical decisions, and may equate citizen participation with needlessly looking for trouble. Conversely, some neighborhoods that are especially vulnerable to hazard impact may have a large proportion of lower income or ethnic minority residents, who lack knowledge about, or mistrust, the political system. All of these concerns need to be balanced because any perceived unfairness in

the policy itself or its adoption is likely to cause problems in the implementation phase. Even after a policy has been developed, there are many veto points at which interests can block the implementation of policies they consider undesirable. The key to getting policies adopted is persistence, because conflict is certain and some interests are likely to be threatened by any policy change. The successful policy advocate may spend decades promoting a course of action before seeing results. The necessary coalition building takes time, as does the legislative process. And even after a policy has been adopted, the story is not over because successful policy implementation is needed to ensure that hazard mitigation policies are effective.

Execution of hazards mitigation policy: Execution may be defined as those events and activities that occur after a policy is adopted, and

Table 2: Policy implementation variables

Tractability

Technical difficulties
Diversity of target population
Target groups as percentage of population
Extent of behavioral change
Required

Adequacy of statute

Clear and consistent objectives
Adequate casual theory
Initial allocation of resources
Coordination among implementing agencies
Decision rules of implementing officials
Recruitment of implementing officials
Formal access by outsiders

Non-statutory factors

Socioeconomic conditions and technology available
Public support
Attitudes and resources of constituency groups
Support from sovereign
Commitment and leadership skill of implementing officials

which include the administration of the policy and its actual effects. Implementation is crucial because all policies are implemented through “street-level bureaucrats”. Implementation of hazard mitigation policy depends substantially upon governmental structure. In India, the government has a federal structure, so strong state and local governments can support or thwart the implementation of central policy hence these institutions need to be closely involved in agenda setting, policy formulation, and policy adoption stages, in order to ensure that implementation occurs in accordance with legislative intent.

A widely used model of policy implementation (Table-2) highlighting specific variables and their interactions those produce varying levels of success in policy implementation (Mazmanian, and Sabatier, 1989).

Three types of independent variables are included in this model. First is the easier difficulty in achieving a solution to the problem. Hazard mitigation and socioeconomic development are both highly complex phenomena; so simplistic policies can cause more hence than good whereas comprehensive policies that satisfied all needs are virtually impossible to develop. Consequently, hazard mitigation policies usually are not only difficult to solve but also difficult to implement.

The second group of variables involves the ability to structure implementation. This is where statecraft and legislative skill are needed. One item very important here is a clear idea of how hazard mitigation policy will reduce casualties and property losses. The second component is a set of clear and internally consistent policy objectives that do not work counter to each other. This is extremely challenging because hazard mitigation policy must be carefully crafted to achieve a balance between clear directives for results consistent with the intent of the policy and flexibility so that the implementing agency has the freedom to adapt the policy to the varied situations encountered. Hazards mitigation policy is

especially prone to changes over time, so a significant amount of discretion for the implementer will probably be necessary. Another important variable is the allocation of governmental resources to hazard mitigation, which depends on the fiscal resources available at the time of policy passage and on the importance of hazard mitigation relative to other issues on the agenda.

The third set of variables affecting implementation consists of “non-statutory factors”. The first of these is the states socioeconomic condition and the level of technology available to address the problem. These are constraints over which policy makers have little control in the short term. However, these constraints can be relaxed by means of investments in sustainable economic development and technologies such as geographic information systems, both of which are available to local governments. The second variable is one that carries over from previous stages of the policy process—the level of public support for hazard mitigation policy. Public support tends to be cyclical, but it can be stabilized and even increased by persistent efforts to keep hazard mitigation on the systematic agenda. Public attitude affects the allocation of resources and the overall attitude and support from the state or local government. Finally, implementing officials need to develop high levels of managerial and political skills to ensure successful implementation of hazard mitigation policies. Keys to effective policy implementation are all applicable to hazard mitigation policy. For example, there is a mandate for land-use planning in some states, and we know that land-use planning can be a valuable tool in the mitigation of natural disasters. Landuse planning is not used as much as it could be, however, and the reason may lie in a lack of capacity on the part of the implementing bodies, or a lack of commitment to the use of land-use planning. Although the social environment of the India is stable, frequent turnovers of political leadership at the local level can hamper the consistent use of any

policy, including land-use planning for the mitigation of natural disasters. One factor that is critical to hazard mitigation policy – the hierarchical relationships among central state, and local governments. Shared governance among multiple levels of government can be broadly divided into four modes limited regulatory, general regulatory, mobilization, and collaborative these are distinguished by the form of partnership between central and state governments (general or limited) and the form of activity (regulatory or programmatic) involved. It is found that seismic safety was an example of the collaborative mode, which is characterized by general partnership and programmatic activity. Even though central involvement in earthquake mitigation has long history, few collaborative efforts to improve the states capacities for seismic risk reduction had been successful by the time of this study. The main problems drove from technical expertise which hampered contacts with state agencies. Problems arose between the central government and the states mainly over funding and control of projects.

Another important aspect of hazard mitigation policy is the effect of state mandates on local adoption and implementation of hazard mitigation policy. Previous research has examined the effect of mandate design on policy implementation and compared data from many surveys. Analysis examined the effects of five independent variables: mandate facilitating features, mandate controls, mandate goal clarity, agency capacity, and agency commitment. Two of the state mandate variables had a significant positive impact on the level of state implementation. These were mandate-facilitating features, which is defined by characteristics meant to increase local government commitment and capacity to address mandate goals; and mandate controls, which are the tools state agencies have to affect local government efforts.

Contrary mandate goal clarity had no significant effect. It seemed to be sufficient for agency personnel to have a clear and consistent view of

their duties, even if the statute was vague. The level of commitment by the state agency charged with implementing the mandate also had a significant positive effect, while agency capacity did not. This may be because, if an agency is strongly committed to a goal, sufficient capacity will be allocated to meet that goal even if other programs must suffer. Research confirmed the importance of an adequate level of technical expertise, low turnover of personnel, agency commitment to hazards mitigation, and the existence of adequate facilitating features and controls built into the mandate for the successful implementation of hazard mitigation policy. Further analyses addressed the factors that affect mandate strength. The most important factors affecting the strength and style of state mandates for natural hazard mitigation were the presence of a moralistic state political culture (as opposed to individualistic/traditional political culture), lawmakers perceptions of the seriousness of the hazard, and the political power of the target population. These results suggest that it would be useful for local government officials to impress upon the state legislators the importance of supporting their efforts at hazard mitigation and for affected populations to organize in order to increase political power.

In Indian scenario, the local government does not appear to have made it clear what was the enabling legislation upon which its policy was based. Secondly, the causal theory behind the policy was vulnerable to attack by locals. Thirdly, the intended implementing agencies (city and district officials) were opposed to, rather than supportive of the policy. Consequently, their leadership skills were used to mobilize a coalition of constituency groups – against the policy. Finally, there was a stable political and social environment, but the policy's opponents rather than its supporters exploited this more successfully.

Concluding remarks

Hazard mitigation policy is a major political challenge facing hazard-prone communities.

Policy adoption is a complex process that begins with the recognition of a problem and its emergence on the agendas of different social units—especially the various levels of government. Policy advocates must be skillful in framing hazard mitigation as an important issue to keep it on the agenda until adequate policy is formulated and adopted. The formulation of hazard mitigation policy is facilitated by focusing on an event such as a disaster, but must be initiated even before one occurs to ensure that feasible solutions are available for adoption when an opportune moment arrives. The necessity of involving many different stakeholders, both groups and individuals, is a complicating factor that must be addressed early in the policy process. The successful policy advocate must mobilize a coalition that can agree on the nature of the problem, the best solutions to the problem, and the best ways to achieve a hazard-resilient community. The fact that local government is the point of delivery for hazard policy makes it imperative that communities develop the political sophistication and technical expertise needed to get adequate hazard policy adopted and implemented in their jurisdictions. After adoption, hazard mitigation policy is subject to revision during the implementation process. Its emphasis can be changed or it can be ignored altogether. For this reason, policymakers must adopt a policy that is based upon a firm understanding of the manner in which it will reduce casualties and property losses. In addition, they must ensure that the policy does not overburden the jurisdiction's budget or economic base in the short-term to achieve long-term goals. Moreover, they should ensure that

legislation is written in such a way that program goals are clear to the implementing agencies and that these have adequate staffing and resources to accomplish their assigned mission.

References

Pratar C. S. and Lindell M. K. (2000), 'Politics of Hazards Mitigation', **Natural Hazards Review**, 73, pp.73-82.

Burton, I., et. al., (1978), **The Environment as Hazard**, Oxford University Press, New York.

Burby, R. J. and French, S. P. (1981), 'Coping with floods: The landuse management paradox', **Journal of American Planning Association**, 47, pp.289-300.

Lindell, M. K., and Perry, R. W. (2000), 'Household adjustment to earthquake hazard: A review of research', **Journal of Environment and Behavior Research**, pp. 23-56.

Lindell, M. K. and Prater, C. S. (1999), 'Household adoption of seismic hazard adjustments: A comparison of residents in two states', **Texas A&M University Hazard Reduction & Recovery Center**, College Station, Texas.

Lindell, M. K. et al. (1997), 'Adoption and implementation of hazard adjustments', **International Journal of Mass Emergencies and Disasters**, Special Issue, 15, pp.327-453.

Burby, R. J. (1998), **Cooperating with Nature: Confronting Natural Hazards with Land Use Planning for Sustainable Communities**, Joseph Henry Press, Washington, D.C.

Mazmanian, D. A., and Sabatier, P. (1989), **Implementation and Public Policy**, University Press of America, Lanham, Md.

(Professor Rajbala, Dr. Dinkar Srivastava and Dr. P.S.S.Dhote are associated with H.C.M. Rajasthan State Institute of Public Administration, Jaipur (Rajasthan))

Geomorphic Assessment and Mapping of Gullied Landscapes in the Eastern Margin of Thar Desert Using GIS & Remote Sensing

P.C.Moharana

Abstract

Gullies are typical erosional forms in semi-arid and arid landscapes all over the world. These are linked either with soil/sediment erosion or as the most important sources of sediment. The eastern margin of Thar Desert in India is a part of arid Rajasthan and is roughly co-terminus with the Aravalli hill ranges, representing a comparatively wetter part of Thar Desert with an average annual rainfall of approximately 400 mm. Alongwith favourable topography, slope and soil characteristics, the high intensity rainfalls generate surface run-off cutting through the terrain to form fine network of rills and gullies in the piedmont region of Aravalli hills. Such processes of erosion have significant bearing on the water and sedimentation of vast alluvial plains in this region. In the paper, the eight gullied landscapes occurring on alluvial plains and sand dunes have been studied with respect to their distribution, types and morphological variation so as to understand their impact on the overall aspect of water erosion.

Introduction

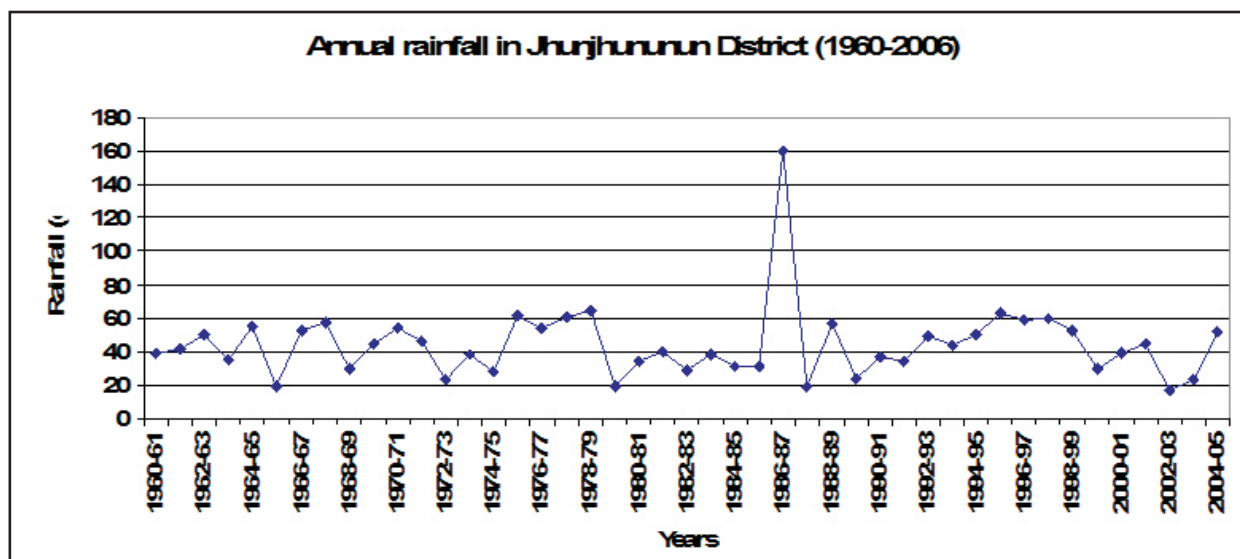
The eastern margin of Thar Desert in India is a part of arid Rajasthan and is roughly co-terminus with the Aravalli hill ranges. These hill slopes are being regularly denuded of natural vegetation cover, which is accelerating rill and gully erosion (Ghose *et al.*, 1977). Gullies are typical erosional forms in semi-arid and arid landscapes all over the world. These are linked either with soil/sediment erosion or as the most important sources of sediment. DEMs have been useful in the study of water erosion (Sharma and Kale, 2009). Moharana and Kar (2002) used height information from 1:50 k Survey of India Toposheets to delineate watersheds in sandy terrain of Rajasthan. A significant amount soil erosion through rills and gullies is taking place in Saurashtra and Kachchh (Gujarat) and along the eastern margin of the Thar Desert in Rajasthan where annual rainfall varies from 400 to 500 mm (Kar and Moharana, 2009). The rainfall intensity is high and the topographic and soil characteristics favour high run-off in the region. The piedmont region of Aravallis has a fine network of rills and gullies having significant bearing on the water and sedimentation of vast alluvial plains down slope. More than one-tenth area of Rajasthan is affected by water erosion

mainly in the eastern part of Jhunjhun, Sikar, Pali, Jalor and Barmer districts and gullies in Sikar district expanded laterally by 20m–250 m between 1931 and 1991 (Balak Ram, 2003). In the present study, high resolution satellite images have been used to map and assess gullied landscapes in Jhunjhun district in western Rajasthan. Administratively, the study area (Jhunjhun district) is divided into 6 tehsils: Jhunjhun, Chirwa, Nawalgarh, Udaipur-vati, Buhana and Khetri. Major gullied landscapes occur in Nawalgarh, Udaipur-vati and Khetri.

Rainfall pattern: Analysis of rainfall data (1961–2006) reveals that during the normal years, the district experiences 400– 600 mm annual rainfall, in the exception of heavy rainfall of 1600 mm during 1986–87. Such situations are responsible for accentuation of water erosion in the region. During the drought/deficient years, the district experiences about 200 mm rainfall.

Data Sources

Multi-temporal geo-rectified Resourcesat - 1 LISS-III data acquired during kharif (2005), rabi (2006) crop seasons were used for delineating and mapping the extent and distribution of gullied landscapes and landform units of the district. Field surveys and large scale satellite



images were used in micro-level mapping and morphological assessment of these surfaces. Mapping was carried out using ArcGIS/ ArcMap GIS software.

Results

Extent and Morphological Characteristics of Landforms

Physiographically, the district can be divided into southern rocky uplands, eastern sandy uplands and flat plains. Based on slope, nature, depth of sediment and drainage characteristics, the district can be divided into following major landform units (Table 1): Hills (H) and intermontane valleys (IV), rocky pediments (RP), flat & undulating colluvial plains (CP), younger alluvial plains (YP), older alluvial plains (AO) and riverbeds (Rb) form the fluvial sequence while sandy undulating older alluvial plains(SUAO), sand dunes(D) and interdune plains(ID) are linked to Aeolian processes. The south and south-east part of the district has a dominant hilly terrain (6.13 % area) having Aravalli hill systems and its off-shoots aligned roughly in NE-SW direction. Isolated and conical hills of sand stone, rhyolite and quartzite origin occur at Bhodan, Chichorli, Hariya, Navta. The hills are in various forms of degradation due to mining activities at Nehra, Modiya, Basri, Kali Pahari and Jai Pahari in Jhunjhunu tehsil and near Chanana, Nasi in Chirawa tehsil. Few

granite outcrops, 8-10 m high in the form of domes or dome inselbergs, with marks of spheroid weathering occurs near Basi, in the north of Jhunjhununu town. In most of the situations, these uplands are barren and rocks at the foot slopes are easily erodable and are dissected by surface run-offs to form well developed gullies as in Papra and Basari. Drainage channels are numerous, most of them have dendritic drainage pattern and are structurally controlled, therefore, flow in different directions. In Udaipur-vati and Khetri tehsil, the hills are affected by aeolian activities in the form of obstacle dunes dissected by rills and gullies. Intermontanne valleys in 18.99 sq km, 1.9% area, have been created by fluvial dissections by mountain streams and are scattered within the Aravalli hills and support good vegetation cover or crops. In Khetri tehsil, about 1.28 sq km area (0.16%) is utilized for dumping of copper-mine waste from Khetri mines. Down-slope the hills, rocky pediments in 129.27 sq km are either barren or debris covered with few xerophytes occupying 2.19% area of the district. The surfaces are armored with rock fragments mainly in sand stone and rhyolite hills in Jhunjhununu, Khetri and Udaipur vati tehsils. The plains have gentle slopes (1-5%) with well developed rills. The surfaces are cut into rills of various dimensions. With an average elevation between 380 ~ 460 m, these surfaces provide ideal geomorphic sites for water

harvesting. Flat and undulating colluvial plains in 18.48 sq km area occur at the distal end of rocky pediments, accordingly, receive the sediments deflated from the upper slopes primarily due to fluvial action. Downslope, about 188.77 sq km is covered under younger alluvial plains in narrow strips along the river Kantli mainly in Chirawa and Jhunjhunun tehsils. These plains are very deep (1-1.5 m) mainly at Bargaon, Bhatiwari, Guda, Barau, Damora, Jhajhar-Basawa--Khirood and Papra-Bagol sector. The maximum area of the district is covered by older alluvial plains which are either plains or dissected. Such landforms in 2325.12 sq km area are quite extensive covering 39.31% area. In Nawalgarh and Jhunjhunun tehsils, these plains are covered under thick and hummocky sand. Such undulating plains occur in 1891.44 sq km area (about 32 % area). Unlike adjoining Churu district, these plains are not extensive and their occasional formations are linked to sand abstraction by Aravalli hills and few isolated hills in the central part of the tehsil. Sand dunes cover 13.32 % area of the district mainly confining to Jhunjhunu tehsil. Major duned landscapes are distributed in Tomkar-Gangiyasar-Nirdhanu-Malsisar-Alsisar-Mandrella-Dabri sector in the western part of Jhunjhunu tehsil, Gudha Gaurji, Chawara, Jaitpura, Kalsiya, Parasrampura and Kair village

in Nawalgarh tehsil. The dunes are classified into longitudinal, parabolics, obstacle and barchans. The longitudinal dunes are mostly 10-20 meter high with occasional formation of 25-30 m big dunes. The parabolic dunes are 18-30m high. Obstacle dunes, next to parabolic types, are the major features of dune landscape. Such dunes have formed against the hill slopes of Aravallies and have varied topography. Compound barchans occur near Gudha-Gauruji where 6-8 m barchans have coalesced to form 18-20m high and 40-50m wide in the leeward slope of the granite hills. The area is drained by river Kantli and its network in NW-SE trend is spread over 15.32 sq km area. Satellite images of channels show a typical dendritic drainage pattern with maximum of 3rd order stream segments.

Assessment of Gullied landscapes

The region, as mentioned above, has an integrated network of streams which have mainly emerged from Aravalli hills. These streams have cut through rocky, sandy and alluvial plains and in the process have formed gullies at many places in Nawalgarh, Udaipurvati and Khetri tehsils. Eight major gullied landscapes have been mapped and studied. It was found that these landscapes (Fig. 3) have been associated with two major land surfaces; alluvial plains and sand dunes. We discuss some of the micro-morphological characteristics of

Table 1. Tehsil-wise distribution of landforms in Jhunjhunun district

Tehsils > Landform units / symbol	Nawalgarh		Udaipurvati		Buhana		Khetri		Jhunjhunun		Chirawa	
	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)
H	22.54	3.29	136.03	16.07	17.39	2.66	184.52	22.88	1.89	0.12	0.21	0.02
IV	0.37	0.55	2.37	0.28	2.24	0.34	14.01	1.73	-----	----	-----	-----
RP	-----	-----	64.15	7.58	4.05	0.62	61.07	7.57	----	-----	-----	---
CP	-----	-----	7.73	0.91	1.69	0.26	7.92	0.98	0.94	0.06	0.21	0.02
YP	-----		45.30	5.35	-----	-----	15.03	1.87	55.60	3.43	72.84	5.6
AO(F)	29.89	4.36	261.09	30.83	431.0	66.00	363.6	45.08	352.77	20.90	886.7	68.15
SUAO	555.32	81.02	221.97	26.21	190.4	29.16	85.82	10.64	526.17	32.43	311.6	23.96
D	71.88	10.49	84.84	10.02	3.76	0.58	58.77	7.29	543.96	33.53	24.6	1.89
ID	----	---	0.62	0.07	-----	-----	0.64----	0.08----	131.37	-----	0.44	0.03
Rb	5.45	0.79	22.65	2.68	2.45	0.38	15.12	1.88	9.74	0.60	4.33	0.33
Total area (sq km)	685.45	100	846.75	100	653.09	100	806.50	100	1622.44	100	1301.15	100

Table 3. Surface manifestations of gullied landscapes

	Site/ Location	Area (sq km)	Drainage density (km / km ²)	Surface Elevation (m)	Major Land use	Surface manifestations of gullied landscapes
1	Jasrapura 75.700 E, 28.017 N	2.29	0.31	406 -412	Open scrub	Duny terrain, obstacle dunes dissected by run-offs to form gullies. Main gully, 30m long is a 3rd order stream segment, joined by 5-15m long tributary channels, Average width, 4-5m and depth, 4-6m. In the crest, the distance between gully head is 25 -30 m while downslope, the arms are 6m apart.
2	Barau 75.700 E 28.018 N	45.62	0.46	458-534	Open scrub	Duny terrain, obstacle dunes, main gully is 33 m long, 5 -5.50 m deep and 18 -20m wide. Because of slope, during rains, flood water through these gullied channels from Khetri hills inundates significant area up to Basant Vihar.
3	Jaitpura 75.523 E 27.799 N	2.71	0.14	480-515	Open scrub	Duny and sandy plains dissected by number of channels to form big gullies, distance between two flanks is maximum at the top (20m) which decreases to 14 -15m down the slope, 2nd order stream, steep flanks, 6m wide and 8-9m deep.
4	Goriyan 75.523 E 27.799 N	3.87	0.21	480-510	Open scrub	Comparatively a bigger gully in the same site, 3rd order stream joined by 5 channels 5.6m to 15m long, width varies from 4.4 to 6.8m, depth 7 -9 m, perimeter is 108m, main channel is 43m long, width at the distal end is 2.10m.
5	Gudha- Gaurji 75.523 E 27.798 N	4.09	0.21	460-488	Cropland	An extensive area under network of gullies on duny landscape, 2nd order gullied channel, about 30 m long, joined by 4 -12 long channels which are 1.5 to 9 m wide and 1.2 to 9 m deep
6	Sephragwar 75.519 E 27.798 N	5.78	0.12	390-410	Cropland	Area is interspersed with network of gullied channels developed over alluvial plains which is a catchment of River Kantli and floods cause excessive damages. A major flood has also has damaged the dam constructed on this stream. Width varies from 1.5 to 11 m and depth 3 to 7.5m
7	Nai Kothi and Kalota 75.726 E 27.819 N	4.07	0.13	380-400	Cropland	An extensive area affected by 75 -80 m main long gullied channel, depth of incision varies from 5m to 7m and width 4.5 to 7.5 m.
8	Baseri	7.5	0.13	455 - 550	Open scrub	Open scrub and partly forestland, an extensive area on obstacle dunes, dissected by 50 -60 m long gullied channel, depth varies from 4.5 to 6m and width from 4-5m.

selected gullies in the following table (Table 2)

(1) Gullies over plains: These landscapes have been mapped at three sites; Gudha-Gaurji, Sephragwar and Kalota which are flat alluvial plains. The surfaces have been dissected by a network of gullies occurring in 15.16 sq km area near Jaitpura, Barau, Kotri and in Guala- Pachlagi sector in Udaipur vati tehsil and in Harriya, Sunari, Sephragura. Barau, Kalota, Gunincha, Nai Kothi, Modki, Chicholi in Khetri tehsil. Genetically these plains are similar to flat older alluvial plains but are morphologically different. The major gullies (20 – 30 m wide and 5 – 7 m deep) are joined by few smaller gullies (0.8 to 3 m wide and 2-3 m deep) to form gullied landscape. Ephemeral gullies cause more damage whenever the channels receive water through flood water abstraction. Instances of such menace are witnessed in Nai Kothi-Sephraguar sector in Khetri tehsil, where a 7-8m wide structure of bridge-cum-road was completely washed away during 2004-05 flood as gully heading from Chainchorli-Roopa ka via-Nolkha sector received sudden flood water and damaged the dam. Similar gullied landscapes are also noticed near Babai and Kalota where the landscape is dissected by 70-100m long, 4-7m deep and 4-8m wide gullies. Such dissections are reported to have deformed cultivated lands and infrastructure and have forced people to abandon agricultural activities in the region. Density of gullied channels varies from 0.12 near Kalota to 0.21 km / km² near Gudha-Gaurji. The interfluvies are wider and channels separating them are 40-100 m apart.

(2) Gullies over obstacle sand dunes: These gullies have formed against the hill slopes near Goriyan, Basari and Gudha Gaurji in Udaipur-vati tehsil (Fig. 2). The dune slopes have been dissected by run-offs creating 5-10 m deep and 3-8 m wide gullies. In Khetri tehsil near Barau, Jasrapura, Kotihan, Jaisinghpura, the gullies are more wide (30-40m) and 20-40 m deep. In Udaipur-vati tehsil, near Goriyan, Basari and Gudha Gaurji, these dunes have been dissected by 5-10 m deep and 3-8 m wide gullies. But in Khetri tehsil near Barau, Jasrapura, Kotihan,

Jaisinghpura, the gullies are more wide (30-40m) and 20-40m deep. The sand grains are fine and their mean grain size varies between 2.75 to 3 phi. Barchans occur in few places in the south of Chirawa, north of Malsisar and south of Mandrella. Drainage density is maximum (0.46 km/km²) near Barau which has a catchment area of 45.62 km². Other gullies on obstacle sand dunes have drainage density varying from minimum 0.13 to maximum 0.31 km / km². The interfluvies are narrow, closely spaced and distances between gullies vary between 20-30 m.

Discussion and conclusion

Interpretation of satellite images, thematic maps shows that this wetter part of the arid region in western Rajasthan is more vulnerable to water erosion. The region has very little problem of wind erosion but water erosion is dominant. The manifestation of water erosion is visible in the form of gully networks along the obstacle dunes at the foothills of Arvallis. Although both kinds of degradation occupy less than 5% area of the district, the potential of gully erosion is high in the shallow intermontane plains of Udaipur vati, Khetri and Buhana tehils of Jhunjhun district. Wind erosion is very less but the sandy plains has have extensively put under cultivation in most part of the region which in turn are responsible for accentuation water erosion during heavy rains. Satellite images and field observations also confirmed that out of 4 gullies occurring on duny landscapes, 3 have developed against the hill slopes on the obstacle dunes. Such dunes have convex slope as these are concentrated in pockets of colluvium located at the foot of hill slopes. The dunes are much bigger at Barau than in Jasrapura, Jaitpura and Goriyan. The NE to SW alignment of Aravalli hills seems to have a major influence in sculpturing and influencing dune morphology by obstructing the blown sands from the west. As these hills are in different stages of denudation, these show discontinued pattern. The narrow corridors between the hills also favour sand accumulation. These dunes are known as obstacle dunes (Ghose et al 1977).

The morphology of most of the obstacle dunes is wider in the upper slope which narrows downslope till the slope is almost reduced to 0-1 % or flat plains at the fringe area of the alluvial plains. While the upper and middle slopes are stable with vegetation cover, the lower slopes show sand activation. Such phenomenon, in arid Rajasthan, is a result of two major factors: (1) human activities which include ploughing of croplands using tractors and (2) grazing pressure on cropland and grasslands. Though tractor ploughing has helped farmers to cultivate even bigger dunes with ease, it has opened up flood gates for wind and water actions to erode these lands during non-crop period. Between middle parts of March till end of April, leftover crop residues and grasses on croplands and open scrubs in arid land situation are heavily grazed by animals. During May till July, these lands are entirely barren. The temperature is high and moisture of the land is almost negligible during the same period. Such situations favour wind to deflate the land surfaces and transport loose sands in every possible direction. Presence of hilly barriers favours formation of obstacle dunes under this situation. Between August and September, the region receives significant rains which create lot of runoffs which flow on the hillslopes and the obstacle dunes. The dry valleys over the sand dunes are again activated to their fullest forms. Irrespective of these three situations, gulling has also occurred on undulating sandy plains near Gudha –Gaurji. The sandy hummocks and low dunes have been dissected by water action to form such topography. In another situation, gullies have dissected the flat plains near Sephraguwar and Kaloti area, this has happened whenever, the channels have received water through flood water abstraction. Average drainage density of gullied channels in plains is low (0.12 to 0.14) where as, in case of sandy uplands, these channels have higher drainage

density (0.21 to 0.46) suggesting higher incision activities. Over the last four decades exploitation of natural resources to meet increasing societal demands for land based products has caused significant changes in land use and land cover. This has happened to many parts of Desert in western Rajasthan which represent environmentally sensitive arid regions with higher rainfall.

References

Sharma H S and V. S. Kale (eds) 2009, Geomorphology in India, Prayag Pustak Bhavan, Allahabad, pp.59-68.

Kar, Amal and Moharana, P.C. (2009), "Progress of Researches in the Arid and Semi-arid Geomorphology in India", in Geomorphology in India, (Eds) H.S.Sharma and V.S.Kale, Prayag Pustak Bhavan, Allahabad, pp.341-358.

Moharana, P.C and Kar Amal (2009), "Application of GIS in automated delineation of watersheds in a sandy terrain of Thar desert", in Geomorphology in India, (Eds) H.S.Sharma and V.S.Kale, Prayag Pustak Bhavan, Allahabad, pp.507-516.

Balak Ram (2003), "Impact of Human Activities on Land use Changes in Arid Rajasthan : Retrospect and Prospects" in Human on Desert Environment (Eds) Pratap Narain, S.Kathju, Amal Kar, M.P.Singh and Praveen Kumar, Arid Zone Research Association of India & Scientific Publishers (India), Jodhpur. Pp. 44-59.

Moharana, P.C and Kar, Amal (2010), Quantitative Measurement of Arid Fluvial Processes: Results from an Upland Catchment in : Thar Desert", Journal of Geological Society of India, v(76), pp.86-92.

Ghose, B., Singh, S and Kar, Amal (1977), Geomorphology of Rajasthan desert. In: Desertification and its Control. ICAR, New Delhi, pp.69 – 76.

(Dr. P.C.Moharana is working at Central Arid Zone Research Institute, Jodhpur
E-mail : pcmoharana@cazri.res.in)

Degradation of Pasture/Grazing Lands and its Impact on Livelihood of Rural Communities in Rajasthan

Balak Ram, J.S. Chauhan

Abstract

Pasture/grazing land is most important land use system which support livelihood of pastoral communities in particular and rural population in general. Based on the digital interpretation of IRS P6 LISS-III data supported with field check, the spatial distribution and characteristics of pasture /grazing lands of Rajasthan are assessed. The State has 1.7 mha or 4.97% area under pasture/grazing lands. Their percentage at district level varies from 0.01 in irrigated IGNP region to 12.7 in rainfed Mewar uplands. Since 1980-81 the area under pastures has declined by 7.15%. In about 40% districts pastures are declined by more than 10% and have been put in other uses. Majority of the pastures are in highly degraded condition in terms of palatable species, carrying capacity and physical deterioration. The drivers of their degradation and impact on livelihood are worked out. Strategies are indicated for their rehabilitation and sustainable development.

Introduction

A quarter of world's land i.e. 56.3 million km² is used for grazing. In India Common Property Resources constitute about 15% of the total geographical area of which 23% are common pastures and grasslands and 16% village forest and woodlots. It is an important component of livelihood assets of communities in semi-arid and arid regions. Rajasthan has well designed management system for pasture and oran lands which occupy 1.7 mha area in the State. These lands support 57.9 million livestock and about 68.6 million human populations directly and indirectly. However during the last four decades these lands not only degraded in terms of palatable plant species, carrying capacity and physical conditions but also reduced in size. On the other hand the human and livestock populations are increased by 166% and 63% respectively. This has adversely affected the livelihood of the pastoral communities. The process of grabbing these common lands and putting them to private uses is continues. Looking in to such a threatening situation, there is urgent need to protect, rehabilitate and develop these lands to meet the growing demands of feed, fodder, meat, milk and other dairy products. The present study aims to assess the physical conditions and distribution pattern of permanent pastures and other grazing lands

in Rajasthan State using modern RS&GIS technologies and to quantify and map the reduction of such lands at district and tehsil level using land records data from 1980-81 to 2007-08. The factors responsible for their degradation under different agro-ecological sub regions are worked out. The adverse impact of this phenomenon on the socio-economic conditions and livelihood system of pastoralists and poor families are discussed. Strategies are suggested for their protection, regeneration, management and sustainable development.

Enviromental setup

The Rajasthan State covers 342239 km² or 10.4% of country's total geographical area. It is located between 23° 30' to 30° 11' North and 69° 29' to 78 ° 17' Eeast longitudes (Fig. 1). The district has 33 districts, 244 tehsils and 249 panchayat samiti (Development blocks). The total population of the state is 68.6 million as per 2011 census and total livestock 57.9 million as per livestock Census 2007. The hot arid region towards west of Aravalli is covered with blown sand dotted with dunes which belong to the Pleistocene and recent times and forms part of 'Thar' Desert. The alluvium covering part of eastern plain and flood plain belong to recent and sub-recent period. The ravines flanking the

Chambal and its tributaries are of very recent origin. Rest central, southern and eastern parts are characterized by variety of exposed rocks which include schist, quartzite, marble, and gneiss of Cambrian age. The Aravalli, the oldest hill range of the world, comprises of the Aravalli super group and Delhi super group with banded gneissic complex. South eastern part is occupied by basaltic flow of Deccan trap of Cretaceous period.

The climate of Rajasthan ranges from semi-arid to arid on the west of Aravalli and semi-arid to sub-humid on the east of Aravalli. The arid region is characterized by low, erratic and highly variable rainfall, frequent droughts, high wind speed during summer and low humidity. The mean annual rainfall varies from less than 100 mm in the extreme western part of Jaisalmer to more than 920 mm in the eastern parts of Jhalawar and Banswara. The annual potential evapotranspiration (PET) vary from less than 1300 mm in the district of Banswara and Dungarpur in eastern Rajasthan to more than 2000 mm in Jaisalmer district in the extreme west. There is wide variation in temperature ranging from below freezing point in winter to as high as 47 °C to 48 °C in summer. The entire state has hyperthermic condition. The length of crop growing period varies from less than 45 days in extreme west to 150 days in Malwa Plateau. The state has been divided into ten agro-climatic zones. The soils of the sandy plains are deep, calcareous and sandy with severe wind erosion. Soils of aeolian plains of Luni are moderately shallow to very deep, calcareous and sandy to loam in texture. Soils of Aravalli landscape are shallow to moderately shallow, loamy to loamy-skeletal and severely eroded. Eastern Rajasthan upland is represented by moderately deep to deep, loamy soils with slight to severe erosion. Malwa plateau has moderately shallow to moderately deep, loamy skeletal to clayey soils (NBSS&LUP, 2000). About 11.51% area of state comes under land capability class II, 21.56% under class III, 34.32% class IV, 6.8% class VI, 19.98% class VII and 5.81% under class VIII respectively (SRSAC, 2010).



Fig. 1

Study Area

About 16.78% area of Rajasthan is occupied by natural vegetation cover of which 4.71 % area is occupied by forest. Scrub and grasslands occupy 9.18 and 2.87% area. Reddy et. al. (2011) have identified and mapped 26 vegetation types class in the state. The major classes are dry deciduous forest, thorn forest, broad leaved hill forest, dhauk forest, teak mixed forest and riverine forest. The state has 23 national parks and sanctuaries. Chambal, Luni, Banas and Mahi are important river systems. There are 14 major river basins divided into 59 sub-basins but most of them are ephemeral and flowing just for one and a half month during rainy season. Rajasthan has only 1% of country's total surface water resources. The surface water available at 50% dependability is 21.71 BCM out of which only 16.05 BCM is techno-economically utilizable. The storage capacity generated as yet is 11.29 BCM. Rajasthan is also getting 18.08 BCM water as per interstate agreement. The Annual replenishable ground water resources are 11.56 BCM. Net annual ground water availability is 11.38 BCM while annual ground water draft is 12.99 BCM which leads to ground water development level at 125%. Out of 237 blocks of the state only 32 are considered safe while 140 are overexploited, 50 critical and 14 semi-critical stages.

Method and materials

Spatial distribution and characteristics of

pasture/grazing lands in 12 district of western Rajasthan are based on the district wise land use maps prepared at CAZRI on 1: 2,50,000 scale using IRS LISS-III digital data of the period 2004 to 2008. For eastern Rajasthan the wasteland maps prepared at SRSAC and RRSSC are considered. To show the quantitative distribution of pasture/grazing lands at district level, the land records data of 2007-08 is analyzed. State level data from 1956-57 to 2007-08 has been used to show the trend. District level changes are mapped using 1980-81 and 2007-08 data. Tehsil wise changes are also mapped by analyzing 1980-81 and 2003-04 data of 244 tehsils. The shrinkage in pastures has been identified by comparing important pastures from each of the district with earlier prepared land use map of respective district. The constraints and factors responsible for physical and quantitative degradation are based on the field knowledge and reports on natural resources appraisal. Based on the integrated approach of natural and human resources, strategies are worked out for rehabilitation and sustainable development of these common lands.

Results and discussion

Rationale of pastures/grazing land Pasture/grazing land is an important component of livelihood assets of rural communities in arid and semi-arid regions (Jodha, 1995). As per land records Gochar, Oran, Agor, Bir, Johad etc. are grouped under permanent pasture and other grazing lands. These are 'gair mumkin' common lands the ownership of which vest to state government and ultimately to village panchayat. Every revenue village has some land under this class which is open for grazing animals by common people. Besides, most of the gochar and oran have pond called 'nadi' which provides water for animals as well as for human use. Such lands not only serve as grazing ground but resting place for animals. Their importance is more realized during droughts. The shrubs and tank mud are used by poor families for making huts. These lands are source of natural wealth like fodder,

fuel, timber, berries, roots and herbs. Landless families having animals depend entirely on common lands. Further, these lands provides worship place for local god and goddess as well as social functions. The oran is dedicated to some god or goddess. Cutting of trees is forbidden from such lands. These lands serve as gene-pool conservation system; preserve the endemic endangered species, medicinal plants and wild varieties of cultivars. Thus Rajasthan has long history of well designed management system for pasture and oran lands which have multi-facet utility and importance. The management system has emerged in light of the key role that livestock plays in peoples livelihoods and for the local economy (V&A Programme, 2009). There are 1100 orans in Rajasthan covering 100000 ha area (Singh and Bahl, 2006). Alwar district itself has 163 oran and each of them has a water body (Singh, 2007).

Distribution and characteristics of Pasture/grazing land Pasture/grazing lands occur almost on all the habitats but more dominantly on sandy undulating older alluvial plain, interdunal plain, flat aggraded older alluvial plain, rocky/gravelly pediment, flood plain, saline aggraded older alluvial plain, saline depression, and gullied/ravinous land. In Rajasthan gazing pressure is 7.68 ACU/ha while existing carrying capacity is 0.68 (ACU/ha). The stocking rates are 1 to 4 ACU/ha against the carrying capacity of 0.2 to 0.5 ACU/ha. The size of gochar and oran varies from 50 ha to more than 10 km². Orans are found comparatively in large size. As per 2007-08 statistics, permanent pastures and other grazing lands constitute 1702558 ha or 4.97% of total area of the state and 16.46% of total area under pastures in India (Anon. 2010). Irrigated Ganganagar and Hanumangarh districts have < 1.0% area under pastures. On the other hand Rajsamand and Bhilwara have more than 10% grazing land. This is followed by Chittorgarh and Dungarpur districts which have > 8% area under pastures. Surprisingly, eastern Rajasthan has 52.3% pastures as compared to 47.7% in western arid part. Distribution of pastures is shown in table 1

fig. 1. Interpretation of P6 LISS-III data reveal 5.05% area under pasture/grazing land in Jaisalmer, 2.24% Bikaner, 6.68% Barmer, 4.37% Jalor 4.83% Jodhpur, 4.43% Nagaur, 1.2% Hanumangarh, 0.74% Ganganagar, 4.51% Churu, 4.44% Jhunjhunun, 4.54% Sikar and 6.96% in Pali district. In eastern Rajasthan, Bhilwara has 11.74%, Baran 6.26%, Ajmer 3.94%, Sawai Madhopur 3.66%, Bundi 3.07%, Kota 2.83%, Chittorgarh 0.78%, Tonk 0.12%, Banswara 0.1%, Dausa 0.08%, Jhalawar 0.02% and Karauli 0.01% degraded pasture/grazing land (NRSA, 2005).

Majority of the pastures in highly degraded condition in terms of eroded, exposed and bare terrain and poor stand of palatable tree, shrub and grass species. The invasion of *Prosopis juliflora* and further suppressed the native flora. In canal command area a number of weeds and unpalatable plant species have come up. In north-western part of Bikaner and north-eastern part of Jaisalmer, well established and dense *Lasiurus sindicus* grasslands are cleared for agriculture. Further in all irrigated areas the ponds (nadi) within the pastures become defunct for want of care. The encroachment over these lands is a common phenomenon. Such lands are grabbed for agriculture, habitation and religious purpose. A number of social institutes have taken these lands in the name of development and converted into private property. Government also allowed the construction of schools, dispensaries, panchayat bhawan and other public buildings on these lands. As such most of the pastures located in the vicinity of village settlement have lost their identity. Large scale plantations to enhance India's green cover threaten to replace common pasture and grassland with inedible and non-usable monocrops. Companies that have grabbed land fenced and privatized the land and began climate unfriendly activities (Ghotge, 2011).

Degradation trend During the last three decades significant changes are taken place towards degrading health and area of the pastures/grazing land. From 1956-67 to 1969-

70 there was increasing trend of 32.97% i.e. from 13.8 lakh ha to 18.35 lakh ha. Up to 1985-86 the area remained almost static and by 2007-08 the area has declined by 7.4% (table 2). Comparison of district level figures of pastures (1980-81 and 2007-08) show a vivid picture (Anon. 1984, 2010). In IGNP command Ganganagar and Hanumangarh districts the pastures are almost vanished (83.18%). Similarly Banswara and Tonk districts recorded very high reduction of 63.39% and 35.31%. The district with more than 10% reduction are Sawai Madhopur and Karauli (20.9%), Sikar (16.0%), Bharatpur and Dhaulpur (16.06%), Kota and Baran (12.99%), Udaipur and Rajsamand (12.27%) and Jhunjhunun (11.47%). On the other hand Jaisalmer, Chittorgarh, Bikaner and Bundi districts have shown an increasing trend of pasture land by 17.14, 11.77, 8.47 and 6.27 percent respectively (Table 1). Actually in these areas the land from the category 'barren and uncultivable land' has been included into the category of 'permanent pasture and other grazing lands' and no real pastures are developed.

The tehsil level changes under pasture/grazing land from 1980-81 to 2003-04 are shown in figure 3. In majority of the tehsils the pasture lands are declined by 5 to 10%. However in few tehsils more than 50% reduction has been recorded. Important among them are Abu Road 81.2%, Churu 77.8%, Anta (Baran) 70.4%, Pipalda (Kota) 68.5%, Tonk 72.2%, Khandar (S.Madhupur) 64.4%, Ramgarh (Alwar) 54.3%, Mangrol (Baran) 53.7%, Amet (Rajsamand) 42.6%, Dungarpur 38.2%, Uniara (Tonk) 36.7%, Jambha Ramgarh (Jaipur) 34.3% and Girwa (Udaipur) 29.9% respectively. In Banswara district all tehsils have shown substantial reduction of pasture lands to an extent of 93% in Garhi, 81.2% in Banswara, Ghatol 62.2%, 52.8% in Bagidora and 60.1% in Kushalgarh. In Bikaner district area under pastures has declined in Nokha and Lunkaransar tehsils while in Bikaner and Kolayat tehsils more area has been put under this category. On the other hand the area under pastures has significantly increased in

Pindwara tehsil (Sirohi) 358.2%, Gangrar (Chittorgarh) 181.1%, Parvatsar (Nagaur) 124.8%, Nimbahera (Chittorgarh) 64.9% and Bari (Dhaulpur) 61.8% respectively. Balak Ram and Pathak (1996) found 25.63% pasture area of Sri Madhopur tehsil (Sikar district) encroached for agriculture and 33.23% area for plantation by forest department. Similarly in Luni Development Block (Jodhpur district) in all the 12 identified pastures encroachments were made for settlement and agriculture.

Drivers of pastures/grazing land degradation
The deterioration of pastures/grazing land may be ascribed to the large bovine population, free grazing practices, lack of management and natural constraints like extremes of temperature, steepness of slopes, variable precipitation and scarcity of moisture (Raheja, 1966). Others are cutting /removal of trees and shrubs for marketing, frequent occurrence of droughts, growth of human population and societal demands (Jodha, 1983), increased commercialization of desert economy, diversion of common lands to alternative uses, privatization of common lands and faulty government policy on land acquisition, allotment and conversion. In fact the density of animal per unit of grazing land has increased from 20.39 animal units per 100 ha of grazing land in 1961-62 to 105. Similarly the livestock population has increased from 24.64 million in 1951 to 57.9 million in 2007 and the human population from 15.97 million in 1951 to 68.62 million in 2011. Other constraints are lack of legal protective measures against encroachment, unorganized animal husbandry sector, inadequate infrastructure, unrespectable cattle rearing profession, lack of wisdom as well as conservative and disorganized society.

Impact of pasture/ grazing land degradation
The degradation and shrinkage of pastures/grazing lands has badly affected the livelihood of households which are entirely depend on raring of animals, landless labourers, marginal farmers and people engaged in household industries. Shifting from cattle to goats, shortage of fodder

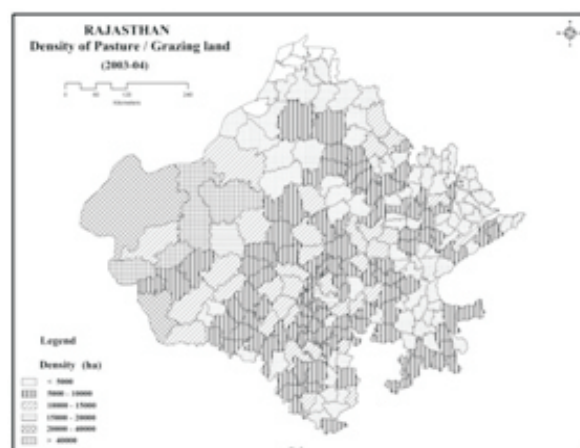


Fig. 2

and abandonment of dry farming and seasonal migration of animals are other negative impacts (Suresh et. al. 2010). Rainfed farming for small and marginal farmers has become ineffective to support their livelihood hence they have left farming and migrated to nearby towns for alternate jobs. Degrading farmland and feed shortage forced people to abandon farming and cattle and turn to goats. In dry season a large number of herds migrate from western Rajasthan to northern and eastern parts of the state and U.P. and M.P. A land where goat used to graze, is not likely to regenerate because they eat rootstock of the grass. Similarly due to unavailability of common land for grazing in a number of villages, some households have stopped cattle rearing and switched over to other occupation. Reduction in body weight and wool production from sheep and goats and reduction in the average age of disposal of lambs are other created problems. The degraded pasture during droughts further cause adverse impact on the survival of the livestock and make regeneration difficult.

Change in Pasture/ Grazing land

Issues and Challenges
The major issues and challenges before the Rajasthan State are protection of common lands from further encroachment and their rehabilitation and development; make animal husbandry and animal grazing a profitable and respectable profession; ensure adequate availability of grazing land, fodder and feed on long term basis

Table 1. Change in Pasture/Grazing land (ha) in Rajasthan from 1980-81 to 2007-08

District	1980-81		2007-08		Change in %
	Area (ha)	%	Area (ha)	%	
Ajmer	77465	9.11	78608	9.31	1.35
Alwar	24496	2.92	24221	3.09	-1.12
Banswara	34047	6.75	12463	2.46	-63.39
Barmer	215110	7.86	202380	7.18	-5.91
Bharatpur and	30685	3.79	7737	1.53	-16.06
Dhaulpur			17854	5.93	
Bhilwara	119607	11.45	120353	11.49	0.62
Bikaner	40054	1.48	46010*	1.70	8.47
Bundi	22989	4.13	24430	4.20	6.27
Chittorgarh	81431	7.79	91017	8.79	11.77
Churu	47163	2.80	43447*	2.72	-7.88
Dungarpur	40038	10.59	34553	8.96	-13.7
Ganganagar and	23025	1.11	140	0.01	-83.18
Hanumangarh			3733	0.38	
Jaipur and	110862	7.94	76994	6.96	-6.94
Dausa	-		26177	7.67	
Jaisalmer	88716	2.31	103926	2.71	17.14
Jalor	51068	4.36	47446	4.49	-7.09
Jhalawar	52842	8.48	48626	7.69	-7.98
Jhunjhunun	44589	7.54	39474	6.67	-11.47
Jodhpur	120174	5.29	121998	5.41	1.52
Kota and	57589	4.64	14183	2.72	-12.99
Baran	-		35918	5.14	
Nagaur	76158	4.27	72472	4.11	-4.84
Pali	92480	7.45	91036	7.38	-1.56
Sawai Madhopur and	70266	6.67	24710	4.96	-20.9
Karauli			30867	6.12	
Sikar	48357	6.17	40622	5.25	-16.0
Sirohi	33214	6.48	33800	6.44	1.76
Tonk	65020	9.08	42064	5.86	-35.31
Udaipur	166196	9.42	88152	6.03	-12.27
Rajsamand	-		57658	12.67	
Total	1833634	5.36	1702558	4.97	-7.15

An area of 5728 ha of Dungargarh tehsil is substracted from Bikaner and added in Churu district

Table 2. Trend in Pasture/Grazing Land in Rajasthan from 1956-57 to 2007-08

Year	Area (000 ha)	Year	Area (000 ha)	Year	Area (000 ha)
1956-57	1380	1974-75	1823	1992-93	1771
1957-58	1397	1975-76	1804	1993-94	1763
1958-59	1526	1976-77	1814	1994-95	1751
1959-60	1641	1977-78	1825	1995-96	1745
1960-61	1684	1978-79	1834	1996-97	1735
1961-62	1735	1979-80	1841	1997-98	1723
1962-63	1770	1980-81	1834	1998-99	1718
1963-64	1752	1981-82	1837	1999-00	1714
1964-65	1784	1982-83	1836	2000-01	1707
1965-66	1812	1983-84	1846	2001-02	1699
1966-67	1810	1984-85	1851	2002-03	1703
1967-68	1817	1985-86	1840	2003-04	1708
1968-69	1828	1986-87	1824	2004-05	1709
1969-70	1835	1987-88	1817	2005-06	1708
1970-71	1807	1988-89	1800	2006-07	1706
1971-72	1805	1989-90	1802	2007-08	1703
1973-74	1808	1991-92	1787		

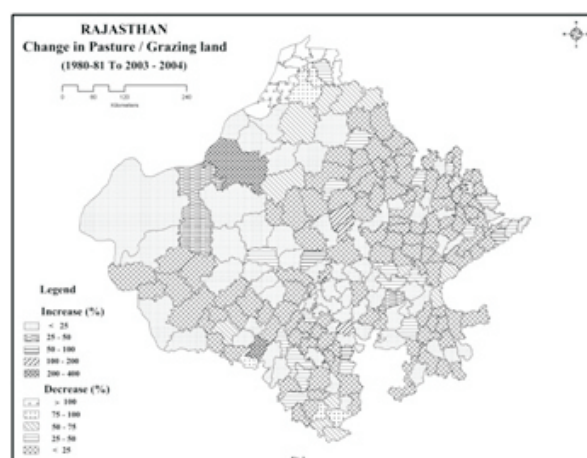


Fig. 3

and specially during droughts; modernization of animal husbandry, livestock production and dairy industry; fulfillment of projected demand of milk and meat; and adequate infrastructures.

Strategies for Development of pastures/grazing lands

- Bio-fence, introduction of top feed species, reseeding and social protection.
- Develop rainfed pasture and create nutritive feed resources for livestock as well as fuel especially for resource- poor families.
- Diligently work on degraded land so as to improve the environment and also the income and nutrition of the village communities (Singh and Behl, 2006).
- Built up local Institutions –The Village Management Committee so as to ensure sustainability of activities and strengthen the Panchayati Raj Institutions (PRIs). Start Grass Growers Cooperatives.
- Provide a range of incentives to farmers and pastoralists to revive old culture for the protection of village common for sustainable use and beneficial purpose.
- Assist communities in regenerating and restoring degraded pastures.
- The area under fodder crops is only 0.02% of the total cropped area and hence it should be increased both under irrigated and rainfed condition.
- Propagate the cultivation of green fodder by introducing highly productive, disease resistant and area specific cultivars of various crops.
- To develop programme for women and landless labourers through Self Help Group (SHG).
- Total protection of selected grassland plot to serve as nucleus for seed bank, secure tenure rights for pastoralists (both resident and nomadic) over pastures and genetic improvement of livestock (Planning Commission, 2007)

- Monitor the pasture improvement and level of biomass production using remote sensing and GIS technologies
- Legal protection to grassland. There should be strict law to stop encroachment of gauchar land
- Formulation of National Grazing and Grassland Policy

Conclusion

Rajasthan has about 5% of its total area under pasture/grazing land. District wise this percentage varies from < 1% in canal irrigated Ganganagar region to > 10% in Udaipur region. Eastern Rajasthan though has higher percentage of pastures as compared to arid Rajasthan but size and density of gochar and oran lands is more in western Rajasthan. Majority of the pastures are highly degraded in terms of carrying capacity, grazing material and surface condition. Their size has also been reduced. Since 1980-81 the area under pastures/grazing land has declined by 7.15%. Higher order of decline has been observed in eastern Rajasthan. The major drivers of their degradation are growth of human and livestock populations, encroachment and conversion to alternative uses, lack of management and natural constraints. Shortage of fodder, reduction of cattle population, increased frequency of migration and losing interest in animal grazing are major impact of pasture degradation. Protection of common lands and their rehabilitation & development is major issue which should be resolved through appropriate strategic plans and their effective implementation.

References

- Anon. Statistical Abstract, Rajasthan, 1982, Directorate of Economics and Statistics, Rajasthan, Jaipur, pp.364, 1984
- Anon. Rajasthan Agricultural Statistics at a glance, (2009-10), Commissionerate of Agriculture, Rajasthan, Jaipur, pp.147, 2010
- Balak Ram and Pathak, S. 'Application of Remote

Sensing in Mapping the Shrinkage and Degradation of Common Property Resources (CPR) in arid Rajasthan', Indian Cartographer, Vol. 16, pp.234-239, 1996

BAIF. 'Common Land & Poor Livestock Keepers: Experiences form Common Land Development in the states of Rajasthan and Madhya Pradesh, India', Foundation for Ecological Security and BAIF Development Research Foundation, Doc.No.021, March, 2009

Ghotge, N.S., 'How grazing lands became wastelands', Info Change Agenda, August 4, 2011

Jodha, N.S., 'The Decline of Common Property Resources in Rajasthan, India', Network Paper 22C, Pastoral Development Network of ODI, London, pp.23, 1986

Jodha, N. S., 'Common Property Resources and Dynamics of Rural Poverty in India's Dry region', Unasylva : International Journal of Forestry and Forest Industry, UN FAO, vol. 46.1995

NBSS&LUP, 'Ago-ecological Assessment of Soil Resources of Rajasthan for Land use planning', NBSS&LUP, Nagpur, Pub.81, pp.88, 2000

NRSA, 'Wasteland Atlas of India', NRSA, Hyderabad, pp.95, 2005

Raheja, P.C., 'Desert can bloom with forage', Indian farming, 15, pp.47, 1966

Report on Task Force on Grassland and Deserts, Govt. of India, Planning Commission, New Delhi, 2007

Reddy, C.S., et. al., 'Mapping the vegetation types of Rajasthan, India using remote sensing data', E3 Journal of Environment Resources and Management, vol. 2 (1), pp.1-9, 2011

Singh, A. and Behl, R. 'Oran Land Issues: A Livelihood Concern for Pastoralist in Rajasthan', Krishi Avam Paristhiki Vikas Sansthan, Alwar, 2006

Singh, A, "Oran' Sustainable Livelihood and Biodiversity Conservation System-experiences' from KRAPAVIS, Alwar, Rajasthan, www.globalgiving.org/pfil/1116/projdoc

Srivastava, K.S, 'Where have all the Pastures gone', Deccan Herald, Aug. 3, 2011

Suresh, A., et. al., 'Degradation of Common Pasture: An Economic Perspective of its Impact on Livestock Farming and Coping Strategies', Agricultural Economic Resource Review, vol. 23, pp.47-56, 2010

V&A Programme, 'Vulnerability & Adaption Experiences from Rajasthan and Andhra Pradesh: Pasture Land Development- Case Study', India. SDC V&A Programme, India, pp.25, 2009

(**Dr. Balak Ram**, Principal Scientist (Retd.), and **Dr. J.S. Chauhan**, Sr. Technical Officer (T-8), Central Arid Zone Research Institute, Jodhpur (Rajasthan)
Email: dr.brmayank@gmail.com)

Identification of Ground Water Potential Zone in and around Dehra Doon Using Index Overlay Method

D. K. Mandal

Abstract

The last decade has seen a phenomenal growth in the use of RS and GIS technology in ground water studies. The ground water has become the most sought-after natural resource due to tremendous pressure on the ground water system by the ever-increasing population and industrial growth. Since last decade, the value per barrel of potable ground water has outpaced the value of a barrel of oil in many areas of the world. There are competing demand for water from domestic, industrial and agriculture sectors; recycling of wastewater requires an emphasis. Establishing relationship between RS data products and hydrologic phenomenon can maximize the efficiency of water resources development projects. The present paper attempts to map different landforms understand geomorphic processes involved and delineate prospective ground water zones making the eastern Doon Valley and its surroundings parts of Uttaranchal State, as a case study with the objectives to: identify and map parameters controlling the ground water occurrence and movement, such as lithostratigraphy, structure, drainage density, slope, land use/cover, etc.; understand the nature and performance of aquifers based on tubewell and dugwell data; and delineate the prospective ground water zones by integrating different controlling parameters along with the well data in the GIS environment. With the help of well data, collected from different government departments, different maps (static water table, aquifer thickness, well discharge, well specific capacity and well yield factor) were prepared. Subsequently, all the layers important from ground water occurrence and movement were digitized and integrated in the GIS environment using index overlay method. The weights to different units/parameters and themes were assigned depending upon their importance. With this integrated GIS analysis, ground water prospects map of the study area was prepared. The ground water prospects have been classified qualitatively as Excellent, Very Good, Good, Moderate and Limited.

Introduction

Lack of adequate safe water for drinking and agricultural activities, water supplies inhibits the progress of developing countries; causing considerable hardship to humans worldwide. In the present study, the satellite images (PAN and LISS III sensors) were digitally enhanced using various techniques to improve their visual interpretability. Enhanced images were visually interpreted to map different landforms and geomorphic units existing in the area and to understand the processes of their evolution. Other parameters which control the occurrence and movement of ground water, such as Lithology/Rock type, structure, land use/cover, drainage density were also interpreted using satellite imagery in conjunction with the

existing maps and literature; and different overlays were prepared. From the well data, collected from different government departments and analysed, different maps (static water table, aquifer thickness map, well discharge map, well specific capacity and well yield factor) were prepared. Subsequently, all the layers important from ground water occurrence and movement point of view were digitized and integrated in the GIS environment using index overlay method. The weights to different units/parameters and themes were assigned depending upon their importance. With this integrated GIS analysis, ground water prospects map of the study area was prepared. The ground water prospects have been classified qualitatively as Excellent, Very Good, Good,

Moderate and Limited. The ground water prospective zones are essentially located in the intermontane Doon valley area, especially in the lower part under semi-confined to confined conditions. The denudo-structural hills of the Siwaliks and Pre-Tertiary rocks and residual hills of old Doon gravel form essentially the run-off zones, wherein the prospects exist only along the valleys/topographic lows, suitable geological structures, springs and seepage zones. The synoptic view provided by the satellite imagery helps in understanding and correlating various landforms, which cannot be readily observed from the ground due to limited range of observation.

Objectives

The main objectives of the present study are to-

- i) identify and map different landforms/geomorphic units and understand the geomorphic processes involved.
- ii) identify and map other parameters controlling the ground water occurrence and movement, such as lithostratigraphy, structure, drainage density, slope, land use/land cover, etc.
- iii) understand the nature and performance of aquifers based on tubewell and dugwell data.
- iv) delineate the prospective ground water zones by integrating different controlling parameters along with the well data in the GIS environment.

The study area

The study area covers eastern part of Doon valley and its surroundings having association with lesser Himalayas in the north, Siwalik Hills in the south, River Ganga in the Southeast and Dehra Dun town in the west. It covers about 740 sq. km and is bound between 78°05'N and 78°25'E, and 30°05' and 30°30'N. It falls in SOI Toposheet Nos. 53J/3, 4, 7 and 8.

Data used

The following data have been used in the present study: (i) IRS-1C/1D PAN & LISS-III data, (ii) SOI

Toposheets (53J/3, 4, 7 & 8), (iii) Well data from UP Jal Nigam & Garhwal Jal Sansthan, and (iv) information collected during selective field checks.

Methodology

The methodology adopted in the present study is given as a flow chart in Fig. 1. The various steps involved are briefly described below:

Problem identification - water is more versatile, vital and abundant for the existence of all forms of life. With increasing demands on water from domestic, agricultural and industrial sectors, no natural resource, other than the quality and clean water, has perhaps given rise to deeper concern about its over-exploitation & conservation. It is in this context that the immense possibilities of utilizing the modern techniques of remote sensing and GIS as an aid in water resources survey are presently being realized & accepted. Considering the usefulness of remote sensing and GIS techniques coupled with the availability of data, approachability, etc, the eastern Doon Valley and its surroundings has been selected as study area for geomorphological and ground water studies.

Pre-field interpretation- The following procedure was adopted for preparing pre-field maps. Digital image processing, especially georeferencing, digital image enhancement and merging of PAN & LISS III data to improve visual interpretability. Visual Interpretation of IRS-1C/1D (LISS III) & PAN imagery of the study area for preparation of geology, structure, geomorphology, hydrology, and land use/cover maps, taking the help of existing map and literature. Preparation of base map with the aid of SOI Toposheet Nos. 53J/3,4,7 and 8 of Survey of India. Data transfer on base map in order to prepare the overlays of geology, geomorphology, and land use derived from imagery. Selection of critical traverses for field checks.

Field survey- The following procedure has been adopted during the fieldwork. The data of existing well was collected from Govt. Depts. (UP Jal Nigam and Garhwal Jal Sansthan). Verification of lithological and geomorpho-

logical units, geological structures land use/cover was done by taking traverses mainly along the roads; and well inventory of tube wells and dug wells in the field.

Post-field interpretation and GIS analysis- The following procedure has been adopted in this stage. Correction of pre-field maps by incorporating field observations. Tabulation of well data and preparation of maps on (a) iso-depth to static water table (b) iso-discharge, (c) iso-aquifer thickness (d) iso-specific capacity and, (f) iso-yield factor. Preparation of slope map (amount and aspect) based on SOI Toposheets, digitization of thematic layers, index-overlay, output generation and report writing were done in a sequential order.

Georeferencing- In a raster model, spatial data are organized in grid cells or pixels, a term derived from picture element. Pixels are basic units for which information is explicitly recorded. Pixels in a raster map have the same dimensions. Hence, storing all their coordinates is not needed as the pixels are arranged in a regular pattern. It is enough to determine the pixel size and the parameters to transform between X and Y coordinates of a map and the pixel locations in the raster map (rows/lines and columns). The process to establish this relationship is called georeferencing. Through georeferencing we calculate the parameters used in the equations to transform between a coordinate system and pixel locations in the image. Initially, the IRS PAN image was georeferenced with the Survey of India Toposheet Nos. 53J/ 3,4,7,8 using reference points in software used for this purpose. Subsequently IRS LISS-III data was co-registered with the already georeferenced PAN image.

Digital image enhancement- Digital image enhancement produces new enhanced images, having better interpretability than the original image. In the present study, digital image enhancement techniques, namely linear contrast stretching, histogram equalization, principal component analysis, inverse principal component analysis, decorrelation stretching, ratioing have been used.

Data Fusion- or data merging is the process of combining, digital data by modifying the data values, using a certain procedure. Before starting the fusion process, data should be properly co-registered. There are several fusion techniques in literature, e.g. principal component transform HIS transform, brovey transform, etc. The IHS transform is commonly used for merging two data sets at different spatial resolutions. In this technique, intensity-hue-saturation, the intensity-hue-saturation, the insentity component is commonly replaced with high resoulation data set is transformed back into the three primary colours. The fusion can be achived through the two data sets in the form of a colour composite. The results are again displayed again as a colour composite. In the present study, IRS PAN & LISS III data have been merged using HIS technique, mentioned above. This image, by providing the multi spectral information from PAN data, proved to be highly effective and optimal image for most of the interpretation purposes.

Slope analysis

As the terrain slope plays an important role in characterizing the nature of the terrain, landforms and hydrological conditions, the slope amount and slope aspect maps have been prepared using SOI Toposheets. The slope amount map has been taken as one of the inputs in GIS analysis for delineating the prospective ground water zones.

Slope amount- The steps followed to prepare slope amount and slope aspect maps of the study area are:-

Step I: Digitization of contours and spot heights from the georeferenced SOI Toposheets (53J/3,4,7&8) in separate layers.

Step II: Defining the heights in the attribute tables of the concerned layers.

Step III: Creation of Triangulated Irregular Network (TIN) model from the digitized contours and spot heights. Drainage map is also considered for better representation of TIN model.

Step IV: Derivation of Slope Amount and Slope Aspect from the TIN model.

Step V: Reclassification of slope amount and slope aspects in the appropriate classes.

In Doon Valley area, slope ranges from 0° to 5°, with local variations. The slope class 3 (2°-5°) is normally found in the piedmont zone. Greater than 5° and upto 20° slopes are found in the lower part of the Lesser Himalaya. In Siwaliks, slope ranges from 5°-10°, and in both Residual Hill of Older Doon Gravel and Residual Hill of Pre-Tertiary rocks, slope ranges from 10°-20°.

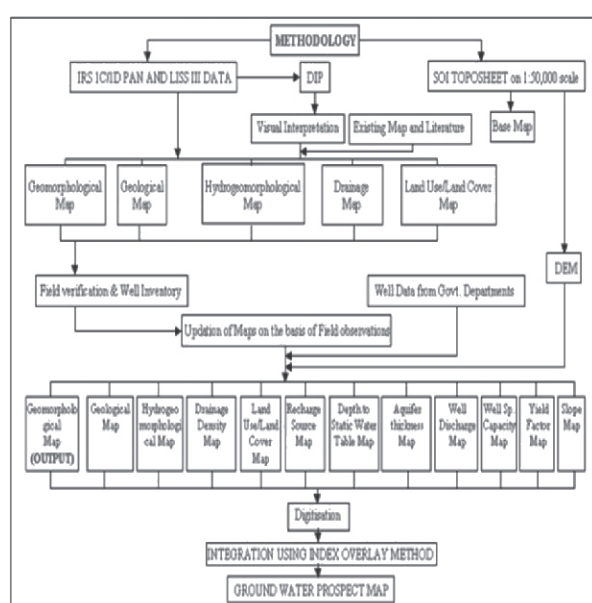


Fig. 1 Methodological Steps

Hydrogeological characteristics

The accumulation and movement of ground water is controlled by litho logy, structure, degree and nature of weathering/deposited material,, drainage pattern, relief, vegetation, climate, land use etc. Hydro logically the area is divided into three categories: consolidated rocks, semi consolidated rocks, and unconsolidated sediments

i) Consolidated rocks- The Pre-Tertiary Lesser Himalayan rocks are exposed in the northern part of the study area from this hydrogeologic unit. They exhibit high relief, rugged and moderately dissected topography. The drainage is sub- dendritic to dendritic, often controlled

by joints and fractures. The pre-tertiary rocks consist of quartzite, sandstone, greywacke, slates, shales etc. The rocks are very compact and do not Many springs are noticed and the area acts mainly as run-off zone.

ii) Semi consolidated rocks- It covers very little part of study area Siwaliks rocks falling in the south-western corner of the study area from this hydrogeology unit. These rocks exhibit moderate relief and dissection. are classified as semi-consolidated rocks, exposed in south part of the area high The drainage is parallel to sub-parallel. It consists of sandstones, conglomeratic boulder bed and clay due to high slope,. The high drainage density indicates that the formation acts as mainly as run-off zones and has poor in ground water prospects. Seasonal springs are occasionally seen.

iii) Unconsolidated sediments- The central part of the study area, situated between Pre-Tertiary and tertiary formations. It consists mainly of sand and with boulder, silt and clay gravel deposited by the rivers, Song, Suswa and Jakhan Rao forms the piedmont zone. Low relief, intense land use, moderately vegetated, coarse, and parallel to sub-parallel pattern of drainage is the character of this zone. Loosing and gaining of river system indicates that the area is good potential for ground water development. Shallow aquifers occur under unconsolidated conditions and deeper aquifers mainly occur under semi-confined conditions. At places, perched aquifers are also present. The water table is deeper in the upper, Doon Valley Fan as compared to the Lower Doon Valley Fan and near the flood/ alluvial plains of rivers.

Mode of ground water development

The water is abstracted from the unconfined and confined aquifers through dug and tube wells. In most part of the study area covered by the loose sediments, where intensive agriculture practices exist, source of irrigation is mainly canal water. Most of the dug wells and tube wells existing in the area are meeting the domestic requirement. However, few private and govt. irrigation tube wells do exist in the area.

Well data- Well inventory data has been collected from different govt. departments (UP Jal Nigam and Garhwal Jal Sansthan) and during field survey in order to study the subsurface nature of the area and to know the performance of wells. The location map of wells which have been observed during field checks or for which the data are available from govt. departments. The details of dug wells and tube wells have been tabulated separately and are discussed below.

Dug well- During the fieldwork, various dug wells were examined and inventory was carried out in order to study the behavior of unconfined aquifers in the study area. Collected data has been tabulated.

Tube well- Tube well data was collected in order to study the subsurface nature of the area and discharge, depth to static water table, draw down, aquifer thickness, their ranges etc. The result indicates that the ground water flow is towards Song river in the Lower Doon valley fan and later towards river Ganga. The study areas show that the thickness of the aquifers, near Doiwala and Lal Tapper is more than 40m. At Joli grant, Ranipokhari, Ghammandpur is around 30 m and is about 35m at Bhaniyawala. The thickness of aquifers is more in Lower Doon Valley zone than upper zone. Similarly the specific capacity show that around Doiwala Specific Capacity is about 1200lpm/m Joligrant, Ranipokhari area exhibit low specific Capacity is about 400 lpm/m. Well yield factor contours showing that yield is high at Doiwala and Surrounding area about 35lpm/m/m) but at Joligrant, and Ghammandpur it is about (30 lpm/m/m). Yield is also high at Raipur, Rishikesh area.

Water Quality- In order to study the water quality of study area, chemical data has been collected. In the study area, vast areas of intensive irrigated- cropland agricultural land, with associated fertilizers and pesticide applications, combined with the usual problems of run-off, landfills and various non-agricultural source of pollution, pose a threat to precious ground water reserve. In Balawala and Nakraonda areas water is slightly brackish.

Whereas, In Soura-saroli area water is slightly alkaline.

Hydrogeomorphology

Geological and geomorphologic set up facilitates the determination of hydro geological condition of the area. Based on morphological, Well Iso-line and litho logical factors, hydrogeomorphological map of the study area has been prepared and after grouping the lithological and geomorphic/landform units, the hydrogeomorphologic unit has been basically divided into the following 3 zones: a) Recharge/Discharge zone, b) Recharge zone, and c) Run-off zone.

a) Recharge/Discharge zone- It includes active flood plain/river Bed, channel/braided bar (Recent alluvium) and valley (inter montane). Coarse textures material and braided drainages indicate high channel-bed infiltration resulting in base flow. Therefore the river beds appear dry, in lower reaches. Some parts are highly porous and permeable with good recharge potential. Ground water occurs under unconfined perched water table and semi-confined conditions.

b) Recharge zone- It includes older alluvium, Doon gravels. This is traversed by seasonal, coarse braided streams signifying, higher recharge potential through underlying deposits. It is an important recharge-infiltration zone. It also consists of productive aquifers. Dug wells tap unconfined aquifers to few perched patches occurring at several places, and tube well taps semi-confined aquifers.

c) Run-off zone- This zone include mainly residual hill, Denudo- structural hills, Older Doon gravel, is dominantly forming a zone of surface run-off, There are a number of perennial and seasonal springs, in this zone. Ground water prospects in this zone essentially exist. Along the valleys topographic lows and suitable geologic structures.

This hydrogeomorphological map has been used as one of the main inputs for preparing the ground water prospects map while doing the integrated analysis of all the controlling parameters in the GIS environment.

Recharge source

Recharge Source map of the study has been prepared as under: This map shows (i) areas receiving direct recharge from rainfall and (ii) areas receiving direct vertical recharge from rainfall and canal irrigation.

Integrated analysis in GIS environment

A direct consequence of integrated geoinvestigation approach has been realization of Geographic Information System (GIS). A GIS can be defined as an automated tool for efficient storage, analysis and presentation of geographically referenced data. In a comprehensive sense, GIS means identifying data needs, acquisition of data, management, processing and decision-making. In the present study, various thematic maps have been integrated in GIS environment in order to delineate the prospective ground water zones. The details are given in this chapter. For digitization and integration, ARC VIEW (Version 3.2a) software has been used.

Themes used for integration

The following themes which are important for characterizing the ground water regime of the study area, have been digitized in different layers:

1. Hydrogeomorphology, 2. Drainage density, 3. Depth to static water table, 4. Well discharge, 5. Well aquifer thickness, 6. Specific capacity, 7. Yield factor, 8. Slope, 9. Recharge Source, 10. Land use/Land cover.

All the above themes have multiple classes. These themes/layers have been converted to raster form before doing the integrated analysis.

Method of data integration

In order to integrate various thematic layers index overlay method has been used. A rating has been developed for the integration of these thematic maps. A numerical rating system ranging from 1 to 10 have been assigned to various classes of individual themes, it is based on degree of influence of individual categories on ground water regime of the region. Secondly,

all the thematic maps have assigned a weightage factor, depending on the importance of themes. The final integrated output in raster format was classified into classes showing different ground water prospectives.

Index overlay method

This model is applied where maps are added together in a weighted combination. In this simplest type of weighted model, input maps are binary and each map carries a single weight factor. However, multi-class maps are also can be used, each class of every map is given a different rating score. This method allows more flexible weighting system. In case the map classes occurring in each map are assigned different score, as well as the map themselves receiving weights, the average score can be defined as:

$$S = \frac{\sum_{i=1, j=1}^{n, m} S_{ij} W_i}{\sum W_i}$$

Where, S is the weighted Score, W_i is the weight of the i th input map, S_{ij} is the rating score for the j th class

(Note: S is the weighted score for our area object (polygon, pixel), W_i of i th input map, and S_{ij} is the rating score for the j th class of the i th map. The value of j depends upon the class actually occurring at the current location. Each map must be associated with a list of scores, one per map class. Class scores can be put into an attribute table of the individual layers).

Results

After assigning the score to different units/classes in occurring in each theme, all the 10 layers were integrated in the ArcView software using index overlay method described above. Here towards giving the weights each theme, we followed two methods: i) all the themes were given the same weights, ii) different weights were given to different themes depending upon the themes importance.

Using the above weighting systems, weighted scores were worked out and reclassified to represent different ground water prospects existing in the area (See Table 1).

The high ground water prospects mainly exist in

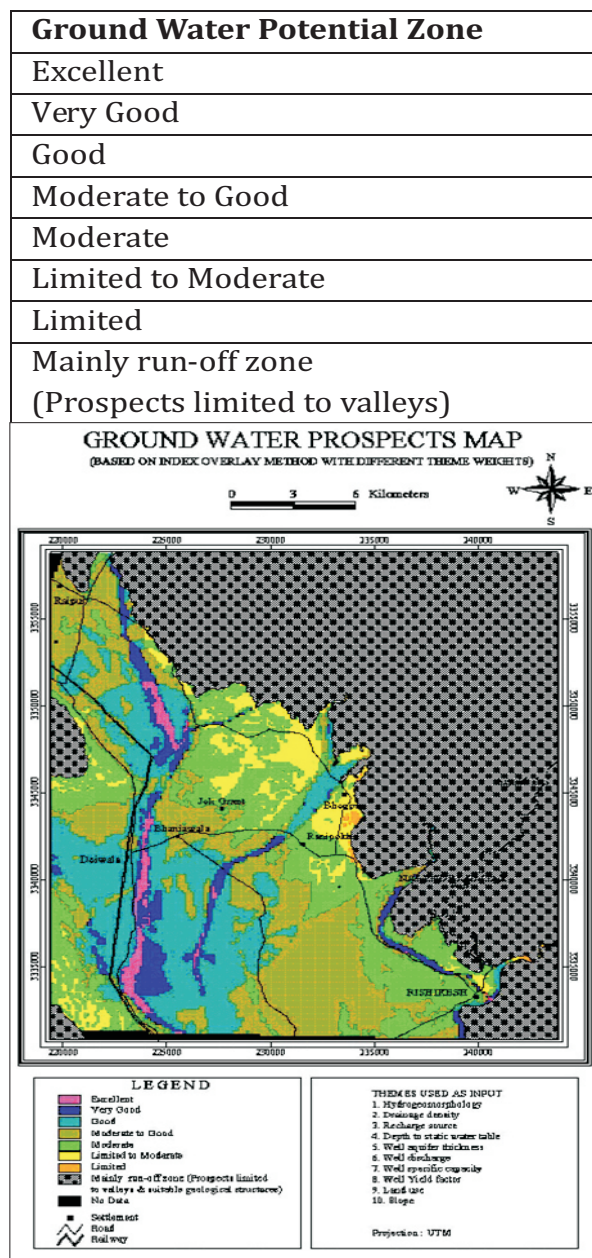


Fig. 2 Ground water prospect zones

the lower part of the Doon Valley fan and alluvial/flood plains of present rivers (Fig. 2). The denudo-structural hills of Siwaliks and Pre-Tertiary rocks, and residual hills of old Doon

gravel and essentially from the run-off zones. The ground water prospects in these zones are limited to only along valleys/ topographic lows, suitable geological structures, the areas near the springs, also form the suitable zone for water resources development.

Concluding remarks

Remote Sensing and GIS techniques are useful tools in geomorphological and ground water studies. Based on visual interpretation of satellite, different landforms/geomorphic units have been identified and mapped in the study area, viz. denudo-structural hills (moderately/highly dissected), residual hills, upper doon valley fan, alluvial plains, flood plains, channel/point/ braided bars, plaeochannels, etc. The denudo-structural hills are basically formed by the Siwaliks and Pre-Tertiary rocks. Residual hill is formed by the old Doon gravel. The central and southern hill is formed by the old Doon gravel. The central and southern part of the area is occupied by the Doon Fan. The area on either side of the major rivers like Song and Jakhan Rao is characterized by fluvial deposits. The distribution and type of land forms/geomorphic units as mapped from the satellite data in conjunction with the field checks helped understanding the geomorphic processes involved in carrying out the present day topography. Integrated approach of Remote Sensing and GIS in conjunction with the available well data helped in delineating the prospective ground water zone in the study area. Productive aquifers in the study area are mostly confined to the lower part of the Doon Valley Fan and to the active flood plains/alluvial plains of major rivers like song River and Jakhan Rao river, wherein the ground mainly occurs in unconfined and semi-confined conditions.

(Dr. Deepak Kumar Mandal is Associate Professor, Department of Geography & Applied Geography, University of North Bengal, Darjeeling- 734013
E-mail: dkmandal_geo@yahoo.co.in)

Slum Mapping and Remote Sensing and GIS Technology

Debjani Mitra and H.R. Betal

Abstract

The modern technologies of remote sensing and GIS allows us to collect data/information with speed repetitively and map that information, which in turn can be used as an effective tool to map phenomena like urban poverty for making location based planning and management decision for alleviation of poverty. Slums, which constitute the physical manifestation of urban poverty, emerge mainly due to rural-urban migration in search of better employment and economic opportunities. Overcrowding, lack of proper sanitation, drinking water and sanitation conditions are some of the common problems of the areas.

The paper argues that any slum improvement approach should aim at up gradation of slums instead of slum clearance. The main aim of the present paper is to demonstrate the role of remote sensing and GIS as a tool for effective planning and management of the slum environment.

Introduction

According to an estimate, the less developed regions of the world will account for nearly 80 per cent of world's urban population by 2030 (UNPD, 2008). Annually, world urban population is increasing by about 70 million persons, needs to be provided with shelter, employment and basic urban services. But the low financial and management capacity of most cities in the developing world means that more than half of the needs remain unattended. In such a situation, the informal sector is providing most of the employment and housing in environments that have come to be known as informal settlements or slums.

Slums are neglected parts of cities where housing and living conditions are appallingly poor. Nevertheless, there is hardly any universally accepted definition of slums. The definition varies in time and space. According to the UN-HABITAT (2002 b: 21), a slum is defined as a contiguous settlement where the inhabitants are characterized as having inadequate housing and basic services. A slum is often not recognized and addressed by the public authorities as an equal part of the city. It is an area, which combines the following characteristics:

- insecure residential status;
- inadequate access to safe water;
- inadequate access to sanitation and other infrastructure;
- poor structural quality of housing; and
- overcrowding

In India, a slum is a compact area of at least 300 populations or about 60–70 households of poorly built congested tenements, in unhygienic environment usually with inadequate infrastructure and lacking in proper sanitary and drinking water facilities.

Globalization that stimulates inequality, rapid population growth rates due to natural increase and rural urban migration, unemployment and unequal distribution of income and wealth are some of the reasons why a slum exists. The urban centers of India have become enclaves of economic power, which attracts and depends on migrated rural labor for its own day-to-day economic survival. It is not only the rural-urban income differentials that activate the push and pull factors, but other factors such as access to basic facilities and amenities trigger off the rural– urban and urban–urban migration and formation of informal settlements.

People often live in extremely overcrowded and

in squalor conditions in slums, often situated on marginal and dangerous land. Here people do not have access to adequate housing, safe drinking water and sanitation. Their waste not only remains untreated, it surrounds them and their daily activities and affects their health.

In spite of improved urban governance, social attitude and organizations, conditions of people living in the slum or the slum environment has not changed much. This failure is mainly due to lack of planning or effective strategy for urban growth monitoring among others. Inadequate information base about slums makes planning a difficult task. Remote sensing and GIS can be an effective tool in providing such information base for proper planning, management and improvement of slum environment.

Slum improvement program in India

The draft on National Slum Policy, 2001 recognizes that is an integral part of the urban areas and contributes significantly to their economy both through their labor market contributions and informal production activities. It is vital that all urban local bodies recognize the contribution of the urban poor in helping to build urban prosperity and make sufficient provision for them to have access to affordable land, house sites and services. The present planning and development framework is exclusive of slums and views them as “problem areas” requiring corrective action. The draft on National Slum Policy thus endorses an upgrading and improvement approach in all slums. It does not advocate the concept of slum clearance except under strict guidelines set down or resettlement and rehabilitation in respect of certain slums located on untenable sites.

Objective of the study

In the absence of proper information, the slums are considered as chaotic masses rather than coherent urban areas. To address this issue, an effort has been made through this study for collecting information on slums for inclusive urban planning. The study aims at integration of the information collected on slums in GIS

environment, which is a powerful tool for integrating low-income settlements (i.e. Slum areas) into urban planning and development.

Methodology

The following methodological steps are involved in the study:-

- The Santrapara Line Dhar Slum area of Chandernagore Municipal Corporation, District Hugli (West Bengal) selected for the conduct of the study consisted of 23 households.
- The map boundary was of slum area marked on Google Earth.
- Thereafter each and every slum household was digitized on this map. A map containing physical features of the slum area was prepared showing the surrounding information.
- Information on streetlights, water points, roads and drains was collected, compiled and then incorporated in the map.
- A door to door survey was conducted to collect information on socio-economic characteristics of each of the slum households.
- The data was compiled as fact sheets and attached to each household in map.
- The conduct of door to door survey of the entire 25 slum household was undertaken during February-March, 2011.
- Socio-economic variables on which data/information was collected from the slum households include: material used in construction of roof, wall and floor of the house, number of rooms in slum household, income level of the household, and number of houses served by the each water point of the slum area.

Slum mapping and planning: RS & GIS applications

The use of RS & GIS to map, plan and manage urban areas is quite common at the level of the

local authorities in developed countries but in developing countries very few local authorities have invested in RS and GIS in planning mainly due to high cost and lack of training facilities.

A map of a typical slum will show the physical features of the area; but tells nothing about its inhabitants and their socio-economic conditions, vital for planning. Again only depicting socio-economic conditions of the slum dwellers with no idea of their location and other physical conditions of the slum would be meaningless. With the integration of RS & GIS technology, a slum becomes a living entity. By clicking the boundary of the slum, information about the slum's location, total population, income structure, language spoken, caste, religion etc. can be obtained. Apart from connecting household level information to each house on the map, a detailed map of the settlement showing manhole points, street lights, water points, toilet blocks, streets, drains etc can also be incorporated.

A major advantage of GIS is that it enables us to run queries, providing not just information but "intelligent information" on GIS platform (Rasika Dhavse, 2003).

For the present study the Santrapara Line Dhar slum of Chandernagore Municipal Corporation, Hugli district, has been surveyed and mapped.

Analysis of socio-economic data helps in the proper planning of the slum. From these data we can have a clear idea about the income structure, tenure of dwelling and their condition of living (see Figs. 1, 2, 3, and 4).

A buffer map has been created to show the number of houses served by the water point of the slum. A 30 meters and 60 meters circles are

drawn around the water point showing the number of houses covered.

Conclusion

Urban planning over the years views slums as problem and chaotic areas. Nonetheless, most of the urban developmental programmes are exclusive of slums, this view and approach needs to be changed. There should be a more enabling approach to the delivery of basic services to the urban poor. For this, there should be a proper information base. In this context, RS and GIS technology can be an effective tool in urban planning and management by analyzing spatial information in conjunction with relevant socio-economic information.

Acknowledgement

Thanks are due to Ms. Sanchita Mondol, M.A. Final (Geography) student, Chandernagore Govt. College for the collection of necessary socio-economic data of the slum area.

References

1. Dhavse, R., (2003). Intelligent Information, India Together, available from Draft National Slum Policy, Oct. 2001, <http://urbanindia.nic.in>
2. Joshi, P., and S. Sen (2002). "Experiences with surveying and mapping Pune and Sangli slums on a geographical information system", **Environment and Urbanization**, 14(2), pp. 225-240.
3. Sharma, R.N., and K. Sita (2000). "Cities, slums and government", **Economic and Political Weekly**, 35(42), pp. 3733-3735.
4. Verma, R.K., S. Kumari, S. and R.K. Tiwary., Application of Remote Sensing and GIS Technique for Efficient Urban Planning in India, available from www.csre.iitb.ac.in

(Dr. Debjani Mitra is Assistant Professor at Department of Geography Chandernagore Govt. College Chandernagore, Hugli, and Professor H.R. Betal is a former Professor of Geography, University of Calcutta, Kolkata

Email: Debjanimitra77@yahoo.com)

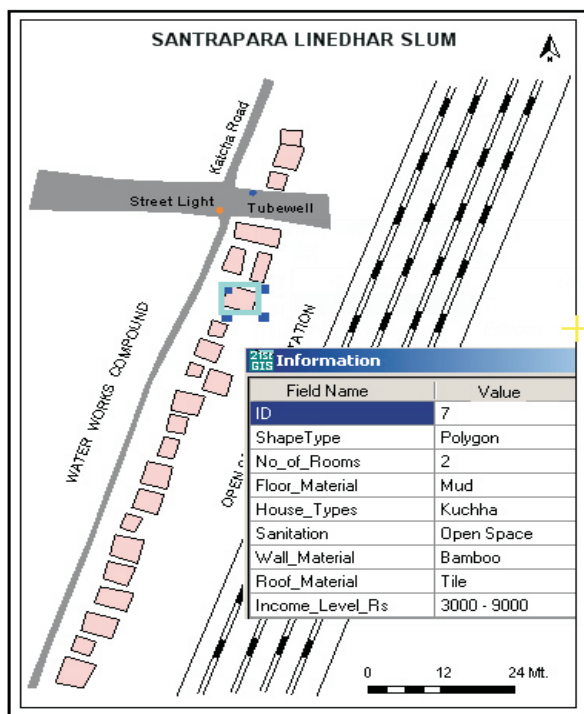


Fig.1 Socio-economic data have been superimposed on physical features map of the area. The dialogue box popped out by clicking on one random house of the slum provides the detailed information about the household. GIS has capabilities to show the information which is visually clear and attractive.

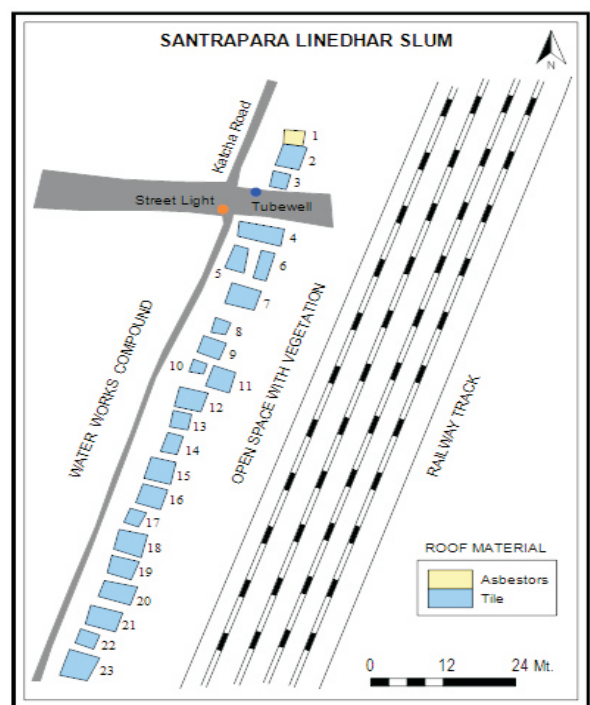


Fig.2 Roof material used in construction of houses in Slum area.

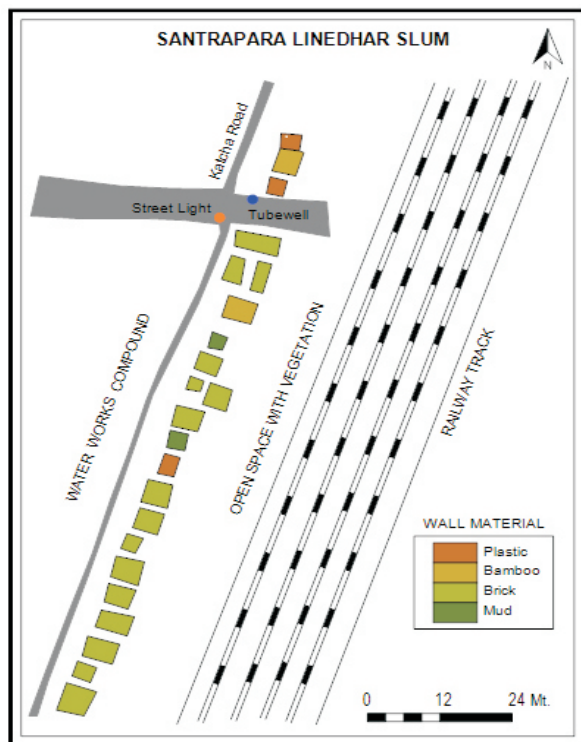


Fig.3 Wall material used in houses in slum area

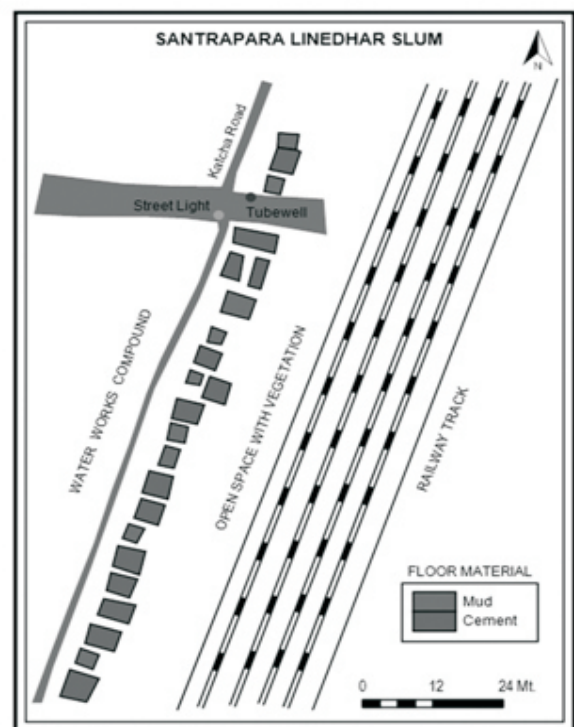


Fig. 4 Floor material used in houses in slum area.

Assessment of Vulnerability and its Impact on Livelihood Caused Due to Shifting Channel of River Ganges in Malda District (West Bengal) using Geoinformatics

Chhanda Dey, Jatisankar Bandyopadhyay

Abstract

Vulnerability in Malda district is closely associated with the shifting course of the river Gange, affecting directly livelihood opportunities of the people living in the area. The study examines the shifting of river course and its impact on human displacement using Geoinformatics (remote sensing and GIS technology). Land sat (Thematic Mapper) data was used to detect river course at different time intervals; and supervised classification technique adopted to generate land use/land cover map. An overlay analysis was performed to map the changes in land cover features within the affected area.

The huge displacement and environmental destruction, caused by the river bank erosion, are the prominent features found in the study area. Application of geoinformatic techniques, applied to measure the spatial shift in the river course due to the left bank erosion of the fluvial channel, proved effectively. In the year 1980 the amount of maximum bank length affected was approximately 7.0 kms, which increased to 10 kms in 1998; resulting in phenomenal increase in the amount of land loss (from 105 hectares to 330 hectares during 1980-1998). The paper recommend for the integrated development strategy to control rapid bank erosion.

Introduction

Malda is the most vulnerable district of West Bengal in terms of natural disaster or physical calamities. The Ganges, considered the life line of India, enters near Ratua Block in the District and covers 76 kms path on it's left bank before engrossing through the region and falling into the another district.

We have introduced here the term 'vulnerability assessment' to identify and analyse the shifting pattern of people and their livelihood. Vulnerability refers to the probability of being negatively affected due to the various natural disasters. Vulnerability assessment is nothing but the assessing of the response magnitude between diverse components of the natural calamities along with the human interaction. Exposure, Sensibility & Adaptive capacity are the few parameters, chosen for the purpose of analysis of the complex system response between physical or natural component with the demographic profile/characteristic of the study area. In Malda District sustained economic

losses and human displacement are the direct consequence of river erosion or flood.

Background of the study

Due to the low velocity and near flat gradient, the Ganges meanders and have a clear cut tendency to erode concave side of the bend, leaving convex side to depositional remnants. The erosional activities of the river are not static. It changes with change in volume of water and frequency of mass movement caused by the hydraulic action. Variation of discharge ranges from about 1,800 cusec meters during January to maximum 79,450 cusec meters during Monsoon months (Iqbal, 2010). It has been observed through bank line survey and old maps since 1922-23 that the river has normally been changing its course except at two points, viz. at Rajmahal and Farakka. The map shows that the direction of flow of the Ganges between Rajmahal and Farakka was more or less straight. Historically, the River direction began to change during 1948-1950 with a prominent tendency to swing to the left below the Rajmahal and to the right

below the Farakka. It is also confirmed by the survey made at that time. Again during 1967 to 68, the bank line had moved considerably towards the left below Rajmahal in the Rajmahal-Farakka reach and towards right below the Farakka, confirming the tendency of shifting.

Objectives

The main objectives of the study are to:

1. Study the shifting channel of the Ganges near the riverine tract of Malda district;
2. Estimate the losses of human livelihood caused by natural disaster;
3. study the association between hydraulic action of the river with the demographic characteristics; and
4. Investigate the spatio-temporal changes of environment.

The study area

The present study has been carried out on Malda District, the southernmost district of North Bengal (Jalpaiguri Division). The latitudinal extension $25^{\circ}32'08''\text{N}$ to $24^{\circ}40'20''\text{N}$ and longitudinal $88^{\circ}28'10''\text{E}$ to $87^{\circ}45'50''\text{E}$. The Northern part of the district is bounded by Uttar and Dakshin Dinajpur districts of West Bengal and Purnea district of Bihar. Murshidabad district fall on its southern side while eastern part touches with the district of Dakshin Dinajpur and also with the Rajsahi District of Bangladesh. Western part is covered by the state of Bihar (Fig. 1). It covers an area of about 3733sq kms. There are 15 blocks in the district, Manikchak, Ratua-I, Kaliachak-II and Kaliachak-III being the most susceptible to natural disaster.

Climatically, Malda district is very hot during the summers and is characterized by Monsoonal rainfall. The normal rainfall is 1453.1mm.

Topographically, the district consists mainly of low lying plains, sloping towards the south with undulating area on the northeast. The river Mahananda divides the region into two parts: the eastern (known as 'Barind') and the western.

The Kalindri river divides the latter into:

northern (known as 'Tal') and the southern (known as "Diara"), which is very fertile and densely populated (DHRD, 2007). This portion is markedly affected by the hydraulic action of the Ganges.

The Ganges is the main river of Malda district. Fulahar and Mahananda are other important rivers, traversing the Tal region and also the Tangan and Punarbhava which drain the old alluvial uplands of the Barind. All the rivers are prone to seasonal flooding.

Methodology

Multidate LANDSAT Thematic Mapper (TM) data for the years 1948, 1990, and 2006 was acquired, rectified and registered in ERDAS IMAGINE-9.0 GIS software, with respect to top sheet (no. NG45-11 and NG45-15, series U502 on 1:250,000 scale. Following this, the study area is delineated from the satellite imagery using the subset extraction technique. Thereafter digitization was done to layout the

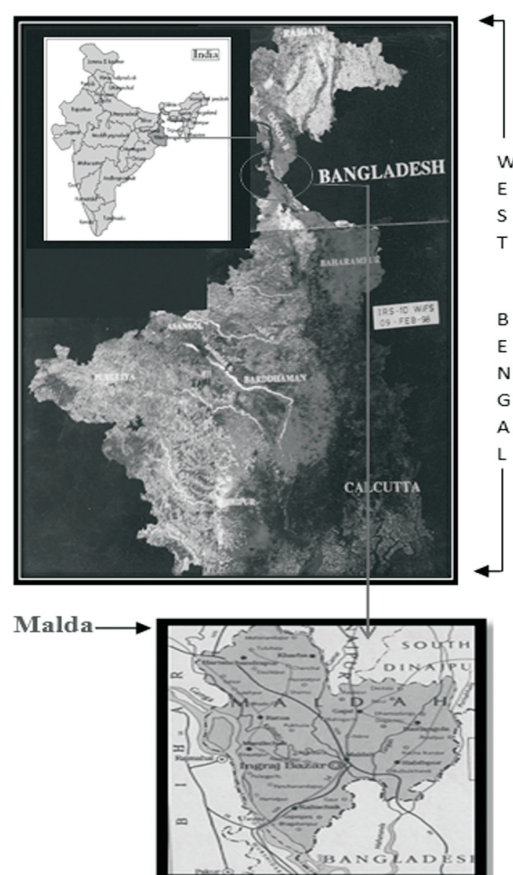


Fig. 1. Locational Setting of Study area

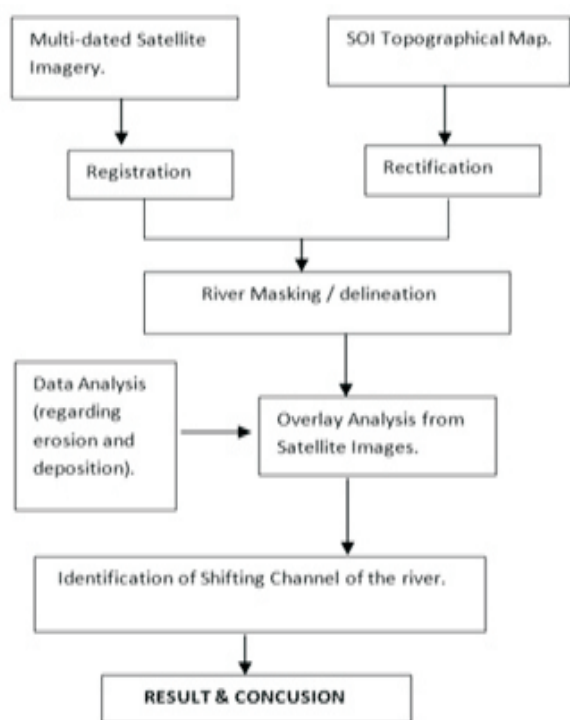


Fig. 2: Flow chart showing Methodological Steps

river on both sides from the different satellite imageries as well as from the top sheet. Then all the layers were overlaid to analyse the changing river course and also detecting the effect of bank line erosion (see Fig. 2).

Vulnerability assessment

Vulnerability, a function of the character and the rate of environmental degradation caused by the natural disaster, reveals the interaction between the nature and demographic characteristics to which a system is exposed to its sensitivity and adaptive capacity. To assess the vulnerability of the livelihood within the study area, we consider here the three parameters, namely, Exposure, Sensitivity and Adaptive Capacity.

A.Exposure: reflects the external factors to the system of interest or the factors by which a system is influenced externally i.e. shifting of river course, climatic condition and the construction of a barrage (in this case Farakka Barrage) are regarded as external factors for the changing pattern of human livelihood.

B.Sensitivity: is the degree to which a system gets affected. The effect may be direct or

indirect. Damages caused by the floods are considered as a factor upon which the degree of sensitivity is depends.

C.Adaptive capacity: is the ability of a system to adjust with the changing environmental conditions caused by the natural disaster. Adaptive capacity is dynamic in nature and depends on a combination of economic and social factors.

A.1.Shifting of River Course: is a long term phenomena near the riverine track of Malda district. We detected and earmarked the change in the river course from a long time period.



Fig.3: Showing the process of erosion



Fig. 4. Showing Formation of Char land

Manikchak and Kaliachak- II are the blocks where river is changing its form periodically. Shifting of river course plays a dual role of

erosion and deposition. Shifting of river course is prominent (see Fig. 5 showing the shift in river bank).

Depositional effect: Deposition of silt beds is found near the region where river course is narrower and it's free flow gets some obstacles result in the frequent rise of Diara Island. Bhutni, the largest island caused by the depositional activities of the Ganges, is located just below the Rajmahal hills.

A.2.Climatic Factors: Gangetic plains are affected by the monsoonal climatic conditions. The active presence of southwest Monsoon increases the amount of discharge of the Ganges by a factor of about 50 times, accelerating the rate of erosion and flooding that have a direct bearing on people and their livelihood.

Years	Maximum bank length affected (kms)	Estimated erosion width (m)	Land Loss (in hectares)
1979	5.0	200	60
1980	7.0	150	105
1981	11.0	400	260
1982	5.0	150	65
1983	5.0	200	90
1984	7.0	100	70
1985	6.0	150	90
1986	6.0	200	105
1987	8.0	300	240
1988	7.0	100	70
1989	10.0	150	150
1990	8.0	200	160
1991	11.0	150	170
1992	9.0	150	130
1993	7.0	200	145
1994	7.0	1250	160
1995	8.0	200	145
1996	15.0	250	310
1997	6.0	100	60
1998	10.0	900	330

Table.1: Left bank erosion by the Ganga in Malda district.

Source: Superintending Engineer, Farakka Barrage Project. In (Iqbal, 2010)

A.3.Farakka barrage: Huge displacement and environmental degradation takes place due to

the construction of Farakka Barrage. In fact, most of the rural settlements become refugee due to the construction of such a big dam. In present case, the Farakka Barrage blocked the natural flow of the Ganges and the leftward erosion increased at the time of high discharge of water (Parua, 1999). The rate of erosion in Malda district is shown in Table 1.

It is clear from Table 1 that while the maximum bank length affected in 1979 was about 5.0 kms, it went up to 11 kms in 1981, within a span of two years; and then rose to peak of 15 kms in 1996. Consequently, the amount of land losses also increased dramatically: 60 in 1979, 260 in 1981, 1250 hectares in 1994. However, the land loss was only 250 hectares in 1996, when bank length affected was the maximum (15 kms). The

Affected Blocks/Municipality	Area affected (sq.km)	GPs wards affected	Villages affected	Persons affected	Families affected
Kaliachak-I	140.5	14	195	300000	60000
Kaliachak-III	127	14	219	214664	44000
Ratua-I	183	10	198	200000	40000
Kaliachak-II	209	10	399	173000	37000
English Bazaar	220	11	144	170000	34125
English Bazaar(M)	12.1	25	85	170000	32690
Habibpur	110	9	485	140000	28000
Manikchak	230	8	99	140000	28000
Chanchal-I	111.46	8	191	107035	21407
Chanchal-II	170	6	101	106000	21132
Gazole	250	12	166	100611	21000
Ratua-II	101	8	75	85000	17000
Old Malda	77	5	91	77625	15525
Old Malda(M)	9.54	17	88	62325	16250
Harishchandrapur-II	212	9	74	75000	15000
Bamangola	50	6	50	55000	10640
Harishchandrapur-I	171	7	213	50000	10000
District Total	2383.6	179	2873	2226260	451769

Table.2: Flood damage during the 1998 floods in Malda district. (Impact on Blocks/GPs).

Source: Uttarbanga Unnayan Parshad, 2001. In (Iqbal, 2010).

amount of land losses achieved was the highest (330 hectares) in 1998, when bank length affected was only 10.0 kms..

B.1. Flood Effect: Malda has a long history of flood occurrences. During 1850-1899, six floods occurred in the district. The number went up to eight floods during 1900–1950. Again, there were 21 floods during 1971–2005, of which the flood of 1998 was the most devastating, when the river Ganges rose to a high water mark of 25.40 meters. This was followed by another flood in 1999, hitting different parts of the District. During the flood of 1998 more than 22 lakh persons were directly or indirectly affected, 4.4 lakh houses were either completely destroyed or suffered moderate to severe damage. There has been an extensive damage to standing crops in all the blocks of the district, amounting to a cumulative area loss of 1.48 lakh ha. Tables 2 and 3 show the flood damage during 1998 flood in the district.

It is clear from Table 2 that the vast affected areas by the flood in 1998 were falling in the development blocks of Gazole (250 sq.km), Manikchak (230 sq.km), and English Bazaar (220 sq.km). 179 GPs or ward and 22.3 lakh persons were affected due to the cruelty of flood in Malda district.

Thus in terms of duration and frequency of flood recurrences, the district of Malda can be called termed as a Chronologically Flood Affected Area (CFAA) on the basis of the criteria suggested in the 'Report on the Development of the Backward Areas in India, set by the Planning Commission, Govt. of India, 1981(DHRD, 2007).

Adaptive Capacity: refers to adaptation capability of human beings to survive with the changing environment. From the previous discussion, it is clear that river bank shifting and floods are the two major factors governing the land forms being either eroded or deposited. It has been observed since the construction of Farakka Barrage in 1962 that the intensity of erosion has increased enormously. The encroachment by the Ganges has wiped out a

large chunk of fertile land. Settlements have also been destroyed in the district. Manikchak, Kaliachak-III and Kaliachak –II are badly affected blocks of the Malda district. A large number of people are displaced from their actual locations due to the destructive nature of the river course. Most of the victims due to erosional process migrate to Chars losing everything to the river. A few people start agricultural activities with a hope for the new beginning (DHRD, 2007). A large number of so called environmental refugees are living below the poverty line. Erosion victims are suffering from the problems like the lack of sanitation, safe drinking water facility, education and medical care. Homelessness often cause an over supply of agricultural labour. Paddy, pulses, vegetables, water melons are the main agricultural product. Some of them are engaged as a daily wage labourer. The conflict over the possession of Char land is common feature in the social life on Char (Rudra,2000).The place where river marked as a boundary between two states gave birth a socio-political issues due to the bank line failure and the neo -refugees use to enjoy the dual identity (from Jharkhand and West Bengal states).

Results and Discussion

After studying the whole region it can be said that the natural calamities or disaster have dual impact on the life and livelihood of people in Malda District, causing vulnerability. In a large part, where the majority of people are vulnerable, especially the poor are living constantly under the grip of uncertainty caused by the occurrence of floods. Table 3 shows that most of the blocks are lying on in that part where the suffrage due to repeated loss to standing crop, residential buildings and livestock's are quite high. On the other hand, along the bank line that is owned by another section of vulnerable people whose lands and livelihood had already been collapsed permanently due to the evil effect of riverine erosion. The impact of natural calamities on this second group is far more vital compared to the previous ones. This is one of the

Affected Blocks/Municipality	Houses fully damaged	Houses partly damaged	Crop damaged moujas	Crop damaged area (hec)	Human lives lost
Kaliachak-I	18000	28500	66	3050	18
Kaliachak-III	11225	19575	74	10690	7
Ratua-I	31075	5025	101	15000	4
Kaliachak-II	35000	1720	48	5130	10
English Bazaar	30358	3100	146	6400	4
English Bazaar(M)	937	6927	-	-	-
Habibpur	17000	11000	103	9500	-
Manikchak	12509	15491	184	12860	15
Chanchal-I	10870	4600	91	11850	2
Chanchal-II	11762	9370	92	12600	1
Gazole	8197	7994	123	21231	3
Ratua-II	68000	10000	51	10500	4
Old Malda	1495	13970	100	7000	3
Old Malda(M)	3920	11530	-	-	-
Harishchandrapur-II	4000	6000	54	8300	-
Bamangola	2500	4500	84	9492	-
Harishchandrapur-I	3000	6000	44	5205	-
District Total	269848	165302	1361	148808	71

Table.3: Flood damage during 1998 floods in Malda district. (Impact on Household & Livelihood).

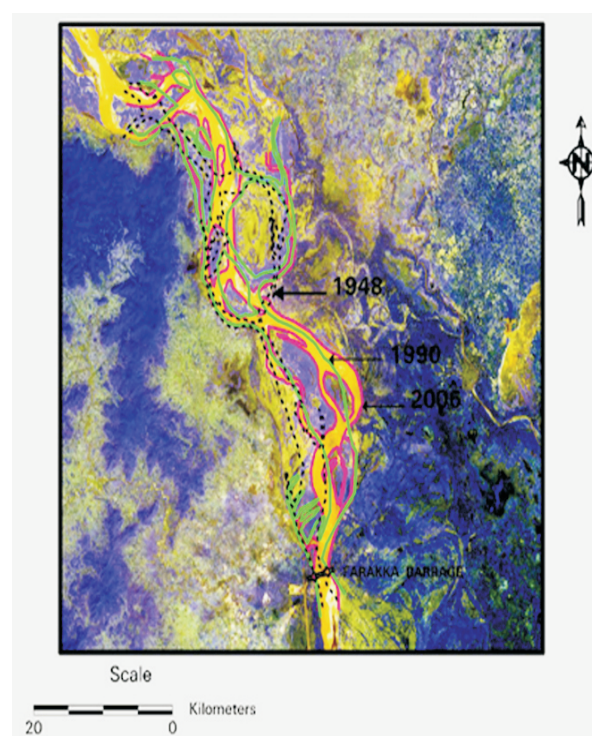


Fig. 5 showing shifting of River bank

reasons for the underdevelopment of the study area. Due to the land loss land, cultivating households are compelled to become wage labourer due to the loss of their land loss. Due to the lack of job opportunities and economic instability most of the Young people prefer to migrate to nearby towns or metros. People who have already lost their houses due to the evil effect of riverine erosion prefer to stay in some outskirts regions after converting the agricultural or crop land for residential purposes. The amount of conversion of agricultural land into settlement land is higher in Gajol Block (9.6 hectares), followed by Englishbazar (6.64 hectares). From all this, it is clear that the land use pattern and the livelihood of the people both are changing day by day with change in the amount of land loose and human demand for survival with the changing environment.

Conclusion

Geoinformatics has the great potentiality to study the changes taking place both in the natural environment and livelihood pattern of the people in study area. Manikchak and Kaliachak- II are the blocks in Malda district where the river Ganges is changing its form periodically. Shifting of river course plays a dual role, as an active agent of erosion and also an agent of deposition. Such a kind of depositional and erosional behaviour of the river make the people in the area environmental refugees to become vulnerable to the furies of the nature. This study may be useful for the purpose of future planning and assessing the vulnerable regions.

atics has the great potentiality to study the changes taking place both in the natural environment and livelihood pattern of the people in study area. Manikchak and Kaliachak-II are the blocks in Malda district where the river Ganges is changing its form periodically. Shifting of river course plays a dual role, as an active agent of erosion and also an agent of deposition. Such a kind of depositional and erosional behaviour of the river make the people in the area environmental refugees to become vulnerable to the furies of the nature. This study

may be useful for the purpose of future planning and assessing the vulnerable regions.

References

1. Basu, S.R. (2001): "Impact of Farakka barrage on the Bhagirathi-Hugli and the port of Calcutta", In **Impact of Man on Environment: Some Cases of Concern**, published by Prof. R.N. Dubey Foundation, Dept. of Geography, University Allahabad, Allahabad, pp.39-68.
2. "Human Vulnerability in Malda District", the Malda **District Human Development Report 2007**, Chapter 7. pp. 1- 23.
3. Iqbal, S. (2010): "Flood and Erosion Induced Population Displacements: A Socio-economic Case Study in the Gangetic Riverine Tract at Malda District, West Bengal, India", **Journal of Human Ecology**, 30(3).pp.201-211.
4. Panda, S. and Bandyopadhyay, J. (2011): "Morphodynamic Changes of Bhagirathi River at Murshidabad District using Geoinformatics", **Journal of Geographic Information System**, 2, pp.310-315.
5. Parua, P.K (2002): "Fluvial Geomorphology of the River Ganga around Farakka", **Journal of the Institution of Engineers**. 82, pp.193-196.
6. Rudra, K. (2000): "Living On the Edge: The experience along the bank of the Ganga in Malda district, West Bengal", **Indian Journal of Geography & Environment**, 5. pp.57-67
7. Rudra, K. (2003): **The Encroaching Ganga and Social Conflicts: The Case of West Bengal, India**. Department of Geography. Habra S.C.Mahavidyalaya(College), West Bengal, India

Ms Chhandra is a research is scholar and **Dr. Jatishankar Bandopadhyay** is a Assistant Professor, Department of Remote Sensing & GIS, Vidyasagar University, Midnapore-721102, West Bengal, India. email: dey.chhanda@gmail.com, jatiban@gmail.com

Mapping of Soil Moisture in Kollam District Using NDVI and Tasseled Cap Analysis

P. Deepthi, B.Sukumar, Ahalya Sukumar, S. Sandhya

Abstract

Comprehensive database on soil and land resources is essential for agricultural planning. Spatial and temporal variations in soil moisture can be studied through techniques like Tasseled Cap Analysis and NDVI using satellite imagery. This paper attempts to study soil moisture conditions in Kollam district of Kerala with help of digital image processing techniques of Tasseled Cap Analysis and NDVI. SOI Topographic maps on 1:50,000 scale and LANDSAT ETM satellite Bands 1 to 5 and 7 of January 2002 were used for the study. ArcGIS and ERDAS Imagine software were used. Soil moisture in the district is controlled by the relief, rainfall, soil texture and vegetation distribution. There are variations in soil moisture in the district. Soil moisture is found high in the eastern compared to the western part of the district.

Introduction

Soil moisture, the water held in the spaces between soil particles, is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. Hence, soil moisture plays an important role in the development of weather patterns and the production of precipitation. Simulations with numerical weather prediction models have shown that improved characterization of surface soil moisture, vegetation, and temperature can lead to significant improvement in forecasting. Soil moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers.

The concept of tasseled cap transformation is useful for compressing spectral data into a few bands associated with physical scene characteristics (Crist and Ciccone, 1984). Originally constructed for understanding important phenomena of crop development in spectral space (Kauth and Thomas 1976), the transformation has potential applications to study forests including species. The Tasseled Cap Transformation in remote sensing is the conversion of the readings in a set of channels into composite values; i.e., the weighted sums of separate channel readings. One of these weighted sums measures roughly the brightness

of each pixel in the scene. The other composite values are linear combinations of the values of the separate channels, but some of the weights are negative and others positive. One of these 'other composite values' represents the degree of greenness of the pixels and another might represent the degree of yellowness of vegetation or perhaps the wetness of the soil. Usually there are just three composite variables. The Tasseled-Cap Transformation is a conversion of the original bands of an image into a new set of bands with defined interpretations that are useful for vegetation mapping. A tasseled-cap transform is performed by taking "linear combinations" of the original image bands - similar in concept to principal components analysis.

Objective

The main objective of this paper is to study soil moisture using Tasseled cap analysis in Kollam district of Kerala in RS and GIS environment.

Materials and methodology

For the purpose, data were compiled from the Survey of India Topographic map on 1:50,000 scale and LANDSAT ETM satellite data of January 2006. Attributes such as relief, slope, soil, land use/cover, panchayat boundaries were mapped. The software used for the study are Arc GIS, MapInfo professional, ENVI, ERDAS and IDRISI.

Bands 1 to 5 and 7 of Landsat ETM are used as input for Tasseled Cap analysis. Six bands or channels of the Thematic Mapper data are reduced to just three principal components. Soil brightness, Greenness and Moisture are the three output received from the analysis. They are classified into five zones (very high, high, moderate, low and very low).

The study area

Kollam is historically well known for its trade relationship with foreign countries, and the variety of agricultural products. It is one of the oldest port towns situated on the south west coast of Peninsular India. It is bounded on the North by Alappuzha and Pathanamthitta districts, East by the Western Ghats and Tamilnadu state, South by Thiruvananthapuram district and West by Lakshadweep Sea. There are 104 villages, 72 panchayats, 5 taluks, 13 Blocks, two municipal towns and one MC town. Achankoil, Kallada, Ittikara are the three rivers flowing through the district. Besides, there are water bodies of Kayal (back water) – 2 (Ashtamudi and Paravur) Freshwater Lake-1 (Sasthamkotta).

Results and discussion

The main hill ranges in this district are Kulathupuzha, Aryankavu, Achankoil and Sabarigiri. The altitude in these hills vary from 1500 m to 1900 m. Major parts of the district is well drained by rivers. The coast along the district is fringed with lakes.

Slope increases towards eastern part of the district and the maximum slope is in upland areas of the district i.e, Kulathupuzha and Aryankavu. The general land use and land cover is comprised of water bodies, marshy land, paddy, coconut, mixed crops, mixed trees, rubber, and barren land, (Fig. 1).

NDVI shows that most of the area ranging from moderate to low vegetative cover. NDVI is very high in the coastal areas, having lakes and other water bodies. It is high in eastern part of the district (Fig.2).

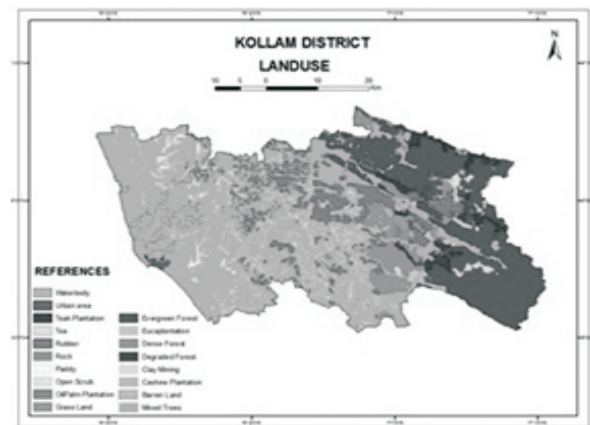


Fig. 1

Table -1
Kollam District Soil Moisture

Zone	Area in Sq Km	Percentage to Total Area
Very High	195	7.82
High	287	11.5
Moderate	1100	44.15
Low	637	25.5
Very Low	234	9.3

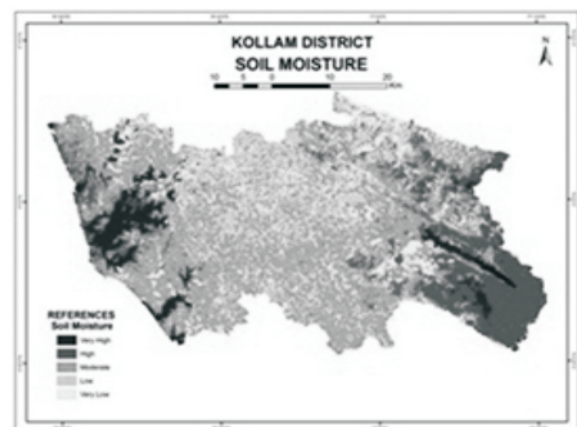


Fig. 2

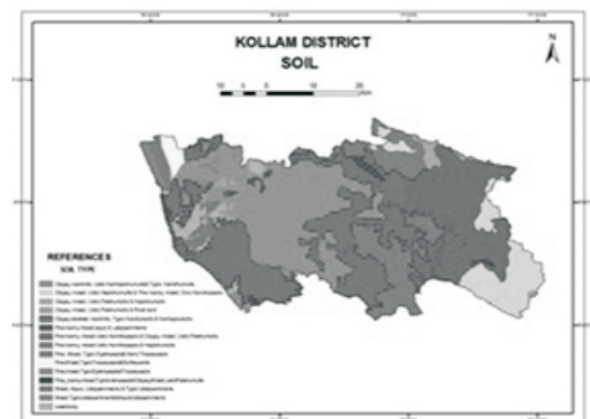


Table. 2
Area Under Soil Moisture
Percentage to the total area

Sl. No	Panchayats	Area in sq. km.	Very high	High	Moderate	Low	Very low
1	Adichanalloor	23.65	19.28	2.28	65.07	6.51	6.72
2	Alappad	8.76	11.53	51.6	30.02	2.85	3.54
3	Alayamon	55.83	0	13.04	63.85	18.18	5.59
4	Anchal	27.04	0	0	66.83	27.77	6.4
5	Ariencavu	215.27	2.79	32.49	36.19	19.66	8.61
6	Chadayamangalam	25.25	0	0	50.42	41.03	7.76
7	Chathannur	29.28	5.09	2.02	78.01	10.21	6.05
8	Chavara	12.13	10.47	18.55	60.76	3.63	7.42
9	Chithara	59.36	0	1.89	72.64	21.82	3.18
10	Clappana	10.39	11.65	15.11	53.8	11.55	7.41
11	Edamulackal	36.51	0	2.47	61.93	32.84	2.16
12	Elamad	29.59	0	0.68	65.09	27.51	6.56
13	Eroor	42.49	0.12	1.06	57.45	30.1	11.41
14	Ezhukone	17.82	0	0	62.74	30.42	4.71
15	Ittiva	49.03	0	0.43	75.06	20.29	3.77
16	Kadakkal	42.33	0	0.14	68.01	24.55	7.82
17	kalluvathilkkal	38.06	0	0	58.15	26.33	15.37
18	Karavaloor	26.16	0	0.15	27.83	59.06	12.73
19	Kareepra	22.72	0	0.7	58.93	33.41	6.29
20	Karunagapally	18.33	20.35	34.42	38.95	2.89	0.49
21	Kizhakkellada	13.03	22.49	3.76	45.97	7.6	19.03
22	kollamCorporation	56.92	8.96	14.02	62.51	6.78	6.41
23	Kottamkara	24.83	0.6	5.68	83.13	8.66	2.94
24	Kottarakkara	18.29	0	0	34.06	57.68	8.58
25	Kulakkada	32.23	0.65	0.25	14.77	66.15	17.87
26	kulasekharapuram	17.16	0.82	36.66	57.4	2.21	2.1
27	Kulathupuzha	398.09	16.68	28.55	26.98	16.14	11.09
28	Kundara	13.15	1.06	0	67.91	23.27	8.59
29	Kunnathur	21.47	6.15	0.23	38.24	48.72	6.52
30	Mayyanad	19.88	17.4	1.56	68.01	4.98	7.8
31	Melila	19.01	0	0	24.51	64.12	11.68
32	Mundrothuruthu	13.15	71.86	25.48	2.43	0.38	0
33	Mylam	22.95	0	0	22.92	58.08	18.95
34	Mynagapally	20.46	9.38	1.03	68.04	8.6	12.32

35	Nedumpana	25.06	8.18	1.16	66.28	19.63	4.67
36	Neduvathoor	22.38	0.36	0.49	40.53	51.97	7.86
37	Neendakara	6.94	51.15	27.67	12.39	0.76	0.72
38	Nilamel	18.98	0	0.42	56.9	31.88	6.06
39	Oachira	13.49	0	3.41	64.2	12.53	11.34
40	Panmana	16.77	5.31	53.19	37.98	1.55	1.01
41	ParavoorMunicipality	19.19	30.12	2.76	59.04	2.81	2.81
42	Pathanapuram	41.02	0.07	3.85	40.74	42.25	10.24
43	PattazhiThekkekara	18.5	0	0	17.03	71.78	11.95
44	Pattazhivadakkekara	16.98	0	0	10.95	74.03	14.72
45	Pavithreswaram	24.35	4.39	1.4	23.37	54.7	16.22
46	Perayam	14.6	64.38	0	33.84	0.82	2.81
47	Perinad	15.79	32.87	13.81	46.99	2.34	3.04
48	Piravanthur	134.23	0.04	5.13	32.5	39.02	22.33
49	Poothakulam	17.05	18.18	0.41	48.27	10.73	22.29
50	Pooyapally	23.49	0	0.17	71.14	24.14	4.77
51	Poruvazhy	19.17	0.42	0	59.21	28.22	12.26
52	Punalu Municipality	36.2	0.11	0.25	24.5	55.47	19.14
53	Sasthamcottah	25.01	25.15	0.72	54.78	12.16	7.04
54	Sooranad North	23.14	3.24	0.3	32.67	40.75	22.99
55	SooranadSouth	17.38	2.99	1.09	63.58	14.44	17.84
56	Thalavoor	34.29	0	0	21.84	64.25	13.47
57	Thazhava	23.79	11.14	0	55.53	17.78	15.34
58	Thekkumbhagham	13.92	74.5	10.56	15.16	0	0
59	Thenmala	128.81	0.8	18.26	53.85	20.65	6.22
60	Thevalakkara	16.88	19.31	15.64	61.08	0.41	3.08
61	Thodiyoor	20.72	10.47	3.47	69.16	8.35	7.92
62	Thrikadavoor	14.69	58.41	23.28	17.36	1.29	0.27
63	Thrikkaravu	27.45	59.09	12.97	23.72	0.91	4.01
64	Thrikkovilvattom	18.85	0.42	2.23	82.07	2.6	12.63
65	Ummannur	34.95	0	0.46	44.12	47.47	8.58
66	Velinalloor	24.99	0	0	58.78	30.93	9.76
67	Veliyam	30.69	0	0	57.61	37.83	4.59
68	Vettikkavila	34.78	0	0.14	40.94	49.86	9.11
69	Vilakkudy	20.14	0	0.35	22.14	59.04	17.87
70	West kallada	13.38	33.18	14.65	33.78	9.64	8.22

From the analysis it is found that very high soil moisture zone occupies about 8.0 per cent, high 11.5 percent, moderate 44.2 percent, low 25.5 percent and very low 9.3 percent of the total area of the district (Fig. 3).

Very high soil moisture zone is found along the coastal area and around kayal, moderate to high along the side slopes of the relief, very low and low soil on high relief area. Soil moisture shows very high in and around water bodies and the NDVI is high in western part compared to eastern part of the district (see Table 2).

Conclusion

High soil moisture is found in coastal and valley areas; decreases towards higher elevation. Relief controls the agricultural land use in the district. Highly elevated area in the eastern part is mainly used for plantation. The soil moisture is helpful for agriculture planning. Soil moisture Index map reveal very high in and around water bodies and the NDVI is high in western part compared to eastern part of the district.

References

1. Durbude, Dilip G. *et al* (2004), "Site suitability analysis for soil and water conservation structures". **Journal of the Indian Society of Remote Sensing**. 32(4).
2. Horne, J. H. (2003), "A tasseled cap transformation for IKONOS images. ASPRS 2003 Annual Conference Proceedings". ASPRS. http://www2.erdas.com/supportsite/downloads/model_files/IKONOSTcap.pdf.
3. Kauth, R.J. and G.S. Thomas (1976), "The tasseled Cap – A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as Seen by LANDSAT". **Proceedings of the Symposium on Machine Processing of Remotely Sensed Data**, Purdue University of West Lafayette, Indiana. pp. 4B-41 to 4B-51.
4. Koohafkhan A.P (2000), **Land Resource Potential and sustainable land management for 21st century**. Soil Conservation Society of India, New Delhi, pp. 1-22
5. Qian Zhang, Yifang Ban (2010) "Monitoring Impervious Surface Sprawl using tasseled Cap transformation of LANDSAT data". **ISPRS TC V11 Symposium**, 38 (7A)
6. Saha S.K. *et.al* (1993) "Land Productivity Assessment and monitoring through integration of Satellite and terrain slope data in Dehradun". **Journal of the Indian Society of Remote Sensing**. 27, pp157-16

(Ms P. Deepthi, Dr. B.Sukumar, Dr. (Mrs) Ahalya Sukumar, and S. Sandhya are working with Resources Analysis Division, Centre for Earth Science Studies, Akkulam, Trivandrum-695031, E -mail: deepthi_maya@yahoo.co.in)

Vulnerability Assessment of Slums in Chandigarh City

Ravinder Kaur

Abstract

Of recent, the notion of vulnerability has evolved into a concept offering potent explanations for varying degree of damages incurred from natural hazards on individuals, communities, cities or regions. The paper in a similar vein attempts to explain what makes slum dwellers vulnerable by analyzing their everyday living conditions. Nine of each ten slum dwellers in the city reside in kutcha or semi-pucca houses. Safe drinking water supply is inadequately available and toilet and sanitation facilities are almost absent in the slums. This fragility of living environment is a perfect recipe for increase in the frequency and intensity of disasters. A vulnerability index has been worked out to indicate the slums which are extremely vulnerable and need immediate attention of the city administration. Not only the life of slum dwellers is at risk but health of people living in adjoining sectors is equally affected. The critical need of the hour is to improve the accessibility and the availability of various basic amenities in the slum localities.

Introduction

The question of urban poverty is crucial to the urban scene. The slum dwellers in the country constitute nearly one seventh of the total urban population of the states and the union territories reporting slum population; and 23.1 percent of the population of 640 cities/towns reporting slums. The big industrial and faster growing cities portray this human misery on a more colossal scale owing to the greater availability of economic opportunities. Researchers, planners, administrators, and social activists have voiced their concern for reducing their vulnerability in various academic and professional forays. As per Census 2001 even in planned city of Chandigarh, about 13 percent of the population is sheltered in slums and thus is characterized by a very significant presence of the urban poor. A significant portion of this burgeoning slum population in the city remains illiterate (50 percent) and exhibits a higher concentration of scheduled castes population (44 percent), child population (32 percent) and a lower sex ratio (762 females per thousand males). This kind of social milieu makes them vulnerable on both social and economic fronts. Such people of low socio economic status are not only forced to settle in unsafe locations but also live in deplorable conditions. They are deprived of even basic amenities and facilities. Majority (93

per cent) of the slum dwellers in the city reside in kutcha or semi-pucca houses. Safe drinking water supply is inadequately available (46 per cent households) and toilet and sanitation facilities are almost absent (16 per cent households) in the slums. Outbreak of water borne diseases like malaria, dengue, cholera, diarrhea, etc. during the rainy season is quite common in slums. This beautiful city is now experiencing a number of such environmental hazards whose roots can be traced to the slums.

Slum dwellers are vulnerable on two counts. Firstly, they form the segment of disadvantaged people who are illiterate, marginal workers, labourers and belong to largely lower rung of the society. Secondly, they live in slums (fragile conditions lacking services) e.g. kutcha house with no separate place for cooking, no toilets and defecation in the open, no water supply, clogged drains and tapped electricity. Conventional economic definitions of urban poverty using income and consumption often fail to measure complexities in accessibility and availability of basic services and other factors of contextual vulnerability. Not only the face of urban poverty changes at state level but the differences are stark amongst cities as well as within a city. In such conditions it becomes evident that for any programme planning or implementation

targeting a needy slum is the practical approach rather than identifying and trying to target specific families in a slum and leaving out the others. Moreover, the approach of targeting vulnerable slums recognizes that undesirable conditions of a target family are influenced by their environment and the access to basic services.

The paper follows a structural perspective on vulnerability and focuses on the everyday living condition of slum dwellers which play a key role in understanding vulnerability. A structural perspective focuses on the social, economic, cultural and political context people live in and their everyday living condition. The model probably best known for summarising the structural perspective on vulnerability is the 'Pressure and Release' model ('PAR'). Within the PAR model as presented by Wisner (2004), the pathway of vulnerability runs from "root causes" (such as the political and economic system), to "dynamic pressures" (like rapid urbanization, lack of local job markets) to "unsafe conditions" (such as unprotected buildings and dangerous locations). Only when a hazard impacts on vulnerable population like slum dwellers, disaster occurs. In other words, living conditions of people's everyday life is key to understand their vulnerability. This paper in a similar vein attempts to gain an insight into unsafe conditions of slums which make them vulnerable to hazards. An attempt has also been made to analyse chronology and location of slums to reflect on the root causes (such as political and economic systems) responsible for slum formation in the planned city. This paper is divided into three sections. The first focuses on the chronology and location of slums. The second deals with vulnerability assessment of slums and the third raise some policy concerns.

I. Chronology and location of slums

The genesis of slums in Chandigarh began with the raising of the city itself. The construction labourers who had to build the city were neither provided with any housing provision nor was there any provision of their shelter in the project estimates, so they built their own unplanned

shelter. This is in fact a paradox because construction of the planned city began with unplanned hutments which gradually grew into slums (Sarin, 1982). Soon after the new city was selected, land acquisition work began. Land in 27 contiguous villages in 12 partially and in 15 entirely of the erstwhile Kharar tehsil of Ambala district was acquired. The construction work of

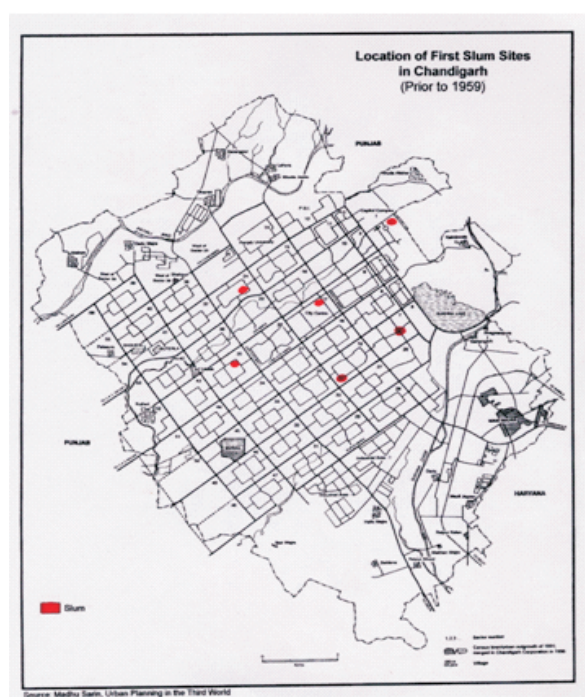


Fig. 1

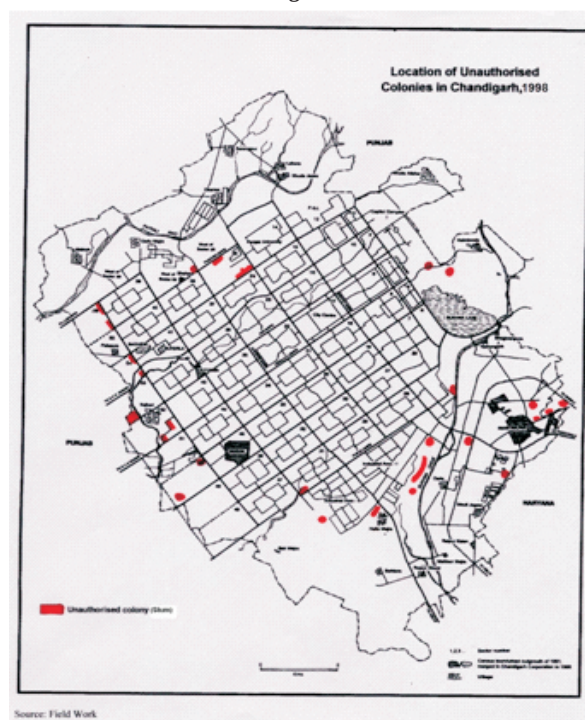


Fig. 2

Chandigarh started in the beginning of 1951 and by the end of 1952-53 the tempo of construction activity picked up fast enabling Chandigarh to act as the seat of governance (Kalia, 1988). Unfortunately, the local labour did not participate in this venture because people were deadly against the idea of evacuation of villages and led a movement called Anta Rajdhani

Movement (Evenson, 1966). In such a situation, the contractors were left with an option of hiring the construction labour from outer stations. The labour was by and large hired from Uttar Pradesh, Bihar, Rajasthan, Andhra Pradesh and Tamil Nadu. Since the construction continued for more than three decades, the emigrant labour not only opted to stay in the city but brought their kith and kin along and never went back. This speaks of the genesis of slums in the city.

The first six slums which appeared on the scene of Chandigarh as soon as its construction started came up in the capitol complex, the City Centre and sectors 7, 19, 24 and 35. All of them were in close proximity to the areas where development was taken up first (Fig. 1). In 1959 these settlements were shifted to peripheral locations in sector 14, 15, 26 and the Industrial Area. This relocation did little to contain their growth. In addition to a continuing expansion of the relocation sites, new slums appeared in other parts of the city. A survey conducted by the Chandigarh Administration in 1971 put the number of city slums at ten.

As per the statistics of Chandigarh administration in the year 1971 there were 4454 jhuggis which multiplied to 8003 in 1974 thereby registering a two fold increase in just a span of four years. During this period, the construction activities were in full swing. the first phase sectorsv (sector 1-30) were witnessing construction on a massive scale. Hence, the influx of migrant labor continued unabatedly. In 1998, the number of jhuggis reached 55670. This proved alarming (Map 2). As far as location pattern of slums is concerned, the bigger ones are located in the city's eastern

parts near or within the industrial areas, grain market and railway station. Other slums display a concentration in the southern and western parts of the city close to the new construction sites. The most noticeable feature of present slums is their construction on the periphery and in proximity to work places (Fig. 2).

II. Assessment of slums vulnerability

The vulnerability index of slums in Chandigarh has been worked out on the basis of accessibility and availability of basic amenities and facilities like housing, drinking water, toilet and sanitation facilities and source of lighting. The basic premise is that vulnerability stems from unsafe conditions such as unprotected buildings and dangerous locations, deficiencies of preparedness and lack of local relief institutions (Wisner, 2004).

In order to assess the vulnerability of slums, we have gauged the extent of excess to most basic amenities to the slum dwellers namely (i) shelter, (ii) safe drinking water, (iii) toilet facilities, (iv) source of lighting and (v) use of fuel. Each amenity has been given a weighted score and accordingly, the weighted average for all the five amenities was calculated. The extent of weightage was determined on the basis of relative importance of the amenity for a suitable living. For example, in case of shelter, kutcha house was given a weightage of 01, semi-pucca house-02 and pucca house-03. Accordingly, the weighted score for shelter for each slum colony was calculated. Further index values were calculated by giving the maximum value of 100 to the highest score and other values were computed accordingly using unitary method. This is referred as shelter index. Likewise index values have been calculated for all the amenities and facilities separately and finally a composite index of vulnerability was arrived at. The slum colonies having poorest accessibility to various amenities and facilities have been listed as colonies with extremely high vulnerability, very high vulnerability and high vulnerability. Slum dwellers living in unsafe conditions become vulnerable because their risk to various hazards exposure becomes higher.

III. Accessibility and availability of basic amenities and facilities

Chandigarh is considered to be a healthy and beautiful city. In this context it becomes very essential to examine how healthily are the slum dwellers living that constitute 30 percent of the total population. In the discussions to follow the availability and accessibility to various amenities and facilities like housing, safe drinking water, toilet facilities, source of lighting have been discussed.

Housing: In the unauthorized colonies housing conditions are very deplorable. 93 percent of the slum dwellers reside in kutcha or semi pucca houses. There are colonies like Gwala Colony, Mani Majra, Sanjay Colony, Mani Majra, Labour Colony, Hallo Majra, Pandit Colony Kajheri and Sanjay Colony Industrial Area where no dwelling unit has been reported to be pucca. It is understandable that on the encroached lands where slums have sprung up, construction of pucca houses may not be possible. But at the same time its manifestations can't be ignored. About 83 percent of the dwelling units have single rooms with no separate kitchen. The fuel consumed by them is also wood. One can imagine the risk of people residing in such houses where there is no ventilation and smoke all round.

Drinking Water: The availability of safe drinking water is an important ingredient in determining the quality of life. Safe drinking water supply is found to be either absent or inadequately available in the unauthorized colonies. The inhabitants resort to using unsafe sources of water thus making themselves prone to water borne diseases.

The data indicates that about 46 percent of the households residing in the unauthorized colonies meet their water requirements from the public taps. Even this supply is neither adequate nor dependable. There is no proper system of maintenance and repair of damaged water taps. As the population dependent on such taps is very large, it involves loss of productive time of the resident labour. Lack of water hit

women, children and elderly hard especially when they have to stand in long queues for hours to fetch water. Sometimes it also ends in quarrels amongst the users. It has also been observed that polluted water gets collected around these taps and seeps into the soils there by farther damaging the water supply. The collected water also becomes a breeding ground for the mosquitoes. Outbreak of water borne disease like malaria, dengue, cholera etc. during the rainy season is quite common.

Toilet and Sanitation Facilities : The sanitation condition in these colonies is very deplorable. In the absence of any such proper system garbage often gets collected in various comers of the slums. Also, there is no efficient system of garbage collection. Besides, there is no drainage system and the kutcha drains get clogged. Over flowing affalents enter the jhuggies thereby causing a lot of problem to the residents. The availability of proper toilet facility enhances the quality of life, but this was found to be inadequately available in these colonies. It was seen that most of the jhuggi dwellers have to go for defecation in open areas nearby. This is most inhuman and especially for women who find it very difficult and unsafe to go in open areas. The data shows that only 16.3 percent of the households use community toilets. It has been observed that maintenance of such toilets is far from satisfactory. It was reported that such public toilets charge the users for each visit. So the surroundings of the unauthorized colonies are being used as open defecation grounds. Hence there is a need for providing more public / community toilets in the uncovered areas and in the areas inadequately covered.

Lighting: In the unauthorized colonies the main source of lighting is kerosene oil. About 55.92 percent of the households use it as lighting fuel. It should be noted that 96 percent of the families stay in single rooms, using kerosene oil as main cooking fuel, with almost no ventilation. With such excessive usage of kerosene oil, the families are living under a very high health risk and more exposure to health hazards as a large amount of carbon monoxide is inhaled by them.

If we compare various slum colonies, we find that invariably their access to basic amenities and facilities is very poor (Table 1). Their fragile living conditions increase their risk and exposure to hazards. Also, their environmental manifestations cannot be ignored.

Following points are evident from Table 1:

1. The colonies needing immediate attention of administration for improving the housing conditions include Kumhar Colony, Sector 25, Janta Colony, Randhawa Colony, Mani Majra, Gwala Colony, Mani Majra, Indira Colony, Mani Majra, Labour Colony Sector 31, Labour Colony Mani Majra, Pandit Colony, Kajheri Bhattal Colony, Kabari Market Colony and Sanjay Colony. They score very low on shelter index.
2. The colonies which require immediate priority consideration for improvement of drinking water facility are Pandit Colony, Kuldeep Colony, Kajheri, Bhattal Colony and Bhagat Singh Colony. These colonies score very low on drinking water index.
3. The colonies which have poor sanitation and lack toilet facilities are Gwala Colony, Randhawa Colony, Mani Majra, Sanjay Colony Mani Majra, Indira Colony Mani Majra, SBS Karsan, Labour Colony, Hallo Majra, Pandit Colony Kajheri, Kuldeep Colony Kajheri, Bhattal Colony, Labour Colony, Kajheri, Sanjay Colony, Industrial Area, Bhagat Singh Colony and Bhatta Colony. The administration should look into the matter without any delay lest it affects the life in the surrounding areas.

Further an analysis on their vulnerability index indicates that about one fourth of the total slum population resides in extremely high vulnerable conditions. These slums are even denied of two basic facilities. In additions, one third of slum dwellers have access to only three basic amenities and even less than half of the slum population manages to have four basic amenities of life (Table 2). It follows from the above discussion that the critical need of the hour is to improve the accessibility and the

Table 1
Colony-wise Index Value on Various Amenities

Sr. No.	Name of the Colony	Shelter Index	Drinking Water Index	Toilet Index	Lighting Index	Fuel Index
1	Madras Colony, Sector 26	64.63	72.70	73.24	89.90	28.77
2	Kumhar Colony, Sector 25	26.64	70.13	82.93	80.58	31.25
3	Janata Colony, Sector 25	31.99	69.83	91.00	85.55	34.19
4	Gwala Colony, Mani Majra	96.15	76.12	49.11	75.57	26.21
5	Randhawa Colony, Mani Majra	58.41	65.82	50.86	77.94	28.03
6	Gwala Colony, Mani Majra	45.05	72.17	59.80	100.00	34.09
7	Sanjay Colony, Mani Majra	32.05	76.18	50.91	75.57	28.03
8	Indira Colony, Mani Majra	34.78	76.59	48.32	76.58	28.10
9	Labour Colony, Sector 31	45.84	99.89	81.54	76.71	29.39
10	SBS Karsan Colony	66.38	100.00	53.75	80.25	28.73
11	Colony No. 5, Nizampur Burail	77.82	61.10	98.55	81.97	28.68
12	Colony No. 4, Industrial Area	61.53	75.39	70.35	81.88	29.88
13	Guru Sagar Sahib Colony, Phase -I	75.99	82.86	100.00	100.00	32.13
14	Labor Colony, Hallo Majra	33.37	75.29	47.07	75.57	28.03
15	Palsora Labour Colony	67.20	58.95	79.42	83.55	29.91
16	Pandit Colony, Kajheri	44.56	39.86	47.52	75.57	28.04
17	Kuldeep Colony, Kajheri	100.00	30.36	48.51	56.41	28.03
18	Nehru Colony, Kajheri	74.78	56.16	59.07	84.04	28.46
19	Bhattal Colony	34.98	36.74	49.24	78.65	28.55
20	Kabari Market Colony	36.67	73.27	54.34	78.62	100.00
21	Labour Colony	91.47	73.80	48.27	80.85	33.00
22	Sanjay Colony, Industrial Area	31.97	75.28	48.52	75.57	28.66
23	Bhagat Singh Colony	75.46	33.99	49.50	77.89	28.66
24	Bhatta Colony	94.93	75.80	50.65	78.93	28.46
25	Rajiv Colony, Sector 38	94.71	89.21	91.02	99.06	60.07
26	Adarsh Colony, Badheri	95.92	92.06	91.06	92.06	59.01

availability of various basic amenities in the slum localities.

So far, the main strategy of the administration has been to resettle the slum dwellers under various rehabilitation schemes but now the government should also work on the slum improvement measures. Their deplorable living environment is a pre-condition for hazardous situations. Obviously there is an inter-connection between vulnerability and exposure: high levels of vulnerability can increase exposure to health risks (Smit and Wandell, 2006). Not only the health of the slum dwellers is at risk but people living in adjoining sectors are equally affected. In recent years, when there has been an outbreak of diarrhea, cholera, or dengue in the city, the roots have been traced to slums.

III. Policy concerns

The city beautiful is facing a great challenge given the rapid rate of growth and the sheer numbers of urban poor to be employed, housed and serviced. Following are some pertinent issues which need to be addressed by the planners and policy makers:

Table 2
Chandigarh: Vulnerability Index of Slums, 2001

Colony Name	Population	(Persons)
*Extremely High Vulnerability Index		
Bhattal Colony	345	
Pandit Colony, Kajheri	1298	
Colony No. 4, Industrial Area Phase-I	16775	
Labour Colony, Hailo Majra	348	
Indira Colony Mani Majra	3144	
Sanjay Colony	497	
Sanjay Colony Industrial Area	579	
Bhagat Singh Colony	4039	
	27025	(22.95%)
** Very High Vulnerability Index		
Randhawa Colony, Mani Majra	254	
Kumhar Colony, Sector 25	10611	
Kuldeep Colony, Kajheri	663	
Gwala Colony, Railway Station	135	
Janata Colony, Sector 25	9822	
Nehru Colony, Kajheri	5147	
Palsora Labour Colony	9440	
Gwala Colony, Mani Majra	149	
	36221	(30.78%)
*** High Vulnerability Index		
Labour Colony, Kajheri	697	
Bhatta Colony	681	
SBS, Korsan	7087	
Madrasi Colony	8385	
Labour Colony, Sector 31	10919	
Kabari Market	254	
Colony No. 5	22021	
Guru Sagar Sahib Colony	1529	
Rajiv Colony, Sector 38	2553	
Adarsh Colony, Badheri	372	
	54498	(46.26%)

Source: CRRID Survey, 1998.

- *Vulnerability Index is less than 250 i.e. the colonies have an access to only two basic amenities
- ** Vulnerability Index is less than 300 i.e. the colonies have an access to only three basic amenities
- *** Vulnerability Index is less than 400 i.e. the colonies have an access to only four basic amenities

Source: CRRID Survey, 1998.

- Will this city be able to retain its planned character and live up to its potential as clean, green and healthy city or get mired in poverty, pollution, congestion and crime?
- Most of the slum dwellings are illegal encroachments on land belonging to government agencies / organizations. At the time of setting up, their illegal possession goes ignored which subsequently becomes a menace when

land owing agency sought to retrieve the land. While claim of original landowner cannot be denied, but at the same time would eviction of dwellers from their residences, where they resided for decades, a rational and logical course of action?

- A significant portion of this burgeoning slum population in the city remains illiterate (50 percent) and exhibits a higher concentration of scheduled castes population (44 percent), child population (32 percent) and a lower sex ratio (762 females per thousand males) vis a vis the city. What kind of social milieu would be created in the city in times to come? Would the slums appear as zones of social conflicts and tensions on the city map?
- Most of the slum migrants are distressed migrants whose migration is poverty induced. Indeed it is a movement from rural poverty to urban poverty. What could be expected from such illiterate or semi-literate and unskilled or semi-skilled migrants? Will such slum dwellers in this city be able to overcome poverty, improve their livelihoods and adapt to the rapidly changing life styles of the city?
- The city beautiful is under great pressure on three counts. The first is inadequacy of existing services to cater the ever increasing flux of migrants. The second type of pressure is the ever increasing cost of maintenance which has resulted in many of the services being run down for want of requisite repair and replacement. The third constant is that the city is falling prey to a number of diseases like malaria, dengue, cholera, typhoid, gastro-enteritis, whose routes are traced to slums. Would it be possible to make this city environmentally sustainable?
- All these issues urgently require remedial measures and solution. The policy makers need to understand the causal relations between various phenomenon related to

distressed migration, urbanization, poverty, underdevelopment and development while formulating strategies. The problem of slums can be best understood as migration - urbanization problem.

- For redressing such problem at a macro scale it is very essential to realize that these are the consequences of imbalances in spatial economy of our country, which in turn is the consequence of excessive polarized economic activities and resources at a few urban nodes and improper policies that arose out of past colonial rule.
- At the micro scale, slums reflect the failures of government to guide and facilitate the growth of low income housing and basic services for incoming migrants through appropriate policy and planning. The city administration should adopt a participatory approach to involve the slum dwellers and co-invest with them improving access to better housing facilities, water supply, sanitation and other basic services in the slums. Involving the urban poor in various activities of their locale will not only enhance the openness

and accountability of local government but also increase the responsibility and responsiveness of the slum dwellers as stake holders in various developmental activities.

This will not only enhance their adaptive capacity but also build their resilience thereby reducing their vulnerability.

References

- Evenson, N. (1988), **Chandigarh**, University of California Press, California.
- Hufschmidt, G. (2011). 'A comparative analysis of several vulnerability concepts', **Natural Hazards**, 58, pp.621-643.
- Kalia, R. (1988), **Chandigarh: The Making of an Indian City**, Oxford University Press, New Delhi.
- Sarin, M. (1982), **Urban Planning in the Third World: The Chandigarh Experience**, Mausell Publishing Limited.
- Smit B, Wandel J (2006), 'Adaptation, adaptive capacity and vulnerability', **Global Environ Change**, 16:282-292.
- Wisner B, et. al. (2004), **At Risk-Natural Hazards, People's Vulnerability and Disasters**, Routledge, London.

(**Dr. Ravinder Kaur** is Associate Professor at Department of Geography (UGC-CAS), Panjab University, Chandigarh- 160014:

Email: kaur_ravinder70@yahoo.co.in)

Mapping of Changes in Landuse and Land Degradation in Nagaur District of Arid Rajasthan

Balak Ram, J.S. Chauhan

Abstract

Using IRS LISS-III digital data of 2008-09 in GIS environment, the land use map of Nagaur district has been prepared on 1:2,50,000 scale. The spatial changes in land use are worked out by comparing with the land use in 1979. For analysing changes in land use, change in irrigation, cropping pattern and crop production at district and tehsil level during 1970-71 to 2009-10 were used as the explanatory variables. Besides the developments in mining of marble and common salt, industrialization, expansion of built-up area and infrastructures were also examined. The environmental impact caused by the degradation of ground water, common property resources, cultivation of marginal lands and unscientific mining has been taken into consideration. Finally, strategies are suggested for efficient management and sustainable development of natural resources in the study area.

Introduction

The last three decades witnessed a significant expansion and intensification of agriculture, mining activities, industrialization, urban sprawl and infrastructure developments in hot arid parts of Rajasthan. On one hand, increased agricultural production and change in cropping pattern has brought about economic prosperity leading to improvement in living conditions of people. On the other side of the scale, over exploitation of natural resources beyond regenerative capability has caused their degradation threatening their long term sustainability. The present study addresses to all such issues making Nagaur district a case study. Using IRS LISS-III digital data of 2008-09 in GIS environment, the land use map of Nagaur district has been prepared on 1:2,50,000 scale and area statistics are generated. The spatial changes in land use are worked out by comparing with the land use map in 1979. The findings are supported by analyzing long term statistical data on land use, irrigation, cropping pattern and crop production at district and tehsil level from 1970-71 to 2009-10. Long term data (1950-51 to 2009-10) have been analyzed to find out district level changes in irrigated area, cropping pattern and other dominant land use systems. Besides, the developments in mining of marble and common salt, industrialization,

expansion of built-up area and infrastructures. The environmental impact caused by the degradation of ground water, common property resources, cultivation of marginal lands, unscientific mining and mismanagement of mined and other industrial waste has also been depicted. Appropriate technologies and measures are suggested for judicious use and management of ground water, increase in water use efficiency, dependable and more productive rainfed farming, rehabilitation and development of mine spoil areas, regeneration and management of pastures and ecological improvement of forest cover and Sambhar Salt Lake.

Location and environment

Nagaur district with a total geographical area of 17718 km² is located between 26° 25' to 27° 40' north latitudes and between 73° 10' to 75° 15' east longitudes. It is bounded by Bikaner and Churu districts towards north; Pali and Ajmer districts towards south; Jodhpur towards west and Sikar and Jaipur districts towards the east (Fig.1). The physiography of the area is characterized by the Aravalli hill ranges along the eastern margin, followed westward by vast alluvial plains and then the dominantly sandy plains and sand dunes, punctuated by rocky/gravelly areas in the west and north-west.

The Mendha and the Luni are the two major ephemeral streams. The Sambhar, Didwana, Kuchaman and Khatu are important salt lakes of the region. Major hydrogeological formations are older alluvium, Nagaur sandstone, Tertiary sandstone, Bilara limestone, Jodhpur sandstone of Marwar Super group as well as phylites, schist, granite and gneiss of Delhi Super group. The climate of the district is hot arid with low and high erratic rainfall, extremes of seasonal temperatures, high wind speed and frequent droughts. The mean annual rainfall is 383 mm, varying from 315 mm to 460 mm in west-east direction. The probability of occurrence of mean annual rainfall is 38%, coefficient variability of annual rainfall is 33.5%, number of rainy days are 19 and crop growing season is 11 weeks. The temperature ranges from 46 ° in summer to 5 ° C in winter. Annual maximum PET is 255.1 mm in May and 76.5 mm in December.

In about one-fourth area sandy soils with hummocky relief do occur, loamy sand to sandy loam soils are 5.7%, deep to very deep loamy find sand soils of sandy plain 9.85%, moderately deep to deep reddish brown fine sandy loam soils 10.88%, loam to clay loam slightly calcareous soils of southern alluvial region 11.44% and fine sandy very deep dune soils 6.98% (Chatterjee and Kar, 1989). Of total soils cover 42.65% qualify for land capability class III, 43.69% class IV and 10.0% class VII respectively (SRSAC, 2010). Ground water is brackish to saline (more than 3000 micro mhos). Fluoride content in ground water (1 ppm to 10 ppm) is another problem. The district falls under medium salinity, moderate SAR and high RSC water zone. At many places the RSC is more than 10 me/L and SAR is more than 26. An area of 3315 ha and 10658 ha has been estimated under saline soils and sodic soils respectively. Depth to water was 10 to 80 mbgl during 2006. Annual replenishable GW resources is 548.369 MCM, net annual GW draft 921.272 MCM and projected demand for domestic and industrial uses up to 2025 will be 228.897 MCM. The stage of GW development in the district is 168% (CGWB, 2009). The human population of the

district is 3309234 as per 2011 census and livestock population was 3115488 as per livestock census 2007. The district has 10 tehsils, 11 development blocks (Panchayat Samiti) and 1536 villages.

Materials and Method

Based on the interpretation of IRS P6 LISS-III digital data of 2008-09 supported with field check, the land use map of Nagaur district has been prepared on 1: 250000 scale in GIS domain

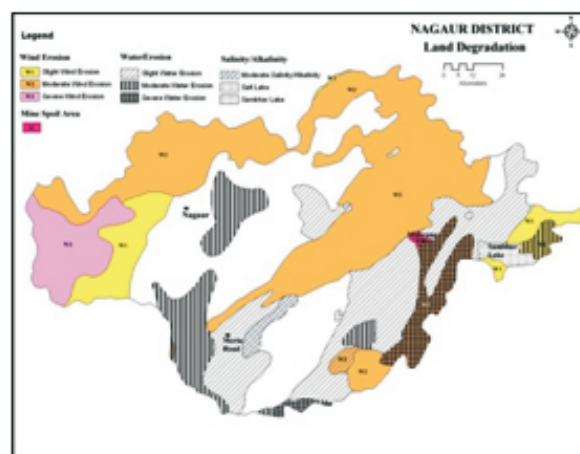


Fig.1

and area statistics were generated. It was compared with land use map of 1979 to worked out changes in the land use. District level land use, cropping pattern and crop production data from 1950-51 to 2009-10 were analyzed to see the trend. Tehsil level land use and cropping pattern data of 1970-71, 1980-81, 1990-91, 2000-01 and 2009-10 were interpreted to assess decadal changes. Technical reports and maps from various organizations pertaining to this region were consulted to assess the resource potentials and constraints and degradation of natural resources.

Results and discussion

Of the total district land area 87.3% (20.72% irrigated and 66.31% rainfed) is under agriculture. Forest land is only 0.61%, pasture/grazing land 4.41%, wastelands 6.8% (2.76% sandy waste, 1.21% saline waste, 0.33% rocky/stony waste, 2.4% gravelly waste, 0.05% gullied and 0.08% mine spoil area). Water

bodies constitute 0.5% and settlement 0.62% of total district area. The data for 2009-10 indicate 2.35% district area under forest, 4.9% land put to non-agricultural uses, 4.58% barren and uncultivable land and 3.9% pasture/grazing land. Culturable waste constitute 17.69%, other fallow land 7.6%, current fallow 6.29%, net sown area 52.67% and double cropped area 11.48%(see for details Table 1). Irrigated area though occurs throughout the district but more dominantly in Nawa, Merta, Nagaur, Khinwsar and Degana regions. Sandy waste occur towards north western part while rocky/stony waste and saline waste in Nawa and Parvatsar region in the east. Makrana, Parvatsar and Ladnu have less agriculture potential. Net and gross irrigated areas are 2.66 lakh ha and 3.57 lakh ha respectively. There are 46911 irrigation wells and tube-wells. The cropping intensity is 115% and irrigation intensity 134%.

Bajra, moong, moth and guar are dominant rainfed kharif crops occupying 33.71%, 16.89%, 13.67% and 8.75% of the total cropped area. Other rainfed crops are sesame 1.92%, jowar 2.82% and cowpea 1.48%. Wheat, mustard, isabgol, gram, groundnut, cotton and barley are important irrigated crops occupying 4.59, 5.58, 2.6, 1.67, 1.22, 0.8 and 0.9 per cent area respectively. Methi, cumin, taramira, fennel and onion are other rabi crops. Of the total cropped area 81.47% is occupied by kharif crops and 18.02% by rabi crops. The total production during 2008-09 was 1.36 million tonnes (Anon. 2010). The fertilizer consumption in the district was 26 thousand tons and 23 thousand quintals of HYVP seed was distributed in 2006-07.

Change in Land Use

The comparison of land use map of 1979 and 2008-09 reveals tremendous increase in area of irrigated cropland from 0.85 % (14980 ha) to 20.72% (367170 ha) leading to 22.3% decline in the area of rainfed farming (Fig.2). Forest land increased by thrice, while pastures are declined by 2.7%. Gullied land, settlement and water bodies which could not be mapped earlier were successfully mapped by interpreting remotely sensed images. The analysis of land use data of

1970-71 and 2009-10 reveals that forest land increased by 7.5 times , land put to non-agricultural uses 26.15%, culturable waste 207.25% and old fallow lands 5.44% respectively. On the other hand barren and uncultivable lands are declined by 31.82%, permanent pasture and other grazing land 10.29% and current fallow land 9.86%. Net sown area remained almost static but total cropped area has increased by 12.9% and double cropped area by 10.8 times. The number of irrigation wells and tube-wells increased from 18527 in 1970-71 to 47639 in 2007-08. Gross irrigated area has increased from 2630 ha in 1950-51 to 3.6 lakh ha by 2008-09. Similarly net irrigated area has increased from 33000 ha in 1976-77 to 266620 ha (Malhotra *et.al.*, 1983). Major expansion of irrigation took place after 1990-91. The expansion of the mining of marble, limestone and salt has taken place even on the private holdings. Comparison of tehsil wise land use data from 1970-71 to 2009-10 (Anon. 1973, 1983, 1993, 2002) indicate that forest area has mainly increased in Parvatsar and Nagaur tehsils by four times. Barren lands are significantly declined in Merta, Deedwana and Nawa tehsils to an order of 47%, 41% and 37% respective ely. Pasture/grazing land shown declining trend. In Ladnu tehsil pastures are declined by 36%. In Degana pastures are increased by 20%. Culturable waste lands were only 5818 ha in 1970-71 which increased to 21268 in 1980-81 and thereafter decline trend was observed. Fallow lands are declined in all the tehsils, more in Jayal (21.5%), Merta (26.4%), Deedwana (29.3%) and in Nawa 42.1%, respectively. Net sown area remained almost static with a marginal increase in Merta, Deedwana, Parvatsar and Jayal tehsils by 7.6, 7.5, 5.1 and 4.1 per cent respectively. Double cropped area has tremendously increased almost in all the tehsils but more significantly in Merta, Nawa and Nagaur tehsils (Table 1).

The expansion of irrigation has changed the cropping pattern. More impetus is being given to cash crops. The practice of sowing mixed crops (bajra+moth+guar) is almost finished. From

1970-71 to 2008-09 the acreage of bajra has declined by 16.0%, jowar 43.5% and sesame 56.81%. On the other hand the acreage of wheat has increased by 109.33%, barley 31.34%, kharif pulses like moong, moth and cowpea 67.72%, gram 43.29%, groundnut 787.4% and mustard by 81 times (from 1000 ha to 81540 ha). Cumin, isabgol, fennel and methi are newly introduced crops in the region. The improved farming practices and innovative technologies have improved the productivity of crops. The total crop production in 1970-71 was just 355000 tonnes which now gone up to 1356753

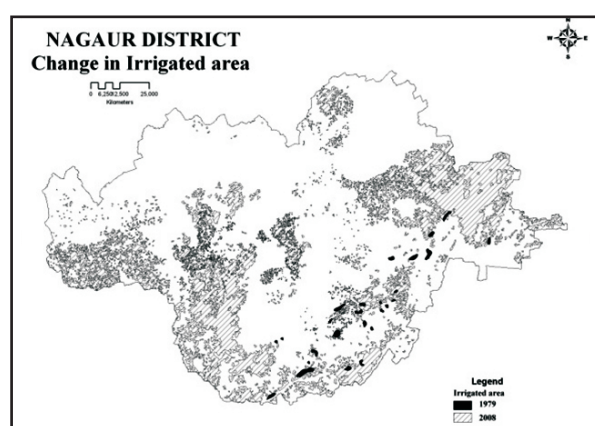


Fig. 2

tonnes in 2008-09. The introduction of sprinkler irrigation system has helped to irrigate more land and that too with undulating terrain. Significant developments are taken place in mining, industries and infrastructure sectors. Mining of marble, salt, sandstone, limestone, lignite and wolframite tungsten and mineral processing activities are considerably increased. There are more than 1000 marble quarries in Makrana, 953 salt producing units in Nawa tehsil and 150 quarries of sandstone in Khatu. More than 17840 registered industrial units and 9 industrial areas have come up.

Land degradation

The expansion and intensification of agriculture as well as mismanagement and inappropriate land use have together caused the degradation of soil, water and vegetation cover; loss of both soil vegetation biodiversity diversity and loss of ecosystem structure and baseline. In fragile hot

arid ecosystem the unwarranted and increased human activities have threatened the production potentials and sustainability of precious natural assets. The desertification map of western Rajasthan prepared at CAZRI (2005) shows about 78% district area under different category of degradation process. This includes 25% under slight degradation, 43% moderate and 10% under severe degradation. Category wise the area affected by wind erosion occupy 45.8%, water erosion 30.7% and salinity/alkalinity 1.5% respectively (Table 2). While looking into land use category, the forest, pasture and wastelands are coming under degraded lands. Similarly the barren and uncultivable lands are severely degraded lands whereas the forest, pastures and culturable waste lands are moderate to severely degraded. Apart from the lands degraded through natural forces, human intervention also contributed towards the degradation of land as well as in converting good lands into wastelands. Such activities include over grazing and cutting of trees and shrubs; cultivation of marginal lands, over exploitation of ground water, excessive irrigation with saline/sodic water, unscientific mining, mismanagement of industrial waste, encroachment of common lands, making unwarranted and illegal uses of government lands, misuse of facilities and infrastructures created by government for development.

The over exploitation of ground water resources led to sharp decline in water level from 33.53 m to 45.92 m i.e. a reduction of 12.4 m during 1995-2009. During 1984 to 2003 it was declined by 8.68 m. Out of total 11 development blocks in the district 7 are over exploited. Jayal, Makrana and Ladnu are in critical stage. Only Nagaur is left over as safe. About one third irrigation wells have gone dry. The unscientific and un-mechanized mining of marble in and around Makrana and fast expansion of mining area has caused manifold problems of degradation. The mining muck, over burden dumps and slurry are put on pastures, open land and road/rail side. These dumps have developed rills and gullies, the wash out from which deteriorated the soils.

Table 1
Land Use Changes in Nagaur District, Rajasthan, 1970-71 to 2009-10 (Area in ha)

Tehsil/ District	Year	Forest	Land put to N-Ag. uses	Barren and uncul. land	Perma- nent pasture	Cultura- ble waste	Fallow land	Net sown Area	Double cropped area
Nagaur and	70-71	01	19222	23097	25495	2325	81145	319388	1679
Khinwsar*	80-81	166	24851	18245	20426	3096	80458	322866	2899
	92-93	477	26567	19411	18500	2427	50851	352552	30387
	00-01	419	27853	17681	19309	1851	67718	348764	39336
	09-10	666	23192	17910	18999	1987	83018	320021	44751
Jayal	70-71	77	7137	7111	12607	22	26536	154624	418
	80-81	77	9153	6033	11022	740	25412	156279	3942
	92-93	103	8330	6052	11294	231	20910	160984	3125
	00-01	104	9725	5627	10642	206	20020	161778	7179
	09-10	105	10916	6017	10713	164	19237	160950	11014
Merta	70-71	10	9100	16480	8160	1506	26283	168142	6790
	80-81	00	11879	10429	10491	5243	40423	151324	16381
	92-93	00	9282	11706	10438	4424	23874	170004	25299
	00-01	62	9579	11291	10343	3748	32121	162584	35290
	09-10	68	11307	8718	10180	3756	19352	175788	38077
Degana	70-71	27	7630	6886	7995	839	30443	136788	2465
	80-81	24	7243	6240	9601	3768	40536	123235	4140
	92-93	67	6557	7326	9516	2228	31720	133233	7768
	00-01	116	6931	7044	9602	3066	29649	134328	143472
	09-10	116	7565	6429	9599	2724	22520	141779	16331
Parvatsar and	70-71	2292	8858	10001	9144	789	46367	144887	1269
Makrana**	80-81	7221	9348	4874	9406	4008	59864	123023	4616
	92-93	7431	8053	6179	9262	14688	250329	139592	5688
	00-01	8751	8101	5594	9004	2742	54759	133461	12128
	09-10	9050	8215	5361	9032	2090	51655	137006	4810
Deedwana	70-71	75	6461	2377	5164	29	29849	120704	1232
	80-81	00	7667	1381	4936	175	14881	135637	1350
	92-93	09	7164	2077	4961	120	27877	122469	5692
	00-01	00	7700	1850	4645	101	45653	104728	13514
	09-10	00	8246	1381	4693	70	38601	111686	15192
Ladnu	70-71	00	6817	101	6156	3	24620	88053	69
	80-81	00	6037	1411	5740	56	26697	85994	798
	92-93	162	8914	51	4267	00	21360	90096	596
	00-01	506	8849	51	3975	76	23025	89258	4279
	09-10	622	8780	51	3938	00	26356	86003	3683
Nawa	70-71	01	6063	15324	4655	266	25360	100820	2316
	80-81	6686	5651	8662	4536	3990	37411	85582	6702
	92-93	5218	5791	11504	4352	1973	25779	92569	15891
	00-01	7936	6308	9842	4273	3075	33408	87344	30341
	09-10	7936	6529	9621	4273	6962	14685	102166	41701
Nagaur Dist.	70-71	2481	71288	81377	79376	5818	290603	1233406	16238
	80-81	14774	81626	57051	67158	21268	329621	1183940	473728
	92-93	13467	80858	64303	72590	12891	252100	1267404	84446
	00-01	17894	85046	58980	71793	14865	306362	1209443	155959
	09-10	18563	89750	55488	71211	17770	275424	1235399	175553

*Excluded from Nagaur tehsil in 2000-01 ** Excluded from Parvatsar tehsil in 2000-01

Source: Zila Sankhikiya Rooprekha, Nagaur Zila-1972, 1982, 1994, 2002 and Bhu Abhilekh Sakha,Collectorate, Nagaur

Table 2
Land Degradation in Nagaur district
(Area in ha)

Category	Slight	Moderate	Severe	Cumulative Total
Wind Erosion	113768 (6.42)	645446** (36.43)	101520 (5.73)	860734 (48.58)
Water Erosion	328436 (18.54)	144728 (8.17)	68184** (3.85)	541348 (30.55)
Sallinity/ alkalinity	00	15753 (0.89)	19591 (1.10)	35344 (1.99)
Mine spoiled area	00	00	1437 (0.08)	1437 (0.08)
Total	442204 (24.96)	805927 (45.48)	190732 (10.76)	1438863 (81.20)

Source: CAZRI, 2005

*Figures in bracket show percent to total district area

**Also includes combined wind and water erosion

Similarly the dust emanating from processing of marble deposited in nearby agricultural fields and caused soil degradation. The total environmental impact (TIS) score of mining area is -3875 (Natani, 2007).

Impact of Land Degradation

The major impacts of land degradation are the reduction of area, carrying capacity and loss of regeneration capability of pasture and oran lands; lowering of water level, abandonment of wells, turning double cropped area into rainfed monocropping, lowering of cropping intensity and crop productivity and deterioration of ground water quality and soil health; reduction of biomass, loss of biodiversity and reduction of grazing material; reduction in cattle population, increase in frequency of seasonal migration, reduction in the average age of disposal of lambs, decline in body weight and wool production and livestock production. Activities of marble mining and processing reduced the life expectancy of workers by 10 years (Pande *et al.* 2005). Diseases like tuberculosis and silicosis are also spread. Besides, a large population deserted their small rainfed farming and opted for labour work in mining sector. Mining has polluted the grazing lands, farm and water

catchment. Private agricultural lands are gone for mining of marble and salt. Extraction of ground water through deep bore wells for producing salt has caused reduction of water level by 40 feet near Sambhar Lake. Besides, the Sambhar Lake is gradually shrinking due to decrease in incoming waters. The destruction of habitat kept migratory birds away from this region.

Strategies for Development of Sustainable Land use and Management of Degraded lands

Important strategies can be the judicious use and efficient management of ground water for enhanced production potential; development of appropriate cropping system and crop rotation; development of sustainable rainfed agriculture system; improvement and enhancement of biomass production; modernization of animal husbandry, dairying and livestock production; rehabilitation and development of degraded lands viz pasture/grazing land, forest, sodic/salinized land and mined spoil areas. Suitable alternate land use systems as well as short term and long term strategies for drought proofing and management should be worked out.

In spite of inhospitable hot arid climatic conditions the region still has scope for development of livestock based integrated farming system with enhanced water productivity; increased fodder, feed and biomass production; modernization of animal husbandry, dairying and livestock production; eco-friendly scientific mining; cultivation of medicine plants and economic utilization of native flora. With the increasing trend of human and livestock population, the demand of water for irrigation and domestic uses is bound to be increased. Hence, proper planning for use and management of this precious and limited resource is very much essential. This can be achieved through rational utilization and management of land and water resources, proper monitoring of land use/land cover developments using modern remote sensing and GIS technologies, formulating long term

sustainable land use policy, political will and support, legislation on land use regulation, involvement and responsiveness of stake holders /beneficiaries, creation of awareness and augmenting extension activities, providing adequate civic amenities and infrastructures and coordination between all the agencies/ department working in the region.

Conclusion

Nearly two-thirds area of the district is under agriculture which include 15% irrigated land through ground water. Irrigated area is dominantly occurring in alluvial plains and interdunal plains in Merta, Nawa, Degana and Nagaur regions. Sandy, rocky/gravelly and saline are dominant wastelands. During the last three decades the irrigated area tremendously increased through development of ground water and use of sprinklers. Mining of marble, salt, limestone and sandstone registered a significant increase. Major drivers of land use changes are development of irrigation, mining and allied activities, industries and infrastructures. Common lands become more degraded. Wind and water erosion are major degradation process affecting more than 70% area. Depletion of water table, development of salinity/sodicity, decline of grazing lands, reduction of biomass and biodiversity loss are major impacts of land degradation. Immediate efforts are needed to address these issues.

References

Anon.(1973) **Zila Sankhikiya Rooprekha, 1972**, Nagaur Zila, Arthik evam Sankhikiya Nidesalay, Rajasthan, Jaipur, p.146.

Anon. (1983), **Zila Sankhikiya Rooprekha, 1982**, Nagaur Zila, Arthik evam Sankhikiya Nidesalay, Rajasthan, Jaipur, p.264.

Anon. (1993) **Zila Sankhikiya Rooprekha,1992**, Nagaur Zila, Arthik evam Sankhikiya Nidesalay, Rajasthan, Jaipur, p.292.

Anon. (2003) **Zila Sankhikiya Rooprekha,2002**, Nagaur Zila, Arthik evam Sankhikiya Nidesalay, Rajasthan, Jaipur, p.150.

Anon. (2007) **Zila Sankhikiya Rooprekha,2005**, Nagaur Zila, Arthik evam Sankhikiya Nidesalay, Rajasthan, Jaipur, p.153.

Anon. (2010) **Rajasthan Agricultural Statistics at a glance for the year, 2009-10**. Directorate of Agriculture, Rajasthan, Jaipur, p.147.

CAZRI (2005)**Desertification Map of Western Rajasthan**, CAZRI, Jodhpur.

Chatterjee, P.C. and Kar, A. eds. (1989), **Natural and human resources of Nagaur district**, CAZRI, Jodhpur, p.142.

Malhotra, S.P. et. al.,(1983)**Population, Land, Crops and Livestock Statistics of Arid Zone of Rajasthan**, CAZRI, Jodhpur, p.148.

Natani, J.V. (2007) 'Geological and Environmental Status of Makrana Marble Mining Area, Nagaur district,' **Rajasthan and Strategy for Sustainable Development**, GSI, Jaipur, p.15.

Pandey, A.K. et. al.(2005) 'Environmental degradation due to marble mining dust on the soil quality of Makrana, Nagaur (Rajasthan)', **Journal of Industrial Pollution Control**, 21 (1), pp.139-146.

SRSAC (2010), **Soil Resources Atlas of Rajasthan**. SRSAC and DST, Govt. of Rajasthan, p.270.

SECTION IV

DISASTER MANAGEMENT

GIS Mapping of Urban Growth, Spatial Transformation and Slum Characteristics in Kolkata (A Comparison Between KMC and KUA)

Anuradha Banerjee, Mala Mukherjee

Abstract:

Kolkata metropolis depicts the typical characteristics of a colonial port city, unplanned urban growth, mixed land use pattern and ubiquitously distributed slums. The main objective of the article is to study not only variations in urban growth across two spatial units; i.e. KMC and KUA, but also to analyse the varying pattern of growth within each of these units. The methodologies followed are- extraction of data on urban growth, density, areal changes from the Census of India, 1991 and 2001; joining operations of spatial and Census data; Query Building ($x > n\%$, where x = indicator/ attribute) to find out the localities with haphazard urban growth and high slum population; and finally thematic mapping using ArcInfo GIS software. The main findings indicate that in case of the main city, wards with high growth are concentrated on the periphery. The city is gradually growing towards the south and the east by encroachment into the surrounding rural areas. Though the growth towards the west has been restricted by the River Hooghly, but the most surprising fact is that Kolkata's growth towards the north is not impressive. In case of the urban agglomeration, linear urban growth is found along both the sides of the river Hooghly, but most of the west bank municipalities show decline in urban growth, while the east bank municipalities close to the core city show an impressive growth (e.g. the spectacular growth of Bidhannagar near Kolkata in the east and decline in urban growth in Hooghly Chinsurah in the west.). GIS mapping of slums shows that certain wards have more than ninety percent of the population living in the slums and are concentrated in the northern and eastern part of the city. Slums are also found outside the main city and ubiquitously distributed between the west and the east bank municipalities. Though it is an obvious fact that the Hooghly industrial belt may have slums, but here, maximum slums are concentrated again in the east bank municipalities.

Introduction

Kolkata, previously known as Calcutta, is the present state capital of West Bengal and one of the most important metropolises of India. Before independence, the city had once enjoyed the pride of being the administrative capital of the British India and played a vital role in the Indian economy as a port city. After independence, the city had experienced economic stagnation and population explosion due to huge influx of refugee from across the border, Created due to partition of Bengal on communal lines in 1947. Haphazard urban growth characterised by mushrooming of refugee colonies and slums everywhere, had distorted the basic planning of the city. The city and its immediate neighbourhood grew

unprecedentedly without any proper plan and strategy. Therefore, unplanned urban growth, spatial transformation and slum development appeared as the most crucial issues before the urban planners and policy makers. Even till date those problems are persisting, though since the year 2000, an economic rejuvenation has arrested the morbid decline, leading to a spurt in the city's growth. Currently Kolkata Metropolitan Area (KMA), the largest urban agglomeration in eastern India, extends of 1887 sq. km and envelops three municipal corporations (Kolkata, Howrah and Chandannagar), 39 municipalities (Haringhata is the latest addition) and 24 Panchayat Samitis (KMDA Annual Report, 2010). The KMA has a population of 14.77 million according to the

2001 Census, as against 22.5 million total urban population of west-Bengal. The urban primacy of the metropolis is the result of a vibrant economy that lures million of migrants across the country.

Objectives:

The main objectives of the paper are to :-

- i) Identify the localities with high urban growth and population density within KMC and KUA
- ii) Demarcate the areas with major spatial transformations witnessed during the last decade
- iii) Delineate the major slum pockets within Kolkata and the micro regional concentration of slum localities across the city, and
- iv) Attempt a comparison between Kolkata Municipal Corporation and Urban Agglomeration in terms of urban growth, spatial transformation and slum concentration.

Data Sources and Methodology

Following methodological steps are involved in conduct of the study:

- Extraction of data on urban growth, density, areal changes from the Census data pertaining to 1991 and 2001; joining operations of spatial and Census data; Query Building ($x > n\%$, where x = indicator/attribute) to find out the localities with haphazard urban growth and high slum population; and
- Thematic mapping using GIS technique.
- The Census of India, 2001, Series -20, West Bengal, Provisional Population Totals. Distribution of Rural-Urban Population, Director of Census Operations, Kolkata, West Bengal (2001), Registrar General of India, Government of India
- The Census of India, 1991, West Bengal, Part XIA & XIIB, District Census Handbook, Calcutta, Town Directory, series-26,

Registrar General of India, Govt. of India

- List of Documents on Calcutta, Volume-I, (1764-1800), edited by Prof. Adhir Chakravarty, Director of Archives (WB)
- Metropolitan Kolkata: An Anthology of Socio-Economic Studies and Survey Reports of KMDA, (1970-2004), Vols.-I to V

Variations in Urban Growth

Kolkata is witnessing spectacular urban growth since the beginning of the twentieth century. Fig. 1 reveals that population growth in Kolkata as well as Kolkata UA were always higher than that of the average for West-Bengal. Immediately after the independence population growth was very high in the main city, but declined later. Currently, the urban agglomeration is growing faster than the main city. Fig. 2 shows population transition in Kolkata urban agglomeration. Before 1921, population growth was negative and it reached to its crescendo during the decades of 1931-41 and 1941-51, after that population growth declined sharply and it is declining steadily even at present. However, the decline in population in KMC has been much faster than the KUA and in fact during 1991 and 2001 KMC had a negative growth.

Kolkata urban agglomeration has three municipal corporations, 39 municipalities, many census towns, outgrowths and rural mouzas. Among them, Kolkata (MC) as a whole recorded a growth rate of 3.93 percent, which was much lower than Chandannagar (MC) (15.59 percent) and Howrah (MC) 6.01 percent. Sixteen outgrowths together accounted for 32.69 percent population growth, which is highest among all other components. Rural units also recorded impressive population growth, slightly lower than municipalities and census towns (Fig. 3)

During 1991-2001, Dum Dum recorded highest growth rate followed by Howrah, Uluberia, Garulia, Khardah, Baranagar and Hooghly-Chinsurah municipalities. It is interesting to note that population growth had rapidly declined in South Dum Dum, Panihati and other

municipalities, that earlier recorded very high growth rate. (Figs. 4&5). Kolkata (MC) recorded very high population growth in southern and southeastern part of the municipality, (Garden Reach, Jadavpur and Eastern Bypass areas), while ward number 108 recoded the highest growth rate. (Fig. 6)

During 1991-2001, Dum Dum recorded highest growth rate followed by Howrah, Uluberia, Garulia, Khardah, Baranagar and Hooghly-Chinsurah municipalities. It is interesting to note that population growth had rapidly declined in South Dum Dum, Panihati and other municipalities, that earlier recorded very high growth rate. (Figs. 4&5). Kolkata (MC) recorded very high population growth in southern and southeastern part of the municipality, (Garden Reach, Jadavpur and Eastern Bypass areas), while ward number 108 recoded the highest growth rate. (Fig. 6)

Variations in Population Density, 1991-2001

Population density has a significant importance in planning, as it shows the congestion level. Fig. 8&9 show ward-wise variations of population density in Kolkata (MC). It is evident that the western side of the city recorded the highest density, but it declined towards the south and southeast. Areas with high population growth recorded very low density. On the other hand in case of Kolkata (UA) Titagarh recorded highest density followed by Baranagar, Naihati and Rajpur and others. In 2001 Barrackpore and Rajpur recoded very high densities. Kolkata (MC) had lower density than these municipalities (Fig. 7 & 8).

Spatial Transformation in KMC and KUA:

Detailed survey of Kolkata's land use had been conducted by KMDA since 1970's and recent application of remote sensing have revealed that in Kolkata metropolis there has been a steady increase in residential land and sharp decline of vacant land. Land use map of KMC (1996) showed that the city proper had the highest area under residential land use (< 45%).

Considering the present rate of urban growth

and land use, KMDA had proposed a **multi-center growth pole strategy** in the Kolkata metropolitan region. A well-integrated system of settlements with specific functions would help to eradicate regional disparity in urban growth. Naihati-Bhatpara, Kamarhati and Sonarpore areas with very high population growth have been allocated for 1 to 1.5 million population by 2025 and they would be known as major centres in '**Vision 2025-Perspective Plan of KMA**'. Dum Dum, South Dum Dum, Baruipur, Bansberia, Bhadreswar, Chapdani, Kona, Garia-Jadavpur would be designed to house about 0.05 to 0.75 million population. It is interesting to note that Bhadreswar, Chapdani and Bansberia regions are not as populous as other regions. KMDA had proposed new metro cities in Kalyani, Barrackpore, Barasat, Salt Lake, Uluberia and Baghnan. Among them Saltlake, Barasat and Barrackpore have already recorded high growth rates.

Concentration and Characteristics of Slums in Kolkata Metropolis

Development of slum settlements across the city is an obvious outcome of uneven urban growth and unplanned spatial transformation. They are treated as the physical manifestation of deprivation in the city and the coexistence of slum hutments and multi-storeyed buildings in the same locality, reminds that 'poverty and pride' exists 'side by side' in the 'City of Joy'. Kolkata's slums are unique in nature and possess following characteristics:

1. Slums in Kolkata are also known as 'Bustees', which have been defined by various legal entities in different manner. The Kolkata Municipal Corporation Act, 1980 defines 'bustees' as an area containing not less than seven hundred square metres in area occupied by or for the purposes of any collection of huts or other structures used or intended to be used for human habitation. Kolkata Municipal Corporation is the ultimate authority to declare any areas as slum. Mere collection of huts in an area cannot be called as 'bustees', once an area is notified as 'bustees' the KMC is empowered

by law to undertake physical improvement of the area by providing water supply, sanitation, Sewerage lines, electricity and remodelling of building structures.

2. On the basis of Tenancy status, Kolkata's slums can be classified into three types: the first one is land under thika tenancy system, where slum dwellers have only occupancy rights but ownership bestows to the State Government. Mainly older slums (>100-150 years old) come under this category. The second type of slum lands are those owned by the dwellers and the third type of slums are situated on encroached lands. They are also called unauthorised slums.
3. Census 2001 estimates that Kolkata has 14.9 lakh slum population, which is 32.55 percent of the city's total slum population. The slums cover 31 Sq.Km area or almost 18 percent of the whole city area.
4. Wards with more than seventy percent people residing in slums are mainly concentrated in the north-eastern fringe of Kolkata, as well as some parts of north and west Kolkata. Therefore, slums are concentrated in the peripheries. Fig. 10

show that slum dwellers are mainly Scheduled Caste population and illiteracy is very high among them.

Growth and spatial transformation

Kolkata Municipal Corporation or the core city still acts as the main nuclei of urban growth and determines the land use within the urban agglomeration, though presently, Kolkata (MC) is recording lower growth rate compared to the other municipalities in the urban agglomeration. In terms of urban growth there is a marked difference between the east bank and the west bank municipalities. East bank municipalities especially those that are located in the immediate neighbourhood of Kolkata are growing rapidly. On the other hand, west bank municipalities or the Hooghly industrial belt is showing decline in urban growth. This may be due to a recession in industrial growth and consequent fall in immigration to the city. With the increase in distance from Kolkata, urban growth declines and in the extreme north near Kalyani and Bansberia it is very low. However the immediate neighbourhood of Kolkata comprising the municipalities of South DumDum, Bidhannagar and few others show spectacular growth. Within Kolkata (MC) high

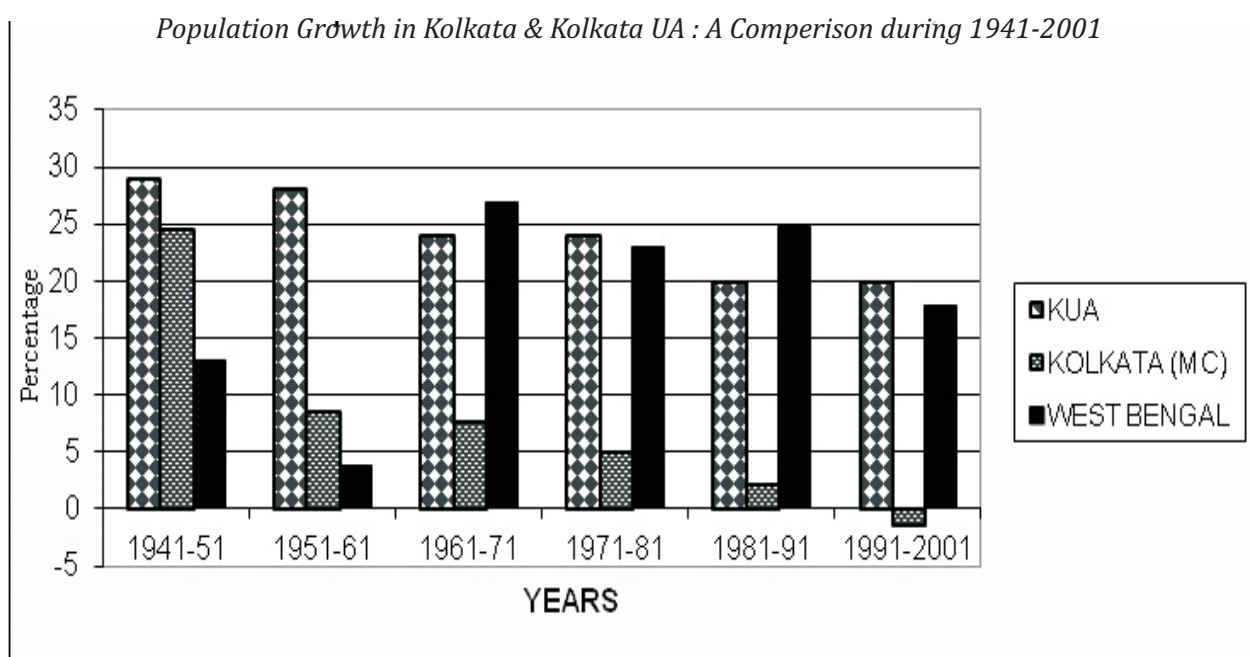


Fig. 1

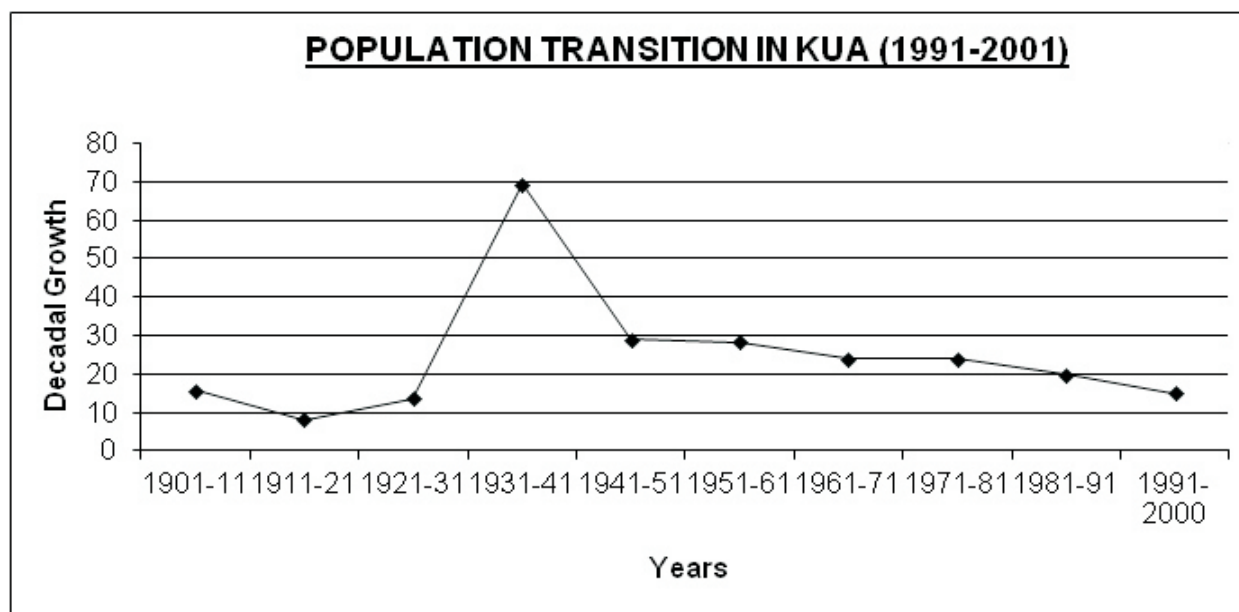


Fig. 2

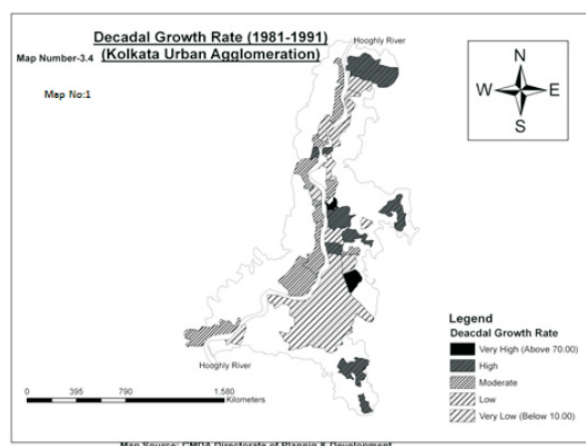


Fig. 3

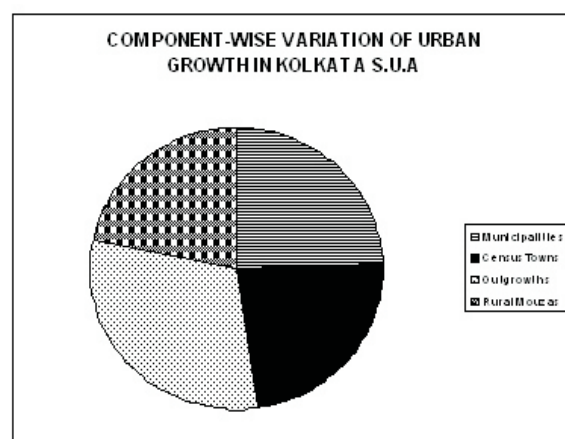


Fig. 4

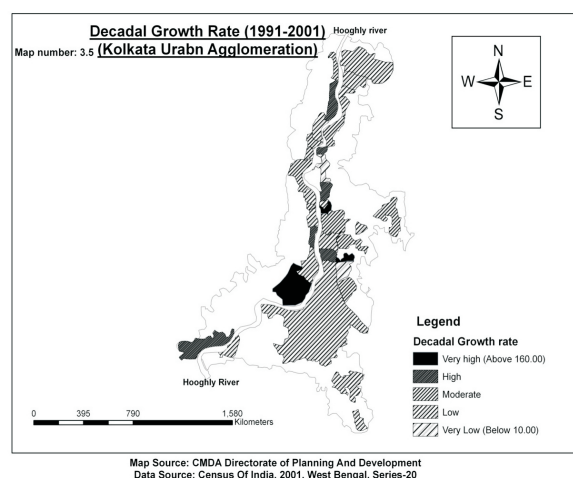


Fig. 5

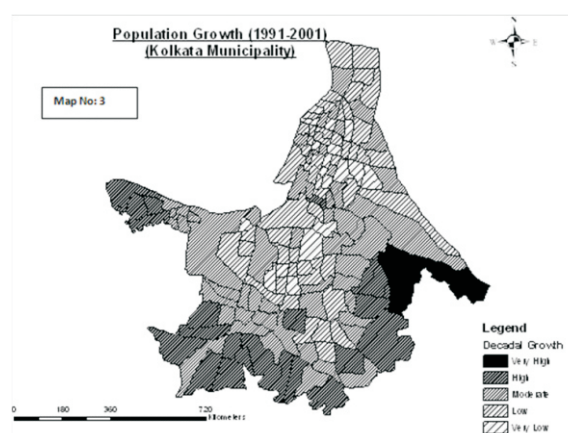


Fig. 6

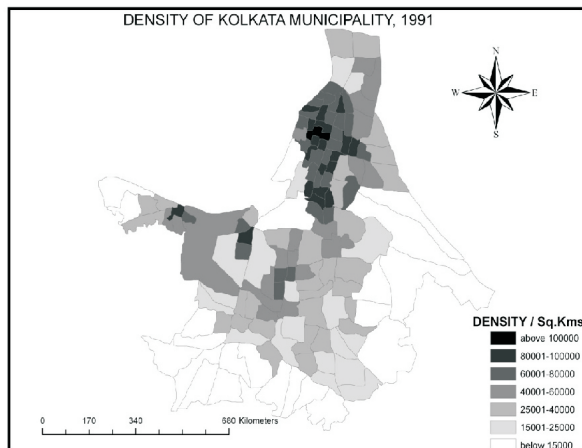


Fig. 7

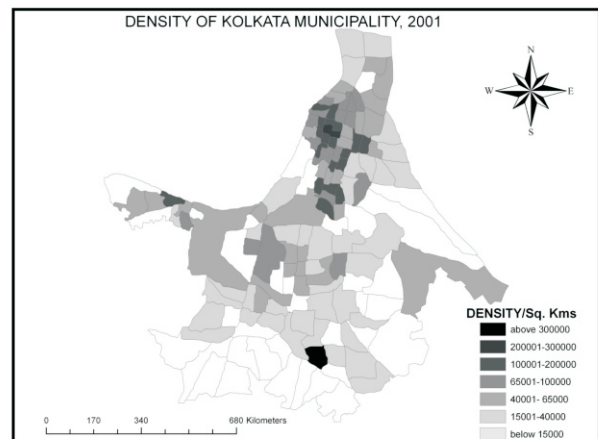


Fig. 8

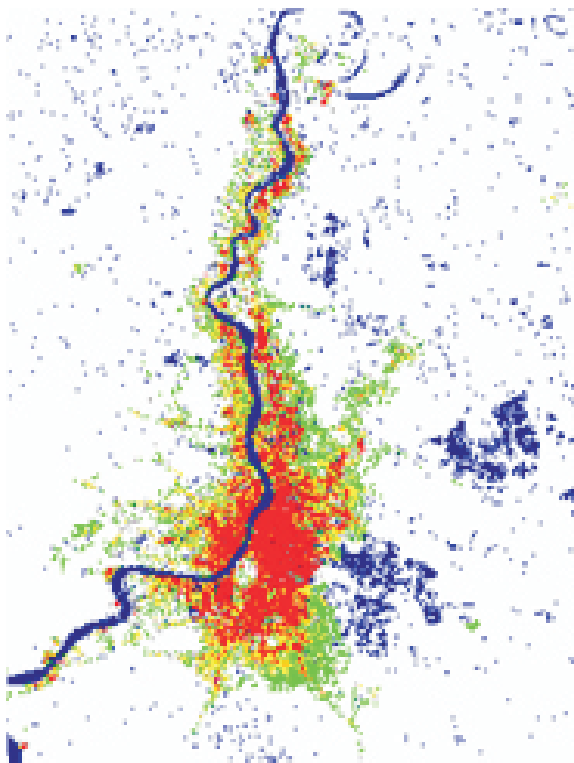


Fig. 9

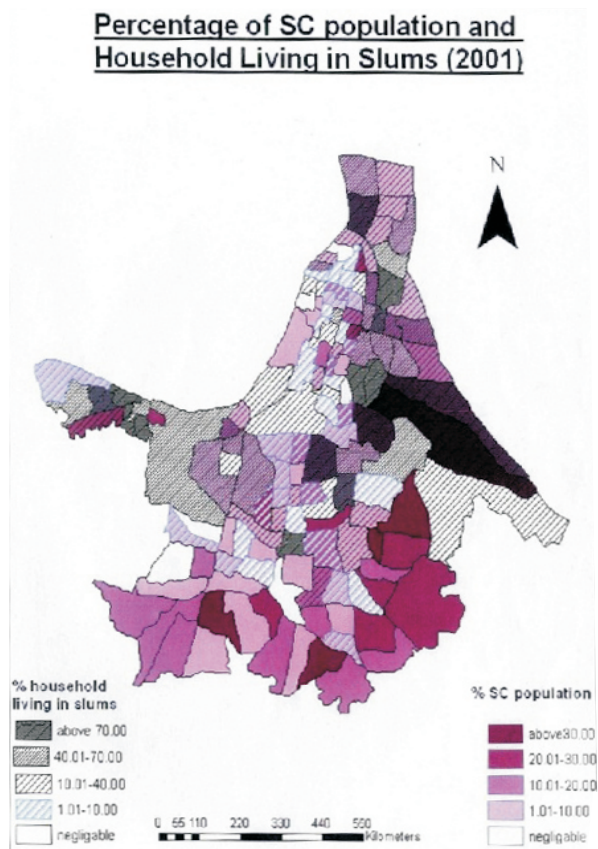


Fig. 10

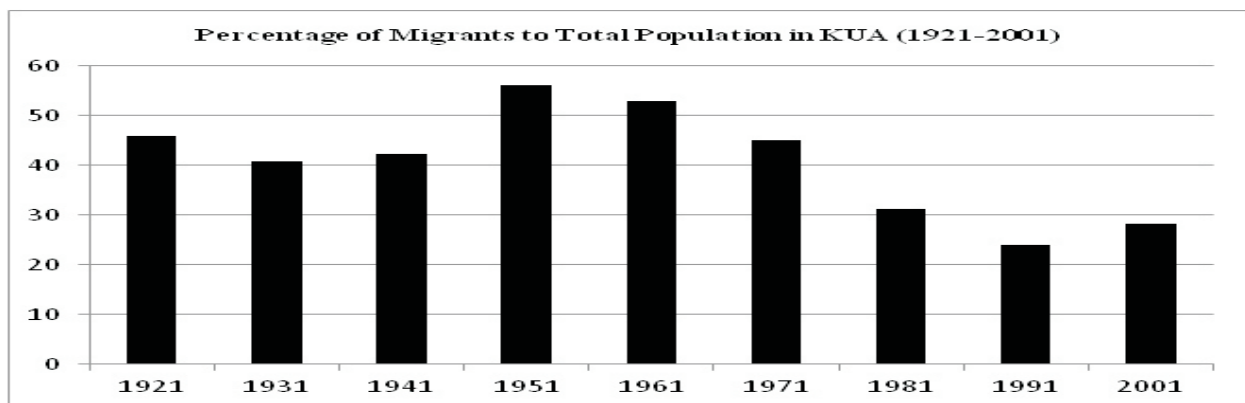


Fig. 11

Source: Computed from Census 2001 and 1991

growth pockets are located in the north eastern and southern peripheries of the city, while high density pockets are located in the city core.

Spatial transformation within the city and the urban agglomeration also shows unevenness in terms of land allocation for different productive and unproductive purposes. In the core city as well as in the urban agglomeration, residential land use plays crucial role while there is no remarkable increase in commercial, industrial and transportation land use. There is a rapid encroachment of vacant land in the metropolis which obviously gets converted into residential use.

Main Findings

- Kolkata shows a primacy in terms of urban growth within the urban agglomeration. However its immediate neighbourhood as well as the periphery are growing at a faster rate leaving rest of the areas marked by a decline in population. Therefore, the strategy of generating multiple growth centres has not achieved much immediate success; since Kolkata still acts as the main and sole growth centre.
- High urban growth in parts of the main city has resulted in the emergence of slum pockets. Slums are found in the core city as

well as in the peripheries, but 'entire-slum wards' are located predominantly in the north eastern fringe and the western parts of the city.

- Though Kolkata has predominantly residential land use, but housing crisis is one of the critical problems, faced by the city dwellers. Rapid encroachment of vacant lands is leading towards ecological crisis. Poor and the deprived sections of the society are the worst victims of this housing crisis.

Briefly, solution to the problem of unprecedented and unplanned urban growth around Kolkata lies in establish new growth centres within the urban agglomeration. Multiple growth centre strategy has already been adopted by the Kolkata Metropolitan Development Authority (KMDA) but the new strategy cannot be called hundred percent successful. The new Government's strategy of the rejuvenation of the Hooghly industrial belt will be able to boost or to create new urban centre in the western side of the River Hooghly. Along with the effort of creating new growth centres, government should pay attention towards housing crisis and slum development. Low income housing programmes in the main city as well as in the urban agglomeration can solve the problem.

(**Dr. Anuradha Banerjee** is Associate Professor and **Ms. Mala Mukherjee** is a Ph.D. Research Scholar at CSRD, SSS, Jawaharlal Nehru University, New Delhi 110067
Email Id: anuradha_csr@gmail.com)

Hazards Mapping for Disaster Management in Andaman & Nicobar Islands

S.C. Chaturvedi

Abstract

The Andaman and Nicobar islands, in a crescent shape stretching from cape Negrais of Myanmar to Banda Arch of Sumatra (Indonesia), are divided into three districts of North and Middle Andaman, South Andaman and Nicobar. Their location in close proximity of the equator and surrounded by sea has been responsible for tropical climate there; the coastline has a length of 1962 kilometers and an area of 8249 square kilometers. Of the total of 512 islands, 38 are inhabited (25 islands in Andaman group and 13 in Nicobar group). There are high peaks with volcanic origin and coral reefs. In addition to barren and Narcondam volcanoes, there are two neighbouring sea mounts in the Andaman Sea. There is one mud volcano in Baratang. Owing to such physiographic and locational conditions, Andaman & Nicobar Islands are highly prone to various kinds of disasters viz. volcanic eruptions, Earthquakes, Tsunami, cyclones and sea level rise. The Islands have a long history of natural disasters. In the present paper an attempt has been made to identify disaster prone location and do hazard mapping using modern technology of remote sensing and GIS so as to help in preparation of better disaster management and mitigation strategy.

Introduction

The Islands are situated in the Bay of Bengal between 6°45' to 13° 41' North and 92°12' to 93°57' East. The Islands located north of 10° North are known as Andaman Group of Islands while those located south of 10° North are called Nicobar group of Islands with a total area of 8249 km², and consisting of 306 Islands and 206 rocks and rocky outcrops with a coastal line of about 1962 km. The total length of Andaman & Nicobar Islands henceforth from North to South is 726 km and maximum width is 52 km, average width being 24 km. The length of Nicobar group of Islands is 259 km and maximum width is 58 kms. There are three districts in the Islands: the North & Middle Andaman (3302 km²), South Andaman (3106 km²) and the Nicobar (1841 km²).

Of the total Islands of 512, 38 are inhabited (25 in Andaman group and 13 in Nicobar group) and remaining 474 are uninhabited. The largest inhabited islands in Andaman group is middle Andaman Island with an area of 1536 km² and the largest inhabited island in Nicobar group is Great Nicobar Island with area of 1045 km². The smallest inhabited island in Andaman group is

Curlew island (0.03 km²) and the smallest inhabited island in Nicobar group is Pillomillow Island (1.3 km²).

A&N Islands are vulnerable to a variety of natural hazards due to its proximity to geodynamically active locales and unique physiography. Presence of hazards viz. earthquakes, cyclones, volcanic eruptions, Tsunami and sea level rise etc. create high probability of disasters.

Objective of the study

The paper attempts to identify location, site, situation and source areas of natural hazards viz. earthquakes, tsunami, sea level rise, volcanic eruptions and cyclones using Geographic Information System and remote sensing technologies.

It also aims to suggest measures for the assessment, prediction, prevention and mitigation of natural disasters through programmes of technical assistance and technology transfer, demonstration projects and education, training tailored to specific disaster and locations and to evaluate the effectiveness of these programmes.

Fig. 1 Andaman Group Islands

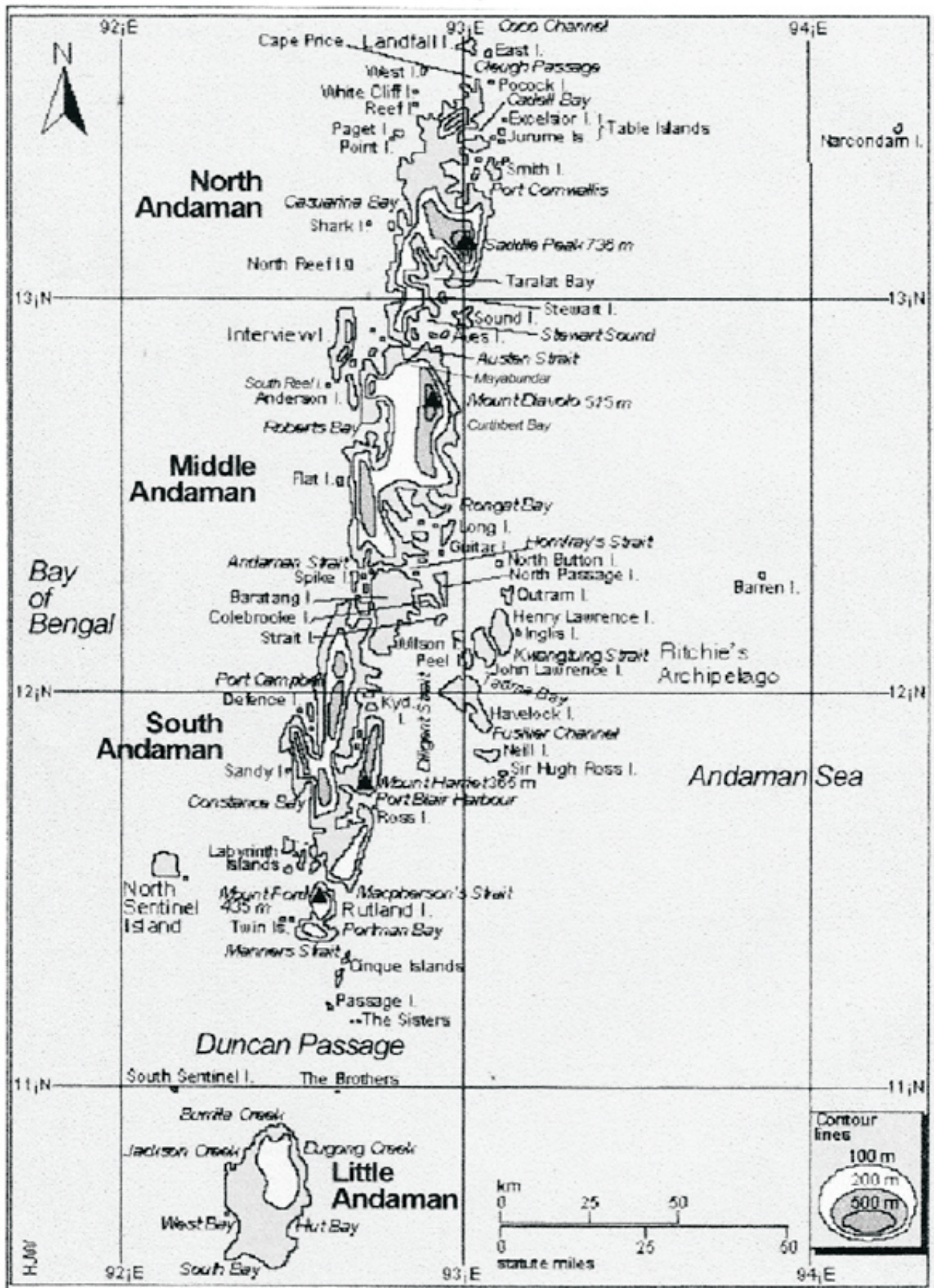
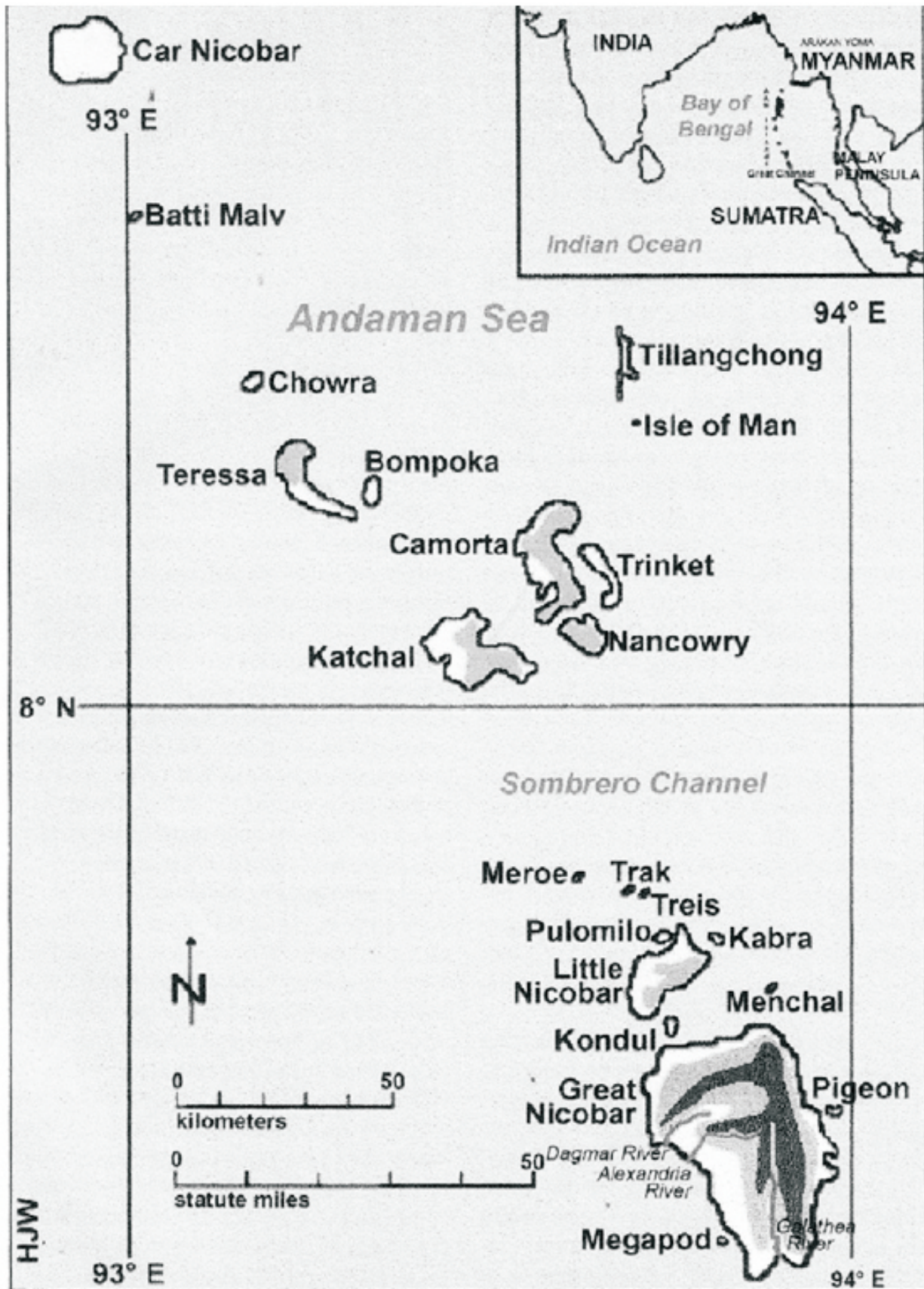


Fig. 2 Nicobar Group Islands



Data base and Methodology

The paper is based on primary and secondary sources of data. The secondary data were collected from various govt. departments such as Disaster Management Department of Andaman & Nicobar Administration, Deputy Commissioner office, South Andaman and Car Nicobar, Andaman & Nicobar integrated Command Geological Survey of India, Census office Port Blair, different books, journals, field survey and NGOs.

The Study Area

The Northern group of Islands, the Andaman group, is 6408 km² and the Nicobar group is 1841km². The nearest landmass in the north is Myanmar roughly 280 km north of Land Fall Island, the northern most Island in the Andaman group(see Figs. 1&2). The closest landmass to the great Nicobar Islands is Sumatra,145 km south.

The Great Andaman group of Islands is made up of North, Middle and South Andaman Islands, with Baratang Island situated between Middle and South Andaman Islands. Ritchie's Archipelago, a group of Islands is located last of Middle Andaman and Labyrinth group of Islands is situated southwest of South Andaman. Rutland lies southeast of South and Little Andaman Islands far away 55 km south of South Andaman across the Duncan passage. The elevation in Andaman is 0-732 meters, Saddle Peak in North Andaman Island is 732 meters, being the highest, Mount Fir Kala Pather is 435 meters in height and Mount Harriet is 365 meters in height are in South Andaman.

The Nicobar group is spread over an area of 1841 km². The Nicobar groups are separated from the Andaman by the 10⁹ channel, a wide gap of 160 km with heavy tidal flows. The Nicobar consist of 24 Islands in three district clusters of which 13 are inhabited with 170 villages and hamlets. The Northern group consists of Car Nicobar and Batti Malv and the Central or the Nancowry group, consists of Tillan Chong, Chowra, Teresa, Bompoka, Trinkat,

Kamorta, Katchal and Nancowry. The Southern group consists of the two large islands Little and Great Nicobar, together with Pigeon, Megapode, Kondul, Pilomilo, Menchal, Tries Trak and Meroe Islands. Great Nicobar also has the highest peak in the Nicobar group, Mount Thullier that is 670 meters in height (Pandey *et. al*, 1991; Das, 2001; Andrews & Sankaran, 2002).

These Islands are in a crescent shape and are considered to be the extension of the submerged Rakhine Yomas (Arakan Yomas) range of Myanmar, a southward trending branch of the eastern Himalayas. They are considered to be of volcanic origin with coral reefs.

Drainage

In South Andaman, the major streams are Dhanikhari, Mithakhari, Burmanallah, Prothrapur nala. Dhanikhari has largest flow from South to North of about 15 km from Chiragutapur to Flat bay. A reservoir was constructed during the British rule for drinking water requirements of Port Blair after

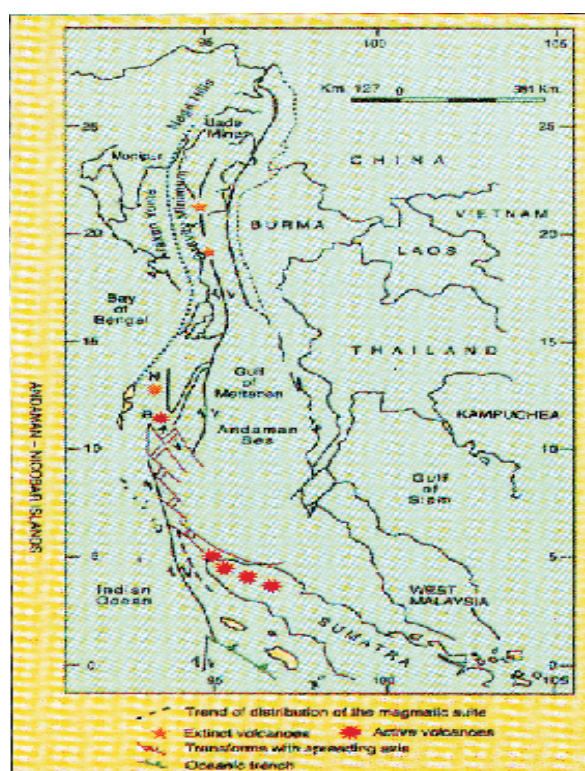


Fig. 3 Location of the Barren and Narcondum Volcanic island and the neighbouring Volcanic sea mounts in the Andaman sea.

treatment. Raigal is the main stream in middle Andaman and Kalpong in the North Andaman.

The Great Nicobar is the only island in Nicobar district with perennial rivers, namely Galathea, the Jublee, the Dak Arung, Dak Tayal and Amrit Kaur, which originate from the mount Thulliar. The Gallathea is longest and widest river which flows eastwards to meet the Gallathea Bay.

Narcondam Volcano

Narcondam, a seven sq. kms island which is 710 meters above mean sea level, is an extinct volcano, 75 kilometer away from Diglipur. The origin of the Narcondam is believed to be from a single eruption and dated late Pliocene to Pleistocene (Chibber 1934; Das 1999). The name is significant as it stands for "NARAKA KUNDAM" i.e. pit of hell, a rite of eternal fire hinting to a volcano. But Narcondam was never active during the historic time and is considered an extinct volcano. Still it has a steep and regular volcano cone which rises to a height of 2150 feet out of the deep sea to the east of the Andaman group (Fig. 3).

Barren Island Volcano

Barren Island (12°29'North; 93° 85' East) lies about 135 km north east of Port Blair and 55 km from Long Island (Fig. 3). It occupies only 10 sq km area. The island rises from a depth of about 2250 meters from the sea floor and stands out at an elevation of 335 meters above the mean sea level

The nomenclature Barren is apparently a misnomer as the island, barring its central part, is covered with thick foliage. The southern slope has thick vegetation whereas the northern slope is partly barren and partly covered by undergrowth. The vegetation is tropical evergreen, deciduous and littoral. Mangrove forest is completely lacking because of very steep sea shore all around the island. No human habitation is ever reported from this island. A 12 meter tall gas -operated light house situated very near to the landing site on the western shore is the only man-made structure on this island. Largest animal is feral goat (Capra

Hircus). A score of goats were left to this island from Port Blair in 1891. Besides, a variety of rats, Andaman flying fox, horse shoe bats, land crabs and varied species of birds are also seen on this Island.

Besides Barren and Narcondam, there are two neighbouring sea mounts in the Andaman sea which are also of volcanic origin, namely Alcock SMT, 60 km east of Barren and the Sewell SMT about 200 kilometer east of Car Nicobar Islands, which lies about 90 km south of the ten degree channel.

The area of Islands can be divided into three parts.

1. Moderately high hills
2. Inter Montane valleys
3. Gently sloping coastal tracts.

Except for a few islands in Nicobar group, topography is generally hilly; the main ridges run from north to south. Between the ridges are deep Nallas and creeks formed by submerged valleys. Only small areas are occupied by flatlands along river banks and coastal body. There are no well developed river systems except for Great Nicobar having 5 perennial rivers. There are no lakes or well formed drainage systems. There are only few springs with average discharge in lean periods of 10 -50 lmp. There are no irrigation projects except Kalpong and Dhanikhari dam, 132x 32 meters, supplying drinking water to Port Blair.

Baratang Mud Volcano

This mud volcano (locally known as Jwalamukhi) is located at Baratang Island about 80 km north of Port Blair. Usually mud volcanoes are found associated with tectonic sub direction zones. They are geological formations created through geo- excreted gases and liquids, and are of global concern; because they emit a large volume of methane gas over 10- 33 Tg/year.

The Baratang mud volcano is currently active and secretes grayish slurry resembling the colour and texture of hydrated port land cement. Fine slurry suspended in clear watery liquid constantly flows through small cylindrical

outlets (3-5 centimeter in diameter). These outlets eject slurry bubbles throughout day and night. Seldom small and medium sized (0.5 to 2.0 centimeter) pebbles are also shot out. The continuously flowing slurry gathers in small puddles and then flakes into fine ash. Seepage from an outlet usually occurs for a period of 4 -6 days and then ceases. In 2004 the number of outlets and the slurry flow have increased. At present it has transformed from flat land into a large cylindrical mound (15 meter in diameter). The islands have heavy rainfall, so cones are constantly washed off. They are 60-70 centimeter high during the dry pre- monsoon period (March – April).

Impact of Volcanic eruption of Barren Island

In Barren Islands, volcanic eruption of 1995 erupted on small scale and its effects were also localised. Remoteness too saved the main Islands from any major catastrophe. No life or property was affected during the recent eruption. However, the 12 meter tall light house was completely buried under the hot lava and about 25 meter high lava ridge was created at the landing site. The effect of eruption so far seen was that the vegetation in the route of advancing lava stream was destroyed. The seawater surrounding the island turned acidic. The coral beds along the western shore were badly affected. Most of the ash particles were carried away from the neighbouring populated islands because of the northerly and easterly wind direction during the eruption period. Big trees, partly charred, were buried under thick cover of ash. The ground temperature measured 62°C to 83°C. About 300 meter to 100 meter, thick aerosol was encountered, about 90 km west south west of the volcano at an altitude of 2100 meters. The seawater temperature at the landing site was measured 38°C to 70°C and the atmospheric temperature recorded was 70°C to 55°C about 10 meter to 15 meter away from the hot lava stream on 11 May, 1995.

Impact of earthquakes on Islands

The A&N Islands falls in zone V of the earthquake belt of South-east Asia in which the recorded

disastrous earthquakes of the history have taken place. The early records of earthquakes in Andaman islands can only be built with a fair degree of precision since the formation of the second penal settlement in 1858. The earthquake which struck the islands in 1883 caused the rising and receding of seawater thrice in the course of few minutes.

Changes in the level of the coasts at the Andamans have been marked in the writing of different geologists who have visited these islands from time to time. Karz (1885) mentioned in his 'Report on the vegetations of the Andaman' that these islands are, and have been during recent times, undergoing subsidence. Oldman (1885) supported the fact that the Islands are gradually sinking but also contended that islands were undergoing elevation that must have exceeded subsidence in the immediate past. He proved it by giving example of raised beaches that fringed the shores of Andamans like northeast corner of Chatham Island, Ritchie archipelago and the east coast of South Andaman.

On 26th December 2004 the Indian plate ploughed into the Burma Plate triggering an earthquake of magnitude of 9.1 on the Richter scale. Epicentre was located at 3.7° north latitude and 95° east longitude near Banda Ache of Northern Sumatra. The Collision caused a massive crack with a length 1000 km and breadth 50–100 km at ground surface under the sea. The impact of the earth quake was so great that the entire archipelago has tilted about 1.15 meters in southeast direction and has sunk about 1.25 meters in general. The rupture of plate, beneath ocean generated towering waves of more than thirty feet height and affected the area far beyond its epicenter—as far as Somalia in Africa.

Aftershocks

The aftershocks are still continuing in Andaman & Nicobar archipelago though it appears to be quieting down except some occasional large tremors as one felt on 24 July 2005 which measured 7 on Richter Scale. The continuation

of the aftershocks has instilled a fear among the people residing in A&N Islands.

Morphological Changes

The devastating earthquake of 26th December 2004 with epicenter off the coast of Indonesia that spawned huge tidal wave in the Indian Ocean region has slightly changed the planet's shape, shaved almost three microsecond from

the length of the day, and shifted the North Pole by centimetres. According to NASA Scientists, "Although all earthquakes leave an impact, the devastating mega earthquake registered nine on new moment scale (modified Richer Scale) made it the fourth largest in one hundred years". According to their latest calculations, the December 26th Earthquake has shifted Earth's mean pole by 2.5 centimeters in the direction of

Table 1
Seismicity in Andaman and Nicobar Islands.

Year	Date	Scale	Place	Shock recorded at
1881	31, December	7.9	North & North west Andaman	Kolkata, Visakhapatnam, Chennai and Port Blair
1914	16, November	7.2	South –west of Barren Island Andaman	-
1925	28, June	-	South –east of little Andaman Island	-
1929	1 August	6.5	Andaman sea, east and south –east of Barren Island.	-
1929	I, December	6.7	South & South –east of Great Nicobar	-
1936	19, March	6.5	Little Andaman Islands	-
1939	14 September	6.0	Andaman sea, South –east of Barren Island.	-
1941	26, June	7.7	West of Middle Andaman	Tsunami recorded on Bay of Bangal along the Coromondal coast.
1945	8 August	6.7	North & Little Andaman Islands	-
1949	23, January	7.2	Andaman Sea, east of Car Nicobar Islands	-
1955	17 May	7.2	Off the east coast of the Great Nicobar Island	-
1957	18 June	6.5	Andaman sea, east and North –east of Narcondam.	-
1967	14, February	6.8	Andaman sea, west of the Margui archipelago	-
1982	20, January	6.2	8.5 km east of the Bannanga, Great Nicobar	
2002	14, September	6.5	23.6 km South & South-east of Diglipur (North Andaman)	
2004	26, December	9.1	Indian Archipelago	Tsunami

145 degrees east longitudes, more or less towards Guam in the Pacific Ocean. The earthquake has affected the earth's shape also. The scientists calculated that earth's oblateness decreased by a small amount – about one part in billion. They have found that the earthquake has decreased the length of the day by 2.68 microseconds. In other words the earth now spins a little faster than it did before.

The Collision of Indian and Burma plates has brought about morphological changes of far reaching consequences in Andaman archipelago. There are some islands which have witnessed the ingress of the sea water in the low gradient areas like Chowra, Terresa, Little Nicobar, Katchal, Trinket, Great Nicobar, South Andaman etc. In case of few other islands like Sentinel, Cinque, etc., the receding of sea water has bared the continental shelf with all its features.

Major Hazards and Their Impact

A. Tsunami

The term tsunami comes from the Japanese language (Tsu –means harbor and nami- means waves). Tsunami refers to a series of waves generated when a body of water, ocean or sea is rapidly displaced on a massive scale. Earthquake, landslide, volcanic eruption and meteorite impacts all have the potential to generate a Tsunami.

The Andaman and Nicobar Islands are worst hit, the brunt of the attack was borne by the coral reef ecosystem, which in most cases, helped reduce the impact on land. Most of the coral reef in Great Nicobar Islands have been reduced to rubble. Sand and silt have been deposited on the reefs, choking them. Many reef dependent species have lost their habitat and their breeding cycles have been disrupted.

The massive sea ingress and submergence of Nicobarese coastal flat lands have uprooted several corals, increased water turbidity and destroyed habitats. A huge population of sponges has been affected and animals such as crabs, lobsters and stomatopods have been displaced from their coral homes. The breeding

cycle of marine turtles has already been affected and the loss of the sea grass which is the main food for endangered species has brought a change in breeding habitat.

Coral reefs in several areas around the Andaman and Nicobar Islands have suffered extensive damage. The damage is mainly breakage of corals and toppling of coral heads while some coral reef areas have been buried under sand and sediments. Some shallow water corals have been carried away to deep sea and they may not survive as their habitat changed drastically. In North Andaman some areas were uplifted, exposing the coral reefs and certainly they will not survive. As concern of destruction to coastal ecosystems mounts, it is feared that the surviving turtles may not find their nesting ground and regular food sources like sea grass as happened in the case of the green turtle.

Ramachanran and others, (2005) have reported that coastal ecosystem of four Nicobar Islands viz Kamorta, Katchal, Nancowry and Trinkat show an extensive damage ranging from 51 percent to 100 percent for mangrove system, 4 percent to 100 percent for coral reef system and 6.5 percent to 27 percent for forest ecosystem. Coral reef of the Jolly Bouy, Red Skin are affected by about 40 to 70 percent.

The Tsunami changed the ground water level in the south western part of the Neil Islands and quality of water also changed. This part of the island has potential changes for seawater incursion (Singh, *et. al.*, 2005). The Real Time Kinematic Global Positioning system (RTKGPS) reading suggested that the run up level for Port Blair South Andaman at many places was between 1.5 and 3 meters and inundation between 100 to 200 meters. In the case of Little Andaman in Hut Bay the run up level was 5.0 meters and inundation was 1200 meters. Malacca in Car Nicobar exhibited 7.0 meters and inundation was 1000 meters. In the case of Great Nicobar in the central Part also it was 3.0 meters and inundation was in 300 meters. However in Northern part it was 6.0 meters and 50 meters (Ramana Murthy, *et. al.*, 2005). As

many as 3513 people died and 2817.58 hectares agricultural land was destroyed and thousands of animals died due to this Tsunami.

B. Cyclone

Tropical cyclones are characterised by destructive wind and copious rainfall. In such storms, winds can exceed speeds of over 120 km/hr. Due to such strong wind, sea water accumulates ahead of cyclone as it moves towards the coast. When a cyclone hits the coast, the accumulated enormous mass of sea-water strikes the coast as a giant. Sea wave called storm surge can have heights of the order of tens of meters. Cyclones pose a major threat to life and property in these Islands. The Andaman & Nicobar Islands experience two types of cyclone season viz, pre monsoon (April and May) and post-monsoon (October and November). More cyclones form in the Bay of Bengal than in the Arabian sea. On an average about 5-6 tropical cyclones form every year. These form between 5°N to 20° N latitudes. Cyclone destruction is often incalculable because of swiftness, speed and force. These cyclones damage houses, buildings, roads, communication system and electricity systems of Andaman & Nicobar Islands almost every year.

C. Sea Level Rise

An increase in sea level rise is likely to be disastrous on people living in coastal area of the Islands. Andaman & Nicobar Islands are under the influence of tectonic activities. Low lying coastal areas are more vulnerable to penetration of sea water in land in association with high tides, tropical storms, storm surges etc. Coastal marshes and swamps are particularly vulnerable to rising sea level because they are mostly situated within a few meters of sea level. Mangroves are highly sensitive ecosystem. Rising sea level would tend to increase the salinity of surface and ground water. Projected magnitude under climate change scenario (20 - 100 cm /110 years) is expected to have serious effects on the socio- economic development of these small islands – specially Car Nicobar, Port Blair, Great Nicobar, Little Andaman (Hut Bay

and Rangat and other Islands. Major beaches of these islands would submerge under sea.

Natural Disaster Reduction and Management

The Andaman & Nicobar Islands was severally affected by the earthquake and tsunami of 2004. One of the major challenges before the A & N Administration was rehabilitation of the affected people consistent with their aspirations particularly in view of various logistic /weather /other constraints. The resilience of the tribal people in adopting to changed scenario and leading a normal life despite the tragedies witnessed by one and all is commendable.

References

1. Asthana, V. (1993), '**Impact of sea level rise in the Island and coast of India, climate change in India: country study**' **Climate Change: An Indian Perspective**, Ministry of Environment & Forests, Govt. of India, New Delhi.
2. Butt, B.A. (1988), **Earthquakes**, W.H. Freeman, New York.
3. Chauhan, H.S. (2011), Fresh water availability in the Islands; Problems of sea water ingress in the Aquifers". pp. 34.
4. Coburn Andrew and Robin Spence (2002), **Earthquake Protection**, John Wiley, New Delhi.
5. **Current Science**, 101 (1), 10 July, 2011.
6. Chaturvedi, S.C. (2008), Impact of Tsunami in Andaman and Nicobar Islands", **Journal of Water & Land Use Management**, 8(1-2), M.D. Publication Pvt. Ltd., New Delhi.
7. Goel, S.L. (2006), **Encyclopedia of Disaster Management, Vol.1.**, Deep and Deep, New Delhi, p.5.

8. Rao, V.R. **Tsunami South Asia: studies of impact of communities of Andaman & Nicobar Islands**, Anthropological Survey of India, Kolkata, Allied publishers Pvt. Ltd., New Delhi.
9. Bera, T. R. (2011), **A History of Nicobar Islands Pre and Post Tsunami**, Woodland Publishers, Kolkata.
10. Govt. of India, (2009), **Forest Statistics 2009**, Department of Environment & Forest, MOEF, New Delhi.
11. Govt. of India (2004), **Disaster Management in India**, Ministry of Home Affairs, New Delhi, pp. 32-46.
12. Gurjar, R.K. and B.C. Jat (2005), **Environmental Geography**, Panchsheel Prakashan.
13. Jat B.C.(2005), 'Tsunami Disaster', **Bhogol Aur Aap**, TIRIs Publication, Pvt. Ltd., New Delhi.
14. Jat B.C (2008), **Natural Hazards and Disaster Management**, MD Publication Pvt. Ltd., New Delhi.
15. Rajan, K. (1999) 'Natural Disaster Management in National Development – An Indian Perspective', In Vinod K. Sharma, *ed.* **Disaster Management**, National Centre for Disaster Management, IIPA, New Delhi, p. 26.
16. Mandal, G.S. (1995), "Tropical Cyclones and their Damage Potential", **Status of Wind Engineering in India**, Indian Society for Wind Engineering.
17. Celley R.K. and T.N. Gupta (1992), 'Dimensions of Natural Disaster Management in India', **Shelter**. October 12, 1992.
18. Simon, Ross (1987), **Hazard Geography**, Longman, U.K.
19. Jayraj, R.S.C. and Harry V. Andaman, (2009), **Andaman & Nicobar Islands Union Territory: Biodiversity Strategy and Action Plan**, University Press, Hyderabad, pp. 3- 5.
20. Singh, Savindra (1997), **Environmental Geography**, Prayag Pustak Bhavan, Allahabad.
21. Scorpa R. and Tilling, R.I. (1996), **Monitoring and Mitigation of Volcanic Hazards**, Springer, New York.
22. Tilling, R.I. (1989), 'Volcanic hazard and their mitigation, progress and problems', **Reviews of the American Geophysical Union, Geophysics**. 27(2).

(Dr. S.C. Chaturvedi is working as a Associate Professor at P.G. Department of Geography, Jawahar Lal Nehru Rajkeeya Mahavidyalaya Port Blair Andaman & Nicobar Islands 744104)

A Study of Change in Land use/cover in Kollam District of Kerala Using Remote Sensing and GIS

S. Sandhya, P. Deepthi, B. Sukumar, Ahalya Sukumar

Abstract

The paper analysis changes in land use/land cover to examine its environmental impact making Kollam district as a case study. Survey of India topographic map on 1:50,000 scale and satellite remote sensing data were used to study landuse/landcover changes. For the study different parameters like relief, slope, aspect, geology, drainage, soil, population, infrastructural facilities like roads, railway, and landuse/land cover maps were prepared and correlated with land degradation. From this study it is found that the land has been affected in the hilly region in the east with regular landslides. Land use change in the midland region has increased surface runoff causing flood in the western part of the district.

Introduction

Land use is constrained by environmental factors such as soil characteristics, climate, topography, and vegetation. But it also reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled to economic growth (Richards, 1990). As a result, control over land and its use is often an object of intense human interactions.

Methodology

Survey of India topographic map on 1:50,000 scale and remotely sensed images were used to study landuse/cover changes. For the purpose, maps on different parameters like relief, slope, aspect, geology, drainage, soil, population, and landuse/land cover were prepared and correlated with land degradation.

The study area

Kollam district, located between 8°45' to 9° 28' N. and 76° 28' to 77° 17' E., has an area of 2491 km² and with a population of 2.58 million (Census, 2001). It is bounded on the north by Alappuzha and Pathanamthitta districts, east by the Western Ghats and Tamilnadu State, south by Thiruvananthapuram district and west by the

Lakshadweep Sea. It has five taluks namely Kollam, Karunagappally, Kottarakkara, Kunnathur and Pathanapuram. There are 104 Villages, 72 Panchayats, 5 Taluks, 13 Blocks, 2 Municipalities and 1 Corporation (Fig. 1).

Aim and Objective

The main objective of the study is to understand and analyze dynamics of landuse/landcover change and its impacts. Landuse changes and its impact studies are very important for planning purpose.

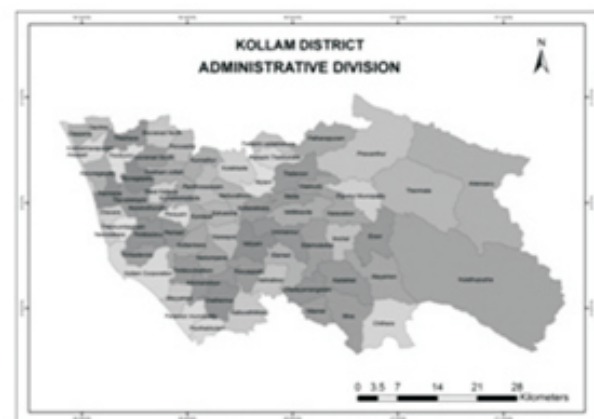


Fig. 1

Relief: The elevation of the district ranges from mean sea level to 1700m. The highest area is in the south eastern part of the district. Gradually the elevation decreases towards the west (Fig. 2).

Slope: The general slope of the area is from east

to west. The maximum area of the district is covered by 0-10 degree slope. Steep slope is found in the eastern part of district, falling in the western ghats (Fig. 3).

Geology: The coastal area is consists coastals sand and and alluvium. East of the coastal sand has clay and sandstone. Most of the district is covered by garnet, biotite and gneiss (Fig. 4). The north-eastern parts have charnnokite and middle part has khondalite.

Drainage: Kallada watershed is the largest watershed in this district (1426.95 km²) and Ittikara, Achancoil. Pallikkalthodu watershed, Ayirur watershed, Vamanapuram watershed (some portions) are the major other watershed of the district. The major lakes are Ashta-mudi Kayal and Paravur Kayal, Idava and Nadayara Kayal lies partly in this district.

Climate: Kollam district has tropical humid climate. It has the maximum temperature of 220C. The hot season, lasting from March to May followed by south west monsoon from June to September.

Relief: The elevation of the district ranges from mean sea level to 1700m. The highest area is in the south eastern part of the district. Gradually the elevation decreases towards the west (Fig. 2).

Slope: The general slope of the area is from east to west. The maximum area of the district is covered by 0-10 degree slope. Steep slope is found in the eastern part of district, falling in the western ghats (Fig. 3).

Geology: The coastal area is consists coastals sand and and alluvium. East of the coastal sand has clay and sandstone. Most of the district is covered by garnet, biotite and gneiss (Fig. 4). The north-eastern parts have charnnokite and middle part has khondalite.

Drainage: Kallada watershed is the largest watershed in this district (1426.95sq.km) and Ittikara, Achancoil. Pallikkalthodu watershed, Ayirur watershed, Vamanapuram watershed (some portions) are the major other watershed

of the district. The major lakes are Ashta-mudi Kayal and Paravur Kayal, Idava and Nadayara Kayal lies partly in this district.

Climate: Kollam district has tropical humid climate. It has the maximum temperature of 220C. The hot season, lasting from March to May followed by south west monsoon from June to September.

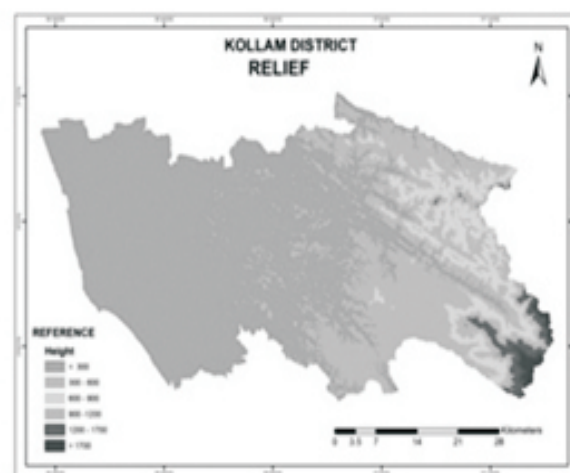


Fig. 2

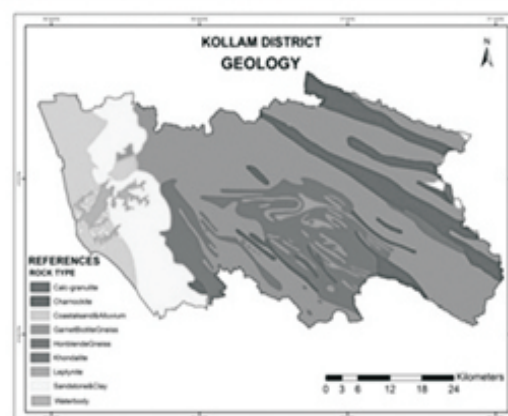
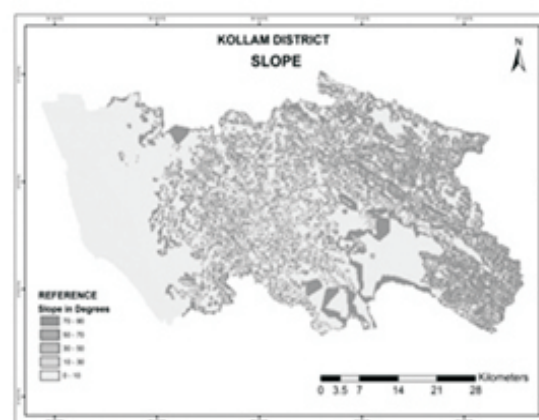
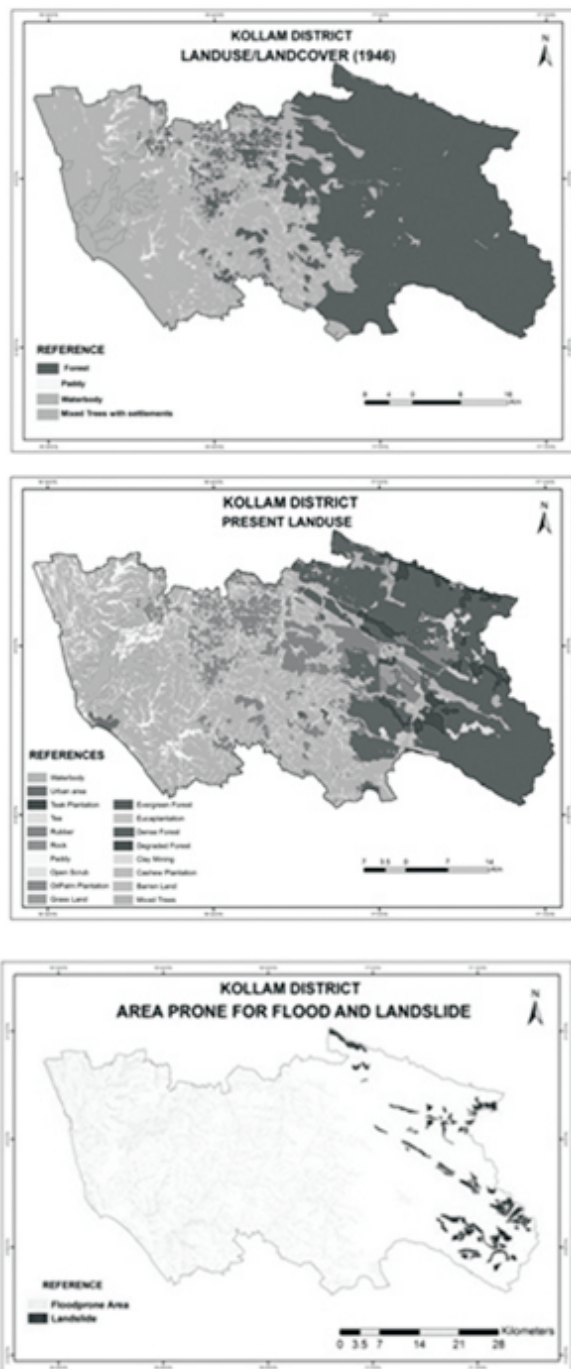


Fig. 3 and 4

Landuse/Land cover

The landuse in 1946 was mainly forest in the east, water body in the west consisting of (Ashtamudi and Paravurkayal). The paddy fields were found along the river valleys and low lying areas (Fig. 5). The other areas were covered with mixed trees and settlements. The landuse has changed to a large degree in the past sixty years (Fig.6).



Figs. 5, 6 and 7

Analysis and Conclusion

The landuse changes have occurred mainly in paddy, mixed trees areas, and forest areas. Paddy area has increased from 102.6 sq. km in 1946 to 278.57sq.km at present. The forest area has decreased from 775.7sq.km to 596.48sq.km. Most of the forest area has been converted to rubber plantations, occupying about 196.65sq.km and also teak and eucalyptus. Mixed tree cover areas are changed to settlements with other crops like tapioca, banana, and coconut. Area under settlements has also increased.

Mixed trees, forest areas and other areas got converted into settlements. Settlement area increased in and around Kollam Corporation. Settlement area and transportation area has increased due to growing urbanization of the district. Forest area has been taken over by rubber plantations which has caused land degradation. Eastern hilly part is prone to landslides. Landslide has been reported by CESS publication (2009). Valley areas and side slopes have been encroached upon which has caused floods during rainy season. The flood prone area has increased in many parts of the district (Fig.7). Landuse change in the midland region has increased surface runoff causing flood in the western part of the district. This part of the district therefore needs attention of the planners.

References

Turner, B. L. *et al.* eds. (1993). **Relating Land use and Global Land-cover Change: A Proposal for an IGBP-HDP Core Project**. Report from the IGBP-HDP Working Group on Land-Use/Land-Cover Change. Joint publication of the International Geosphere-Biosphere Programme (Report No. 24) and the Human Dimensions of Global Environmental Change Programme (Report No. 5). Stockholm: Royal Swedish Academy of Sciences.

Prakasam, C (2010), "Land use and land cover change detection through remote sensing approach: A case study of Kodaikanal taluk, Tamil Nadu" **International Journal of**

Geomatics and Geosciences, Department of Geography, The University of Burdwan, 1(2).

Prakasam. C and Biplab Biswas (2009), Land use, Land Cover Change Study in Ausgram I&II Blocks, Burdwan Dist, West Bengal using Remote Sensing and GIS. **Indian Journal of Landscape Systems and Ecological Studies**, 32(2).

Rajan, K.S. and Shibasaki, R., (2000). A GIS Based Integrated Land Use/Cover Change Model to Study Human Land Interactions, **International Archives of Photogrammetry and Remote Sensing**, 33(3), pp. 12-19.

Eric F. et al. (2003), Dynamics of land-use and land-cover change in tropical regions, First published online as a Review in Advance on July 16, University of Louvain, Place Louis Pasteur 3, B-1348

Integrated District Development Plan-Kollam, Perspective Plan (2009), District Planning Committee, Local Governments, Department of Town and Country Planning, Govt. of Kerala. Vol. I

Human Induced Land Degradation is Preventable. United States Department of Agriculture-Natural Resources Conservation Service.

Eswaran, H.; R. Lal and P.F. Reich. (2001). "Land Degradation: An overview". Responses to Land Degradation. **Proc. 2nd. International Conference on Land Degradation and Desertification**. New Delhi, India: Oxford Press.

Johnson, D.L. and L.A. Lewis (2007), **Land Degradation: Creation and Destruction**, 2nd edition, Rowman and Littlefield, New York

(Ms. Sandhya.S, Ms. Deepthi.P, Dr. Sukumar.B and Mrs. Ahalya Sukumar are Scientists working with Resources Analysis Division, Centre For Earth Science Studies, Akkulam, Thiruvananthapuram- 695031

E-Mail: sandhyasyamala@gmail.com)

Demographic Changes and Agricultural Land use in Kerala

N. Saniya, G.S. Lekshmi, V. Dani and E. Saravanan

Abstract

Geographers have shown keen interest in study of interrelationship between demographic factors and agricultural development. Demographic changes taking place in the developing world have wide implications in socio-economic development in these societies. Among the Indian states, Kerala has experiences demographic transition, recognized all over the world. The state has dense population with low infant mortality and high life expectancy. The visible impact of demographic transition on the agriculture of Kerala is the emigration of workers from the state and changes in labour market. Being an agrarian economy such changes affect the agricultural activities and agricultural land use of Kerala. The high literacy rate in Kerala is also resulting in weeding out labour force from agricultural and related activities. Kerala's agricultural economy is also undergoing structural transformation from the mid seventies as there is a large-scale shift in area from food to cash crops. Out of the Gross cropped area of 26.69 lakhs ha in 2009-2010, food crops occupy only about one-tenth. Kerala, a state characterized by low production of food and high density of population, is facing serious challenges with its limited land area.

Introduction

Geographers have shown keen interest in study of interrelationship between demographic characteristics and agriculture development. Demographic changes taking place in the world now has given much emphasis on socio-economic implications. It is necessary to observe the dominant factor that determines the regional structure of agriculture. This ranking of factors according to the level of dominance over agricultural activities is a complex exercise requiring a detailed systematic investigation. The most geographical investigation on agriculture have emphasized on the role of physical factors and resultant agricultural structure. Since population is a decisive force for conditioning agricultural system a closure study of its impact in patterning land use of an area is definitely imperative for theoretical understanding and practical solutions of many agricultural problems.

Among the Indian states, Kerala has passed through impressive demographic transition with low infant mortality rate, high life expectancy, low population growth rate and high literacy. Kerala's agricultural economy is also

undergoing structural transformation from the mid-seventies as a large proportion of its area is shifting from food to cash crops like coconut and rubber. Of Gross cropped area of 26.69 lakh hectares in 2009-10, food crops occupy nearly one-tenth area. Kerala, a low food producing and high population density state, is facing a serious challenge due to limited land area. In view of this, an attempt is made to study demographic changes in Kerala and its role in determining the agricultural land use in the state.

Aims and objectives

The main objectives of the study are to:

- i. analyse the demographic changes in Kerala,
- ii. study the change in occupational structure in state,
- iii. examine the impact of demographic change on agricultural land use, and
- iv. study changes in agricultural land use

Methodology

The Secondary data on population was collected from Census of India (1981, 1991, 2001), on agricultural land use from Dept. of Economics & Statistics and various other Govt. agencies. Standard Statistical Techniques were used to

study the demographic changes and agricultural land use changes in the state. The relation between demographic factors and agricultural land use change has been studied. ArcGIS ver 9.1 software is used to prepare thematic maps for the present study.

Study area

Kerala is located in the south western part of India and it is lovingly called as God's Own country. It extends from 8°17'30"N to 12°47'40" North and 74°51'57"E to 77°24'47" East. It covers an area of 38.8 thousand km², accounting for 1.18 per cent of the total area of the country. Physiographically the state is divided into highland, midland and lowland. It is blessed with the mesmerizing beauty of its sun bathed golden sea shores dotted with abundant coconut trees. It also accommodates the zig-zag rocky terrain of the Western Ghats, straggling plantations and paddy fields, the azure lagoons, cascading rivers and waterfalls, fascinating bio-diversity and its age old heritage and traditions. Kerala ranks twenty first in respect of area and twelfth in regard to population among the states in India. The population of Kerala as per the provisional population totals of census 2011 is 3,33,87,677 which is 2.76 per cent of the total population of the nation and it has a population density of 859 persons/sq km. Kerala's population is most densely settled in the coastal region leaving the eastern hill and mountains comparatively sparsely populated. In absolute terms, the population of Kerala has increased by more than 15 lakh persons during 2001-2011. However, Kerala's population growth rate (4.86 per cent during 2001-2011) is far lower than the national average and other states. Degree of industrialization is relatively low.

The area also has diverse productive capacity and economic opportunities with marine fisheries, coastal backwaters and Kuttanad zone (Rice Bowl of Kerala) in the lowlands, forestry and plantation along the eastern hills, mountains and agriculture in the valleys.

The crops in the highland are mostly dominated by Tea, Coffee, Cardamom, Ginger and Pepper

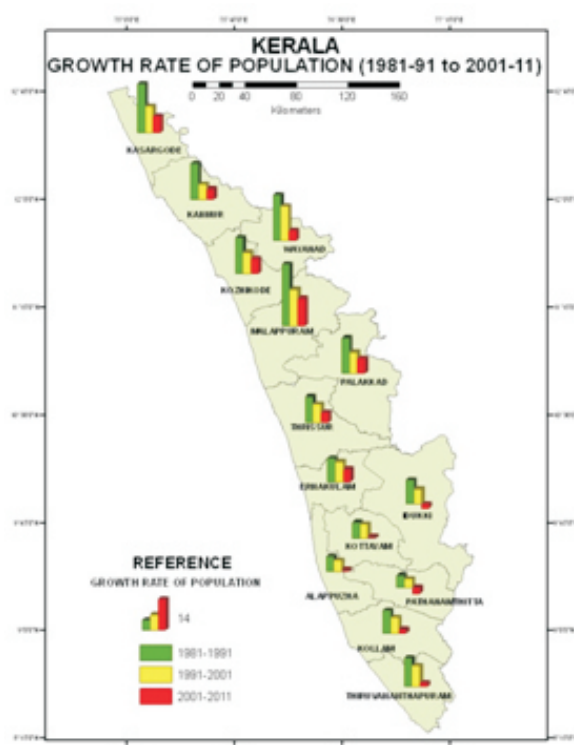


Fig. 1

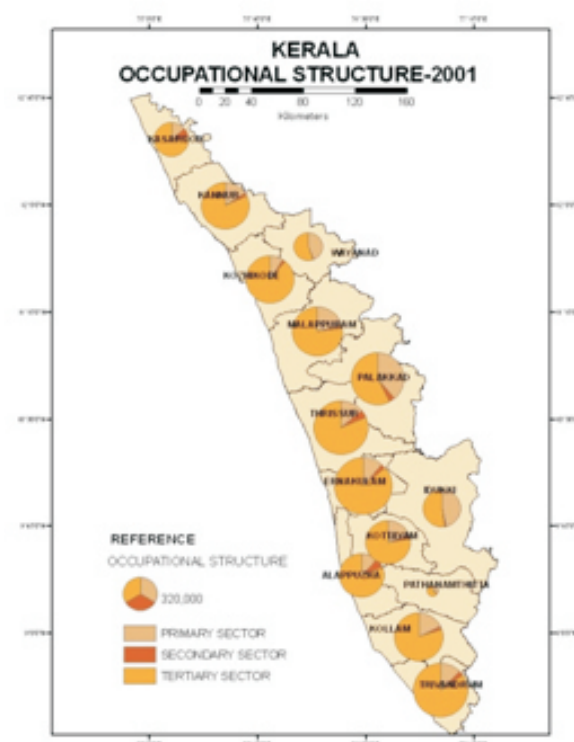


Fig. 2

and along the midland the important crops are Rice, Rubber, Coconut, Tapioca and Banana. Lowland which occupy the Kuttanad zone has extensive Rice cultivation. The Gross area sown (GAS) during 2009-2010 was 26.7 lakh,

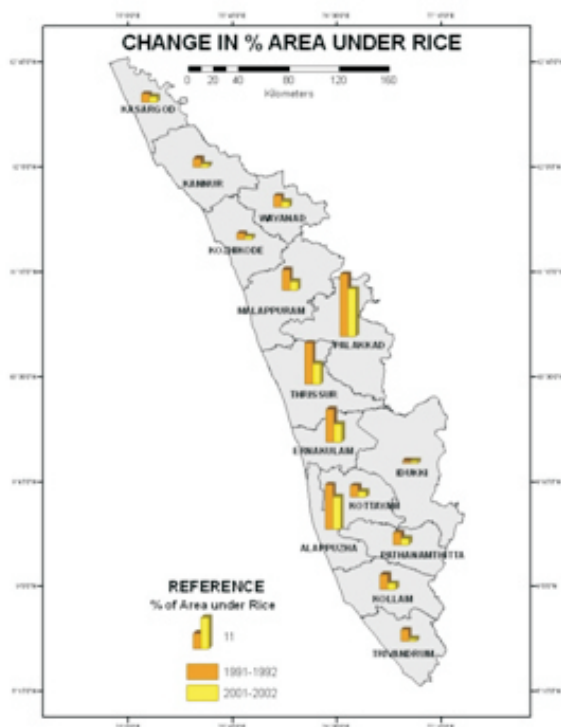


Fig. 3

decreased by about one per cent over the previous year.

The main food crops are rice and tapioca and the main non- food crop is rubber. Palakkad and Alappuzha are the two main rice producing districts of Kerala. Plantation crops dominate in Kottayam, Wayanad and Idukki districts.

Results and analysis

Among the states in India, Kerala has an impressive demographic transition well recognized all over the world. The impressive indicator of demographic transition in Kerala is its high levels of literacy especially among women. Kerala ranks highest in India with respect to social development such as elimination of poverty, primary education and health care. As a result, Kerala has high life expectancy, low birth rate, low death rate and low infant mortality rate. The demographic data obtained from the Census for 1981, 1991 and 2001 are analysed. This shows that the percentage of decadal growth rate of population in Kerala for 2001-2011decade is 4.9 per cent while it was 9.4 per cent in 1991-2001. Thus there is a decrease in growth rate of population. This is due to its decreasing trend in total birth

rate from 25 per thousand (1974-1980) to 17.1 (1994-2001). Also the state has decreasing trend in total fertility rate from 2.9 (1974-1980) to 1.7(1994-2001). In Kerala the highest decadal growth rate is recorded in Malappuram district (13.39 per cent) and the lowest in Pathanamthitta district (-3.12 per cent) see Fig. 1. The density of population of the state is showing an increasing trend from 747 persons per sq.km (1991 Census) to 859 persons per sq.km (2011 Census). The literacy rate of Kerala is 94 per cent according to 2011 Census. The literacy rate is also showing an increasing trend (1991, 89.81per cent, 2001, 90.86 per cent). High level of literacy and educational development lead to great awareness and help people to acquire new skills. With a high literacy rate the work force generally prefers white collar jobs. However, the scope for white collar jobs is rather scarce in the state. As a result, a large number of persons are emigrating from Kerala in search of skilled jobs and shortage of labour is experienced. Hence, emigration out numbers immigration in Kerala. Due to the high rate of literacy the structure of employment is also undergoing major changes in the state. The changing structure has been the result of the rising demand for jobs away from agriculture (Fig. 2). Analysis reveals that employment in primary sector is decreasing (-18.8 per cent), stagnant in manufacturing sector, and increasing in the tertiary sector (19.37per cent).

This impact of demographic changes on agriculture is visible with the shifts in cropping pattern from food to cash crops that are less labour intensive. The area under major crops for the years 1991-92 and 2001-02 has been analysed. The percentage decrease of area under rice cultivation from 1990-91 to 2001-02 is 40.00 per cent (Fig.3). The cereals and pulses also show a decrease of 13.94 per cent and 64.26 per cent, respectively. Tapioca, another major food crop of the state is also showing a decrease of 21.63 per cent. The area under spice has shown an increase of 18.08 per cent. The area under fruits and vegetables has increased to 34.73 per cent. The area under plantation crops

has an increase of 9.20 per cent. The field work in Palakkad has revealed the fact that a substantial land under has been shifted from paddy cultivation to horticulture and other non-food crops due to the lack of labour force and higher wages. The cropping pattern in each districts show that the area under rice is showing a declining trend. In Palakkad the area under paddy crop decreased from 20.96 per cent to 16.17 per cent and in Alappuzha from 15.02 per cent to 10.50 per cent during 1991- 2001.

Conclusion

Kerala's population growth rate is very low in comparison to other states of India. It has high level of literacy and educational development. As a result the educated population prefers skilled jobs, leading to shortage of agricultural labour for agricultural operations. The state has to depend on other states for agricultural labourers with high labour cost. Moreover there is a visible change in the occupational structure with employment under primary sector showing a decreasing trend. On the one hand, it is also found that the cropping pattern in the state is undergoing tremendous change. The area under paddy cultivation has declined by about 40.0 per cent during 1991 – 2001. High labour cost and unavailability of agricultural labourers is one of the major factors for the decline of the area under paddy cultivation. On the other hand the area under plantation crops

and fruits and vegetables has increased due to the low demand for labour for their cultivation. Demographic changes have a visible impact on the social and educational status of the state, playing a dominant role in determining the agricultural land use of the state.

References

- Barah, Bimal (2004): 'Impact of population factors on agricultural development in Jorhat district, Assam, The **Deccan Geographer**, 42(2), pp.43-50
- George. P.S. and Chattopadhyay, S. (2001): Population and land use in Kerala, Part II, In **Growing Populations, Changing Landscape: Studies from India, China and United States**, Indian National Science Academy, Chinese Academy of Sciences and US National Academy of Sciences, pp.36-46.
- Jean, Pierre et al. (2009), 'The demographic impact of the agricultural system in human history, **Current Anthropology**, 50, pp.657-660.
- Tiwari, R.K. (1997), 'A study of rural population and food production in Jhrakhand region', **Geographical Review of India**, 59(2), pp.132-141.
- Zachariah, K.C. *et al.* (1997), **Kerala's Demographic Transition: Determinants and Consequences**, Sage Publications, New Delhi.

(**N. Saniya, G. S. Lekshmi , V. Dani & E. Saravanan** are associated with Training and Extension Division, Centre for Earth Science Studies, Akkulam, Thiruvananthapuram-695031, Kerala
Email: san4ugeo@gmail.com)

Spatio-Temporal Analysis of Cropping Pattern in Palakkad District, Kerala

G.S. Lekshmi, N. Saniya, V. Dani, E. Saravanan

Abstract

The present study attempted a spatio-temporal analysis of cropping pattern in Palakkad district. It reveals that cropping pattern is changing over the years. There has been a decreasing trend in area and production especially in case of paddy cultivation. To analyse the spatio-temporal analysis, two periods have been taken (1999-2000 and 2009-2010). Selecting the ten major crops in the district an analysis of crop diversification and combination was attempted. ArcGIS software is used for the preparation of thematic maps. Palakkad, the only district in Kerala where fibre crop is also cultivated apart from cash crops and food crops, recorded a decreasing trend in the cultivation of this crop also. This is mainly due to insufficient irrigation facilities to raise the second and third crops alongwith the shortage of labour for agricultural operations and the incidence of crop disease, affected the area under crops particularly under coconut cultivation, as the other important factors..

Introduction and the Study Area

Agriculture contributed about 11.0 per cent the gross state domestic product in 2009-10. Agricultural Regionalization, mainly based on the crop dominance, helps in regional crop planning and development.

Palakkad is located between 10°46'' to 10°59'North and 76°28' to 76°39'East. The district has an area of about 4480 km², accounting for about 12.0 per cent of the total geographical area of the state. The district has 13 development blocks (Fig. 1). It has a tropical climate with an oppressive hot season and fairly assured seasonal rainfall. The temperature ranges between 19°C and 42°C and rainfall varies between 292 to 179 cms. The physical features ranges from Highland to Lowland. A unique feature of the highland is the great Palakkad Gap, having significant impact on the agro-climatic conditions of the region. Much of the area in the lowlands is more or less plain, very fertile for cultivation. Hence, the district is known as the "Granary of Kerala".

Aims and Objectives

- To study cropping pattern and change therein between 2000-2010, and
- To study the crop combination and diversification regions in the district.

Data Sources

Secondary Data collected from Department of Economics and Statistics, Govt. of Kerala, Thiruvananthapuram, and from SOI Toposheets.

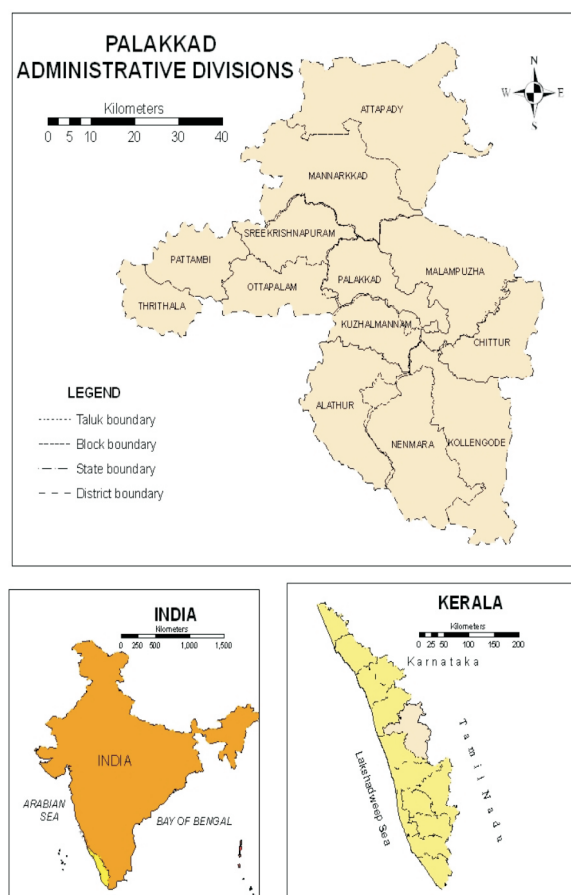


Fig. 1

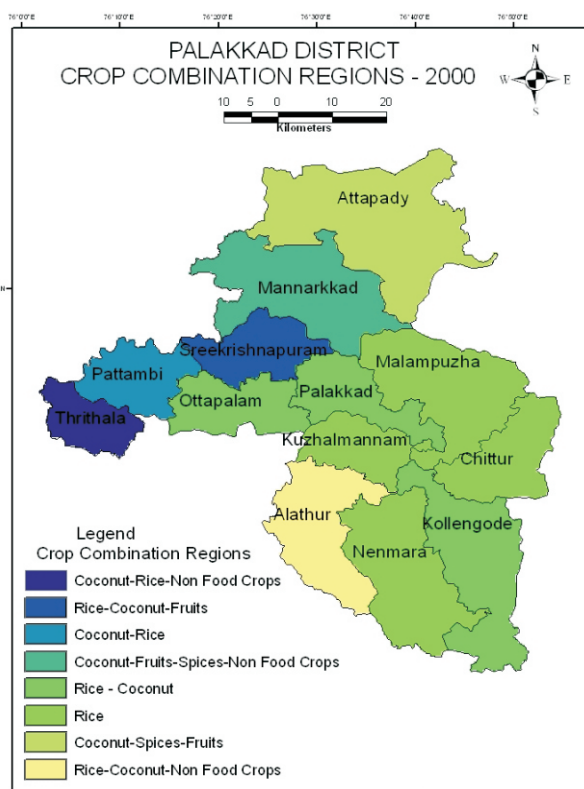


Fig. 2

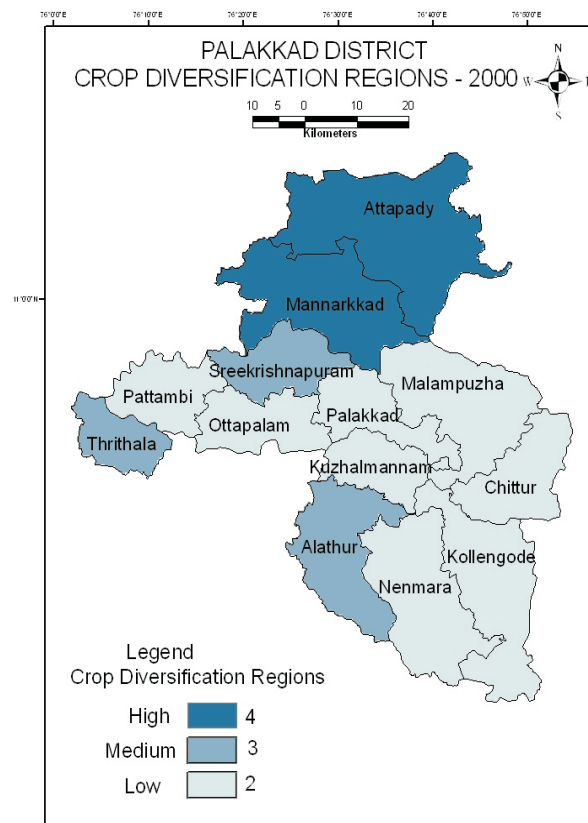


Fig. 4

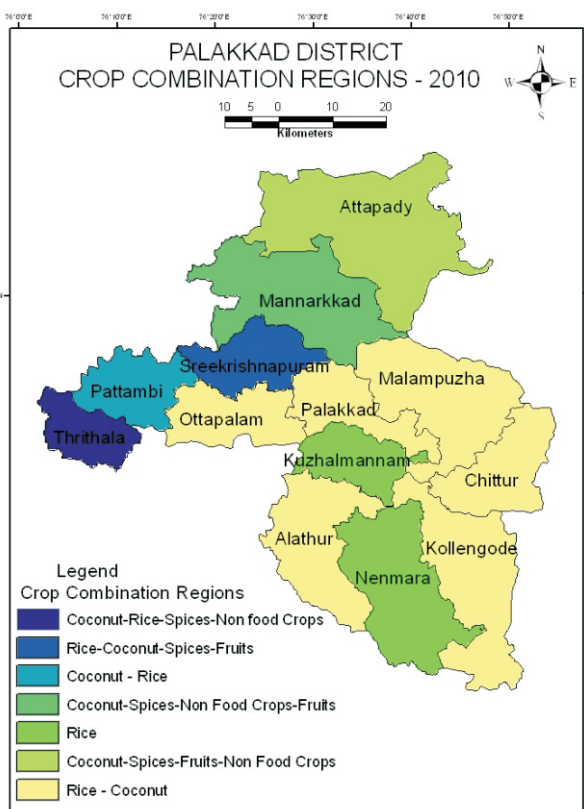


Fig. 3

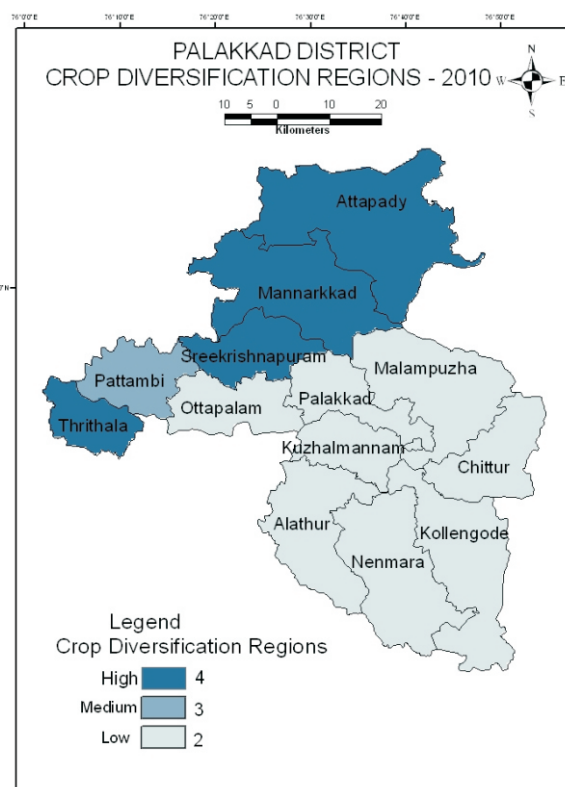


Fig. 5

Methodology

The present study is based on secondary data. Here the agricultural data of two different years (2000 and 2010) of ten years gap have been taken to show the crop land use of Palakkad District. Block has been taken as the study unit. To assess the crop combination Weaver's (1954) method was pressed into service. For crop diversification Bhatia's (1967) formulae was used. Total Cropped Area was also calculated. ArcGIS 9.3 is used for the preparation of thematic maps.

Discussion and Results

The major ten major crops including paddy, coconut, pulses, cashew, tapioca, vegetables, fruits, spices, plantation and non-food crops have been analysed for crop combination. Based on the Weaver's crop combination method, four crop combinations were there in the year 2000 (Fig. 2). Mannarkkad is having the highest crop combination in the district. Against this, Nenmara, Kuzhalmannam, Malampuzha and Chittur blocks have the least. Three crop combinations were there in 2010. Attapady, Mannarkkad, Thrithala and Sreekrishnapuram blocks have the highest crop combination. Nenmara and Kuzhalmannam blocks have the least combination in the district (Fig. 3).

Using Bhatia's crop diversification method it has been found that Attapady and Mannarkkad blocks are having the highest diversification in 2000. Thrithala, Sreekrishnapuram, Alathur blocks have medium diversification and remaining blocks have the least diversification in 2000. In 2010, Attapady, Mannarkkad, Thrithala and Sreekrishnapuram blocks are having the highest diversification, Pattambi block is having the medium diversification, and remaining the least.

Concluding remarks

The area under paddy cultivation is declining

over the period in the district. Nevertheless, steps are taken by the concerned authority to increase the area under paddy cultivation. The area under the plantation crops, fruits and vegetables are increasing due to the lower labour requirements and economic gains. The results of the study can prove good inputs for the planning of agricultural development in the district.

Bibliography

Govt. of Kerala (2000), **Agricultural Statistics, 1999-2000**, Department of Economics and Statistics, Thiruvananthapuram

Govt. of Kerala (2010), **Agricultural Statistics, 2009-2010**, Department of Economics and Statistics, Thiruvananthapuram

Mohammad, Noor (1981), **Perspectives in Agricultural Geography: Regional dimensions in agriculture**, Fourth Vol. Concept, New Delhi

Singh Jhujar (1979), 'Spatio-Temporal Analysis of Crop Diversification in Punjab', 1951-76, **The Indian Geographical Journal**, 54(1):65 – 71

Singh, Surendra (1978), 'Hierarchical Crop Regions of Uttar Pradesh', **Indian Journal of Regional Science**, 10(1): 57 – 62

Krishnakumari, A. and Swaminathan, E. (1990), 'Changing Farming Scene in Nellore District', India, **The Indian Geographical Journal**, 65(2):123 - 129

Singh, Abha Lakshmi (1992), 'Impact of Different Sources of Irrigation on Cropping pattern, Yields and Farm Practices', **Geographical Review of India**, 54(1):19 - 30

Neeraja.K, *et. al.* (2004), 'Crop Regions, Crop Combinations and Crop Diversification in Nellore District, Andhra Pradesh', **The Indian Geographical Journal**, 79(1):45 – 50

(Lekshmi G.S, Saniya N, Dani V, E. Saravanan are working with Centre for Earth Science Studies, Training and Extension Division, Akkulam, Thiruvananthapuram.

Email: girijalekshmi26@gmail.com)

Analysis of Agricultural Land use in Drought Prone Radhapuram Block(Tirunelveli District)Using Geomatics

V.Dani,R. S. Sujarose, N. Saniya, G.S. Lekshmi, E. Saravanan

Abstract

Drought is a normal recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. Defining drought is therefore difficult; it depends on differences in regions, needs, and disciplinary perspectives. Tamil Nadu experiences recurrent droughts. The state's climate may be characterized as dry sub humid to semiarid. The state has three distinct rainfall climates: (1) southwest monsoon (June–September), (2) northeast monsoon (October–January), and (3) dry season (February–May). The state's cropping system depends on the northeast monsoon season. Tamil Nadu is classified into seven agro climatic zones: North-East, North-West, and West, South, Higher rainfall zone, High altitude hilly, and Cauvery delta zone. The severity and extent of drought in the state is believed to be the result of aberrations in rainfall, overexploitation of ground water, lower reservoir levels, and crop stress conditions. Red, black, and alluvial soil types predominate in Tamil Nadu, but sandy soils in the southeast part of the state are prone to chronic droughts. Hence it is essential to study the agricultural land use of drought-affected areas in Tamil Nadu. Keeping this in view an attempt is made to study agricultural land use of drought prone areas of Radhapuram Block in Tirunelveli district of Tamil Nadu

Key words Remote sensing, Gis, Land use, NDVI, Drought Calculator.

Introduction

Remote sensing technology has a vital role to play in resource management and monitoring. Drought, a recurring phenomenon in several parts of India, can very well be identified, monitored and managed with the help of RS, GIS and GPS technology. To determine the start of a drought the degree of departure from the average precipitation or some other climatic variables over a period of time has to be specified. This is done by comparing the current situation with that of historical average, often based on 10 years record. The advanced research approach on drought analysis using remote sensing is the geo-spatial technologies such as GIS and Drought calculator, created by NOAA. Once the spatial and non-spatial data relating to drought studies including meteorological and agricultural data has been built on a GIS platform, various models and decision support systems can be developed.

Study Area

The study area for the present work is the Radhapuram block in Tirunelveli district,

located in the southern part of the Deccan plateau (see Fig. 1). It extends from 8°8' to 9°23' N and 77° 09' to 77° 54' E. to cover an area of about 448 sq. km. It is bounded in north by Nanguneri taluk, in east by Tuticorin Taluk, in south by Gulf of Mannar and in the west by Kanyakumari district. It has an average elevation of 47 meters (154ft.).

Aims and Objectives

1. To identify the drought condition of the study area
2. To analyze spatio-temporal variation in agricultural land use
3. To generate the vegetation indices using remote sensing data.
4. To suggest agricultural land use strategy for sustainable agriculture in the region

Data sources

LANDSAT ETM + of 2006

Secondary data collected from Statistical Office in Tirunelveli, Rainfall stations, Agricultural office, Census of India, and SOI Toposheets

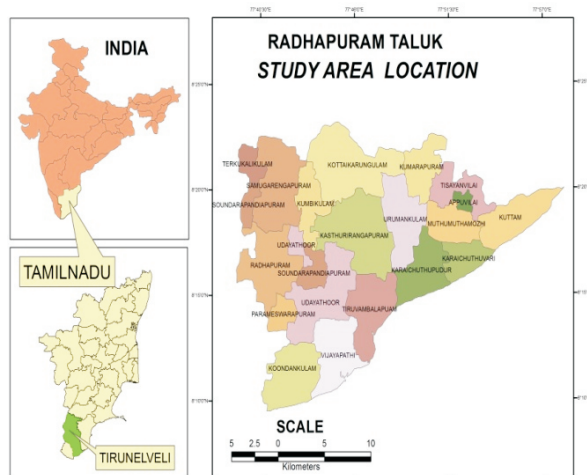


Fig. 1

Methodology

- Land use/cover maps are prepared from the LANDSAT ETM+ images using unsupervised classification algorithm in ERDAS 9.3 Imagine and ArcGIS 9.3 Software
- NDVI is generated depicting the vegetation condition of the study area from the LANDSAT ETM+ Image and using unsupervised classification algorithm in ERDAS 9.3 imagine and ARCGIS 9.3 software
- The agricultural data used for creating the maps of different crops with variation in the cultivation pattern with respective years.
- The rainfall data is used to create rainfall based drought index by using the drought calculator which is created by National Oceanographic and Atmospheric Administration (NOAA).

Results and discussions

A land use/cover map was created by using the LANDSAT ETM+ image of March, 2006 in ERDAS imagine and Arc GIS 9.3 software. Land use/cover of the present study shows that the settlements are arranged in clusters and is near to the agricultural lands. Wasteland and fallow lands are distributed in a large part of the study area. Based on the above analysis it is found that dry agriculture is on about one-fourth land, about one-tenth is waste land, wetland one-sixth, dry tank more than one-fifth, built up only about one-hundredth, waste land with scrub

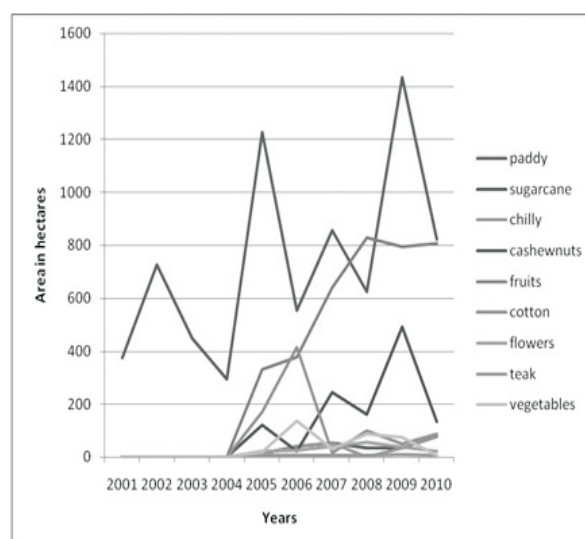
more than one-fifth, waste land without scrub about one-fifteith and sandy area about one-fourth. The study will help in agriculture management and planning (Fig. 2).

The NDVI output depicts the poor vegetation condition and also the poor reflectance of water, but there is high reflection on the bare soil. The NDVI shows the drought severity of the study area (Fig. 3).

Ten years of agricultural data are used to analyze the change in agricultural production of the study area. The agricultural production is directly correlated to rainfall.

Suggestions and Conclusions

1. Drought susceptible crops can be cultivated during summer and monsoon season.
2. Proper bunds can be created for storing of water during rainy season.
3. Artificial recharge should be developed in order to support ground water storage.
4. Multiple cropping can be practiced.
5. A forestation can mitigate drought severity.
6. Good employment opportunities should be created during the drought. The agrarian labor force can be employed to strengthen bunds of irrigation channel and tanks.
 - a) Perform desilting work
 - b) Construct percolation ponds
 - c) Carry out moisture conservation work.
7. If all the channels and river are interconnected, the effect of drought can be reduced



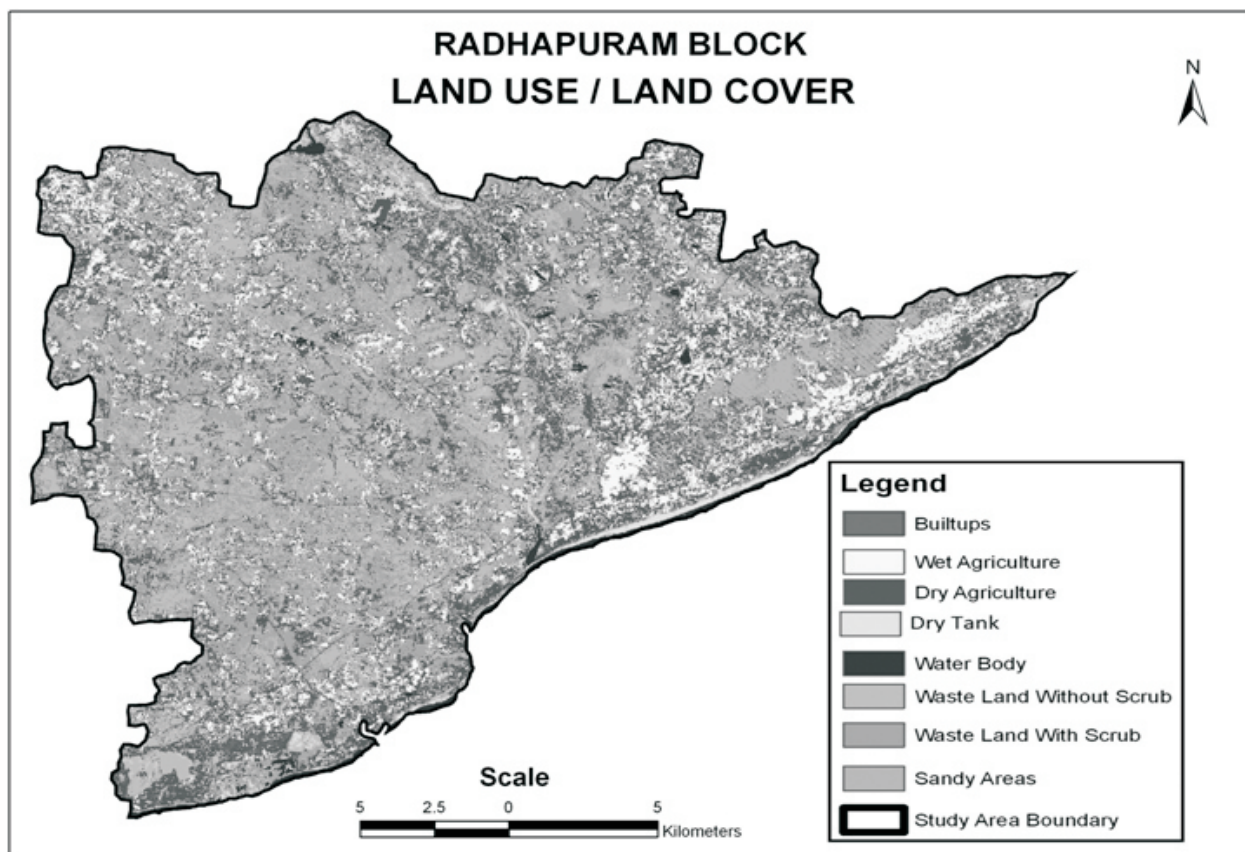


Fig. 2

Output of drought calculator in the year of 1999-2000

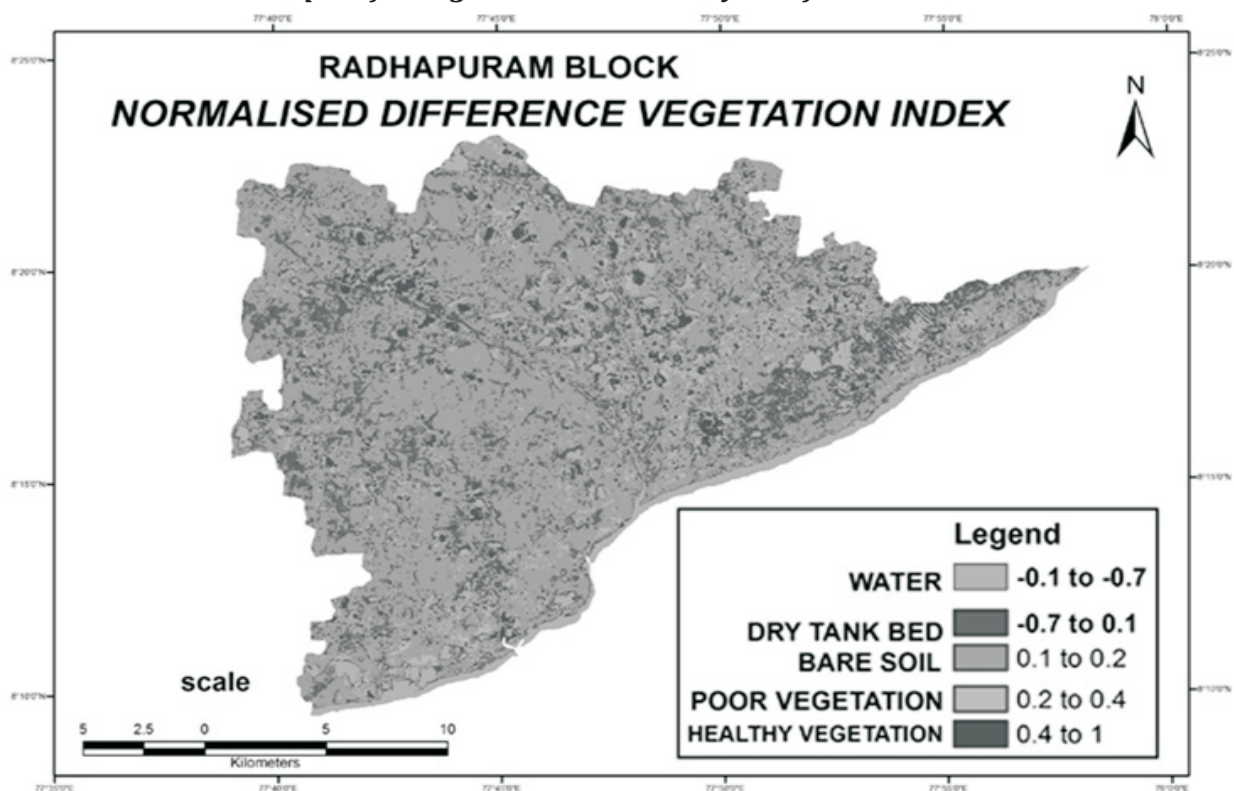
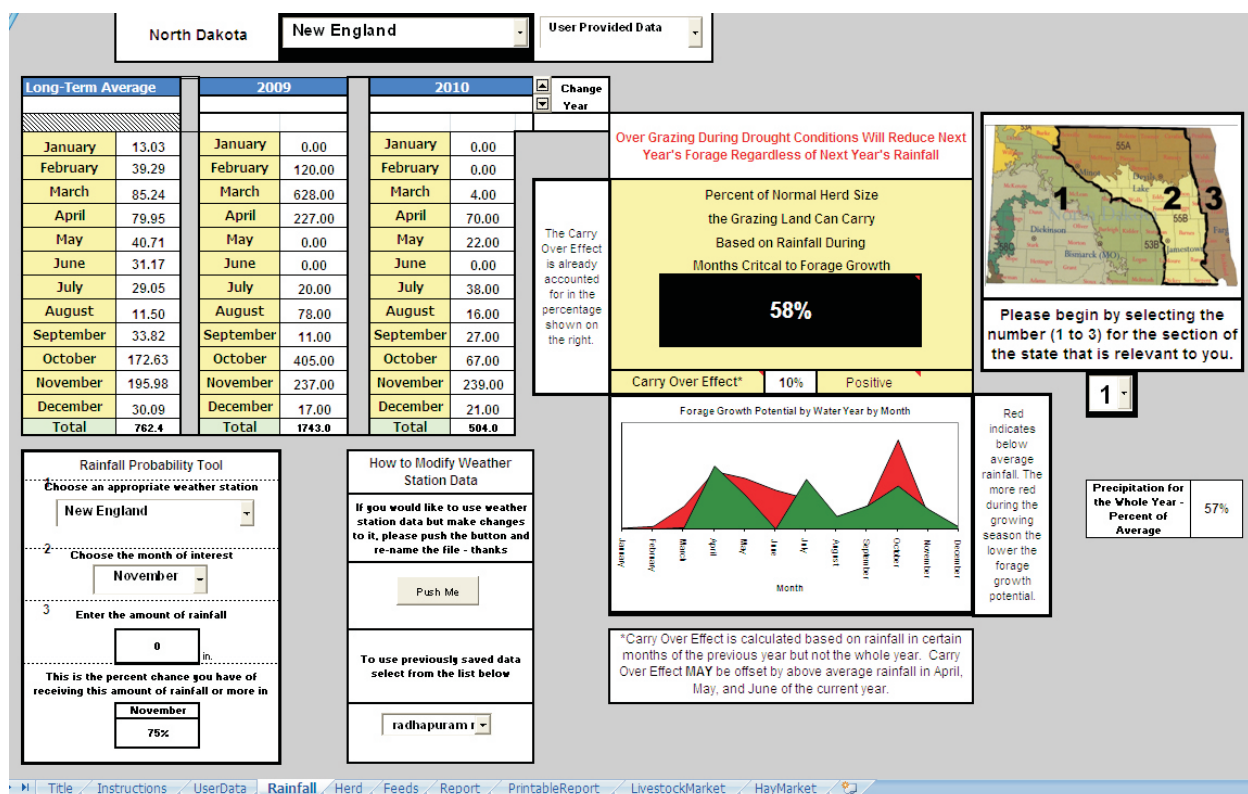
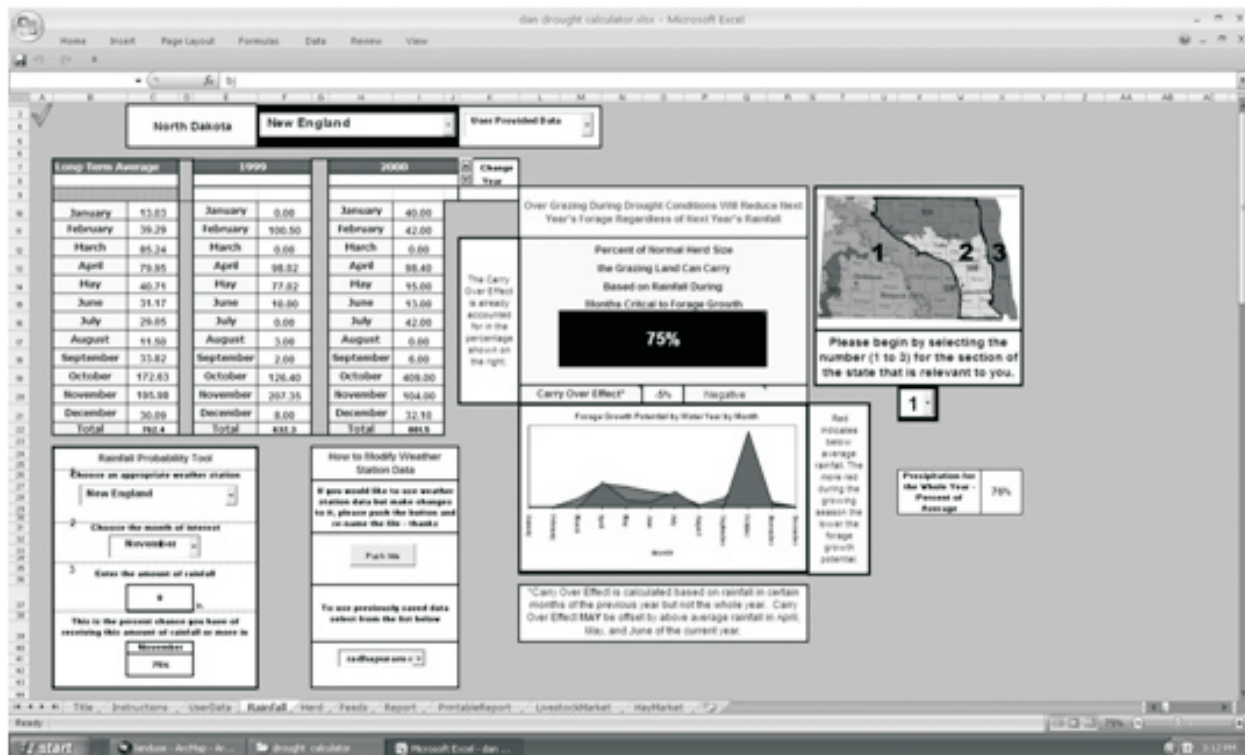


Fig. 3



8. Drought awareness programs should be conducted in order to learn how to react with drought conditions.

The present study proves that Geo-informatics techniques can solve the problems that are created by drought. By using the geo-

informatics techniques, a continuous monitoring is possible to accurately map the changes. The area is facing higher deficiency of rainfall. So the study suggests the need for rainfall information system, but the study area has limited number of weather stations. Apart from this, through geo-informatics vegetation indices can act as major technique for monitoring and decision making for the better management of drought studies.

Bibliography

1. Baaqide, M. (2007). "Drought monitoring using multi temporal NOAA, NDVI and GIS in Isfahan Province". TSAVI: A vegetation index which minimizes soil brightness effects on LAI and APAR Estimation, Geoscience and Remote Sensing Symposium, IGARSS'89. **12th Canadian Symposium on Remote Sensing**, pp. 1355-1358.
2. Carlson, T. N. *et. al.* (1994). "A method to make use of thermal infrared temperature and NDVI measurement to infer surface soil water content and fractional vegetation cover." **Remote Sensing of Environment** 9, pp.161-173.
3. Conghe, S. (2005). "Spectral mixture analysis for subpixel vegetation fractions in the urban environment: How to incorporate endmember variability?" **Remote Sensing of Environment** 95, pp. 248-263.
4. Kallel, A. *et. al.* (2007). "Determination of vegetation cover fraction by inversion of a four-parameter model based on isoline parametrization." **Remote Sensing of Environment**, 111, pp.553-566.
5. Nathan, K.K., (1995) Assessment of Recent Droughts in Tamil Nadu, Drought Network News, Water Technology Research Centre, Delhi

(Dani.V, R.S.SujaRose, Saniya N, Lekshmi G.S, E Saravanan are working with Centre for Earth Science Studies, Training and Extension Division, Akkulam, Thiruvananthapuram.

Email: danivarghes@gmail.com)

Residential Land Use Planning for Raipur City Using GIS

Z.T. Khan, S.K. Mustak

Abstract

Raipur, the capital of Chhattisgarh and a fast growing city, has witnessed drastic changes in land use especially the residential use. The present paper study these changes in residential land use using data obtained from Raipur Municipal Corporation and Town and County Planning Department of Raipur for 1975 and 2006. The residential land use maps of Raipur City for 1975 and 2006 have been prepared using ArcGIS software on scale 1:10,000 in. The prepared residential landuse maps have maintained the standard framework of National Natural Resource Management Systems (NNMRS) and National Urban Information Systems (NUIS) with 90 per cent thematic and 5 metre positional accuracy. In 1975, the residential area was 679hectare (34.90 per cent of total developed land, accommodating more than 206 thousand persons), which increased to 3000 hectare (48.70 per cent of total developed land) in 2006 to accommodate about 10 lakh population. As such, residential area increased by more than four times. The land availability in 1975 was 3.29hectares per 1000 persons, which decreased to 3hectares per 1000 persons in 2006. Land allocated to residential areas in Raipur City is below land ratio suggested in UDPFI (Urban Development and Plan Formulation and Implementation) guidelines. According to guideline, one-half the developed land should be allocated for residential uses. A development plan is proposed for next 15 years (2006 to 2021) to allocate 8000 hectares (50% of total developed land) land for residential uses to accommodate 25 lakh population.

Keywords: Raipur City, Residential Landuse, GIS

Introduction

Raipur, a fast growing capital city of Chhattisgarh state, is a bi-functional (Commercial and Industrial) city attracting the people for business, trade, labour and education. The city is spreading outside to accommodate the rapidly growing population by encroaching upon fertile agriculture land, water bodies, and vegetation; a dangerous trend for the future. To make city healthier, a proper support is necessary.

Modern Geospatial technology plays an important role not only in providing accurate and precise data base to develop an appropriate development plan for residential areas. The present study takes the help of GIS technology to map changes in residential land use of Raipur city during 1975-2006.

The study area

Raipur City, falling in Raipur Tehsil of Raipur

district, is located in between 20°55'N to 21°24'N and 81°30'E to 81°52'E covering an area of about 190.70 km². on Chhattisgarh plain with an average 298.15 metre height above mean sea level. Situated along the Mumbai-Nagpur-Hawrah mainline and connected with others surrounding state by rail, road and airways, the city occupies the north-western part of Raipur District. It is located on eastern part of the Mahanadi Basin as well as the fertile valley of river Kharun and Mahanadi, the main rivers of this city. The climate is characteristics by a hot dry summer and well distributed rains in the monsoon season. The temperature is 460C in summer and fall to 80C in winter having an average rainfall of 1400 mm. The population of Raipur city is six lakh persons and 82.42% literate (2001 Census). The Raipur city has many industrial units as cement industry, rail wagon, plastic industry and cottage industry and commercial and trade centre.

Research objectives

The objectives of the study are to-

- I. Study population growth and existing land use pattern of the Raipur City,
- II. Study changes in and direction of growth in residential land use, and
- III. Prepare a development plan for residential land use with the help of geospatial technology.

Methodology

The present study is based on secondary data obtained from Raipur Municipal Corporation and Town and County Planning (TCP) Department of Raipur as mentioned in the master plan of 1975 and 2006. The residential land use map, 1975 and 2006 of Raipur City, have been prepared in GIS mode on scale 1:10,000 (Figs. 1 & 2). The proposed residential land for 2021 has been delineated on the basis of following criteria: (a) Accessibility (b) Low agricultural productive land (c) Available vacant land (d) Environmentally suitable area for living (e) Trend of residential growth etc. through overlay analysis in ARC GIS platform (Fig. 2). The prepared land use maps have maintained the standard framework of National Natural Resource Management Systems (NNMRS) and National Urban Information Systems (NUIS) with 90 % thematic accuracy and 5 metre positional accuracy.

Population Growth

Raipur City experienced as rapid growing city mostly after 2001(formulation of new state) due to migration of population mainly from adjoining states as Bihar, Jharkhand, West Bengal, Orissa for business, trade, labour, and education (Table I & Fig. 2) and hence many colonies, slums and scatter huts growing haphazardly around commercial and industrial centre on fertile agricultural land. The study of population growth incorporate with the growth of residential unit and forecasting land use change of Raipur City

Existing Land Use, 2006

The study of existing land use of Raipur city

Table I: Population Growth, 1901-2021

Year	Population (Lakhs)	Decadal Growth rate (%)
1901	0.32	-
1911	0.35	10.03
1921	0.38	8.57
1931	0.45	18.39
1941	0.63	39.32
1951	0.89	41.50
1961	1.39	55.60
1971	2.06	47.35
1981	3.38	64.21
1991	4.63	36.79
2001	6.70	44.70
2006	10.00	49.25
2021	25.00	150.00

Source: Census of India, 2001, TACP & Forecasting, 2006 & 2021

Raipur City: Population Growth 1901-2021

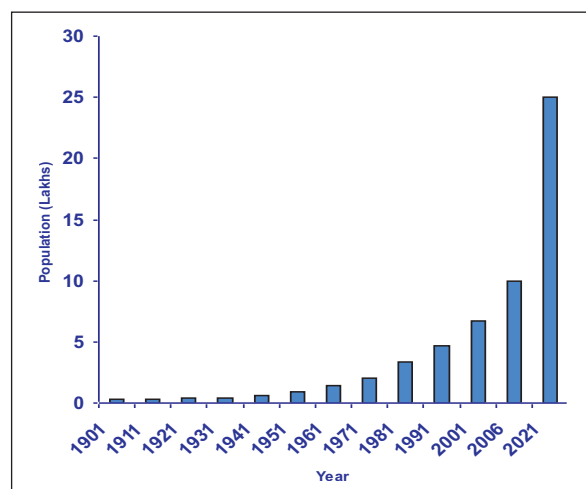


Fig. 1

reveal that 40.1 per cent is developed land and remaining 59.9 per cent is undeveloped of the total land (Table-II). The existing residential land use of Raipur city is 39.38% of total developed land which is insufficient for rapid growing population. The residential land should be 45% -50% of the total developed land to accommodate rapidly growing population for the sustainable growth of the city according to

UDPFI guide lines, 1996. The spatial distribution of existing of Raipur City is showing in Fig.3.

Plan for Residential Land Use, 2021

It is observed that in 1975, the residential area was 678.70 hectare (34.90% of total developed land) to accommodate 2, 05,986 population which has increased to 3010.46 hectare (39.38% of total developed land) in 2006 to accommodate about 10, 00000 (projected) population. As such, the increase in the residential area is more than four times. The land utilization rate (land per 1000 population) is observed to be 3.29 in 1975 which is decreased to 3.00 in 2006. According to the UDPFI guideline, 45% - 50% of the total developed land is required for residential uses which deficit in 1975 and 2006 (Table III). To fulfill the deficiency of residential land, a development plan is proposed for next 15 years (2006 to 2021) to allocate 8000 hectare (50% of total developed land) land for residential uses to accommodate 25,00000 population which showing the land utilization rate as 3.20 in the Raipur City (Proposed). The spatial planning of residential land is showing in Fig. 3.

Table II: Raipur City: Existing Land Use, 2006

Sl. No.	Existing Land use, 2006	Area (Hect.)	Area (%)	% of Developed land
1.	Residential	3010.46	15.79	39.38
2.	Commercial	895.42	4.70	11.71
3.	Industrial	765.35	4.01	10.01
4.	Road Transportation	1012.54	5.31	13.24
5.	Rail Transportation	356.60	1.87	4.66
6.	Public and Semi-Public	535.61	2.81	7.01
7.	Public utilities	5.55	0.03	0.08
8.	Recreational	1063.23	5.57	13.91
9.	Reclaimed/ Vacant land	633.95	3.32	-
10.	Agricultural	10032.56	52.61	
11.	Water bodies	758.41	3.98	
Total		19069.68	100	
Total developed land		7644.76	40.09	100.00
Total undeveloped land		11424.92	59.91	-

Source: Raipur City development, 2006, Raipur

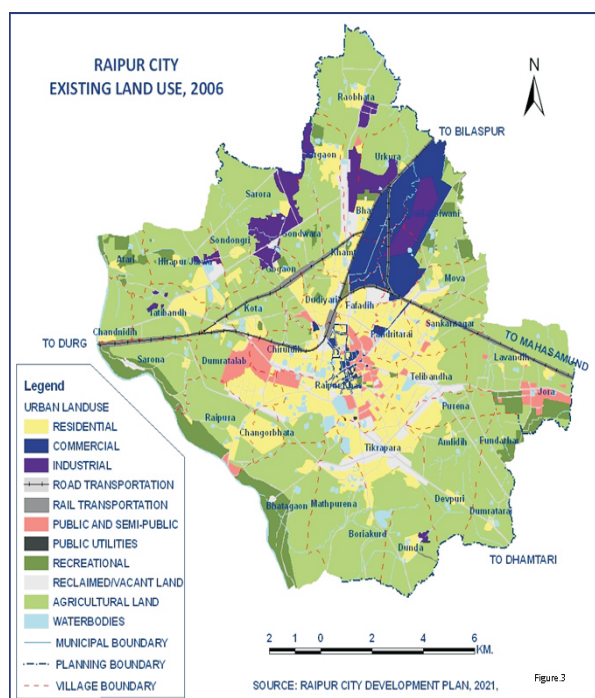


Fig. 2

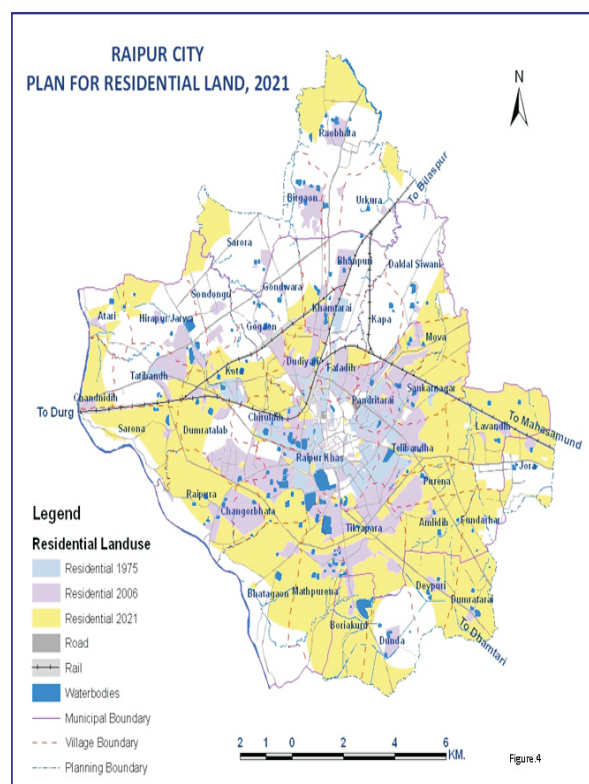


Fig. 3

Table III
Raipur City: Residential Land use Planning, 2021

Year	1975	2006	2021
Population (Lakhs)	2.06	10.00	25.00
Developed Land	1944.70	7644.76	16000
Residential Land	678.70	3010.46	8000.00
Residential Land (% of Developed land)	34.90	39.38	50.00
Land Utilization Rate	3.29	3.00	3.20
Remarks	Deficiency	Deficiency	Sufficient

Source: *UDPFI Guide line, 1996*

Conclusion

It is concluded that Raipur City is experienced as bi-functional city (Commercial & Industrial) which attracts the people for business, trade and labour. Besides a new capital city (Naya Raipur City) is growing adjacent with the city along Mahasamund and Dhamtari Road through which the city is rapidly growing along suitable accessibility, favourable environment, low productive agricultural land, making connectivity with new city for business, trade,

education etc. Now GIS is a powerful tool for the proper planning of residential land which is very essential to control the haphazard growth of the city and to make healthy city providing shelters to the rapidly growing population.

Acknowledgement

We acknowledge with thanks the help and cooperation received from Town and Country Planning, Raipur (C.G) and Shri B. Ramesh (Scientist, Urban Division, NRSC, Hyderabad).

References:

1. Govt. of Ireland (2006), **Guideline for Planning Authority on Sustainable Residential Development in Urban Areas (Cities, Towns & Villages)**, Dublin
2. UNO (2006), **Manuals on GIS for Planning and Decision Makers**, United Nations, New York.
3. Rai, P. K. et.al. (2011), 'Role of geo-informatics in urban planning', **JSSR**, 55, pp.11-24.
4. Govt. of India (1996), **Urban Development Planning Formulation and Implementation**, Ministry of Urban Affairs and Employment,, New Delhi.
5. Upadhyay, Shail Bala (1992), **Urban Planning**, Printwell, Jaipur.

(Professor Mrs. Z.T. Khan is Professor & Head, School of Studies in Geography, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, and **Shri S.K. Mustak** is Research Scholar in the same Department,

Email: mustak.sk5@gmail.com | ztkhan52@yahoo.in)

Management of Ground Water Using Geoinformatics in Dwarkeswar Watershed of Puruliya District

Kartic Bera, Jatisankar Bandyopadhyay

Abstract

The present study uses an integrated Geoinformatics based methodology to evaluate the groundwater resources in Kansachara watershed of Purulian district in West Bengal. IRS p6 LISS-III satellite data of 2nd February, 2011 along with other data sets, existing maps and filed observation data have been utilized to extract information on the hydro geomorphic features of the study area. The ground water level is more than 100 meters from sea level and even more than 200 meters also at some places. The ground water potential zones & scarcity zones have been derived for the entire Kansachara watershed management and divided into mainly four categories namely very low, low, medium and high scarcity & recharge potential zone.

Key words: Ground water, Land use/cover, Weightage, Reclassify, DEM, Scarcity & Potential zone.

Introduction:

Geoinformatics, combining technologies of RS, GIS and GPS, is an appropriate tool to manage ground water resources. RS data can be used for delineating sub-watershed or micro watersheds and streams. For example, SPOT (PAN)/CARTOSAT-1&2 (PAN) can be used to plot boundaries, SRTM data for contour line and then Digital Elevation Model (DEM), DEM data can be processed in GIS for delineation of Sub watershed/Micro watershed boundaries, slope and streams. IRS data are used for land use/cover classification. In addition to the high resolution optical, microwave, thermal- infrared and rader are now used in such studies. We can use microwave for studying soil moisture, and the rate of evaporation and evapo-transpiration. Rader is used for weather forecasting, rainfall and snow depth etc. In a river basin there are many applications of GIS for example defining the watershed or a boundary or finding the coincidences of factors, such as erosion prone areas, mapping land use or land cover and population and interactions between basin water supplies, reservoirs, diversions and demands. GPS can be used to increase existing system maps by verifying and correcting locations of system components. Water system

or sewer system maps can be generated if they do not exit and attributes can be collected for populating the GIS database.

Geoinformatics technology has been successfully employed for identify scarcity and potential zone and also management. The present study aims at identify scarcity zone respectively and management through surface, groundwater and also water harvesting.

Study area: The Dwarkeswar or Dhalkisor watershed having its' origin from the badlands to the east of Tilaboni hill near Bangalia rail station, in Puruliya district, West Bengal, flows easterly through pediment landscape enters into deselected lateritic terrain in Bankura district and further down stream into the Gangetic alluvial plain debouches in the Rupnarayan river. One of the tributaries on the left bank is Kansachara, having five mini watersheds and twenty six micro watersheds in more than 25 thousand hectares. The sub-watershed geographically located between 23° 20' N to 23°30' N and 86° 45' E to 86° 55'E and contains four blocks namely Chhatna, Indpur, Kashipur & Hura (Fig.1).

Physiographic Features

Relief of the study area shows, it is a plateau

region. In the north east part of the study area height is very high (>270m), in the south western part relief is low, with a gentle gradient from east to west. The general elevation of the area ranges from 120m to 300m, with a gentle gradient from east to west. In the high relief area ground water availability is shallow & low relief area ground water availability is near the surface then upper part. Mostly the area covered by fallow land and mixed forest.

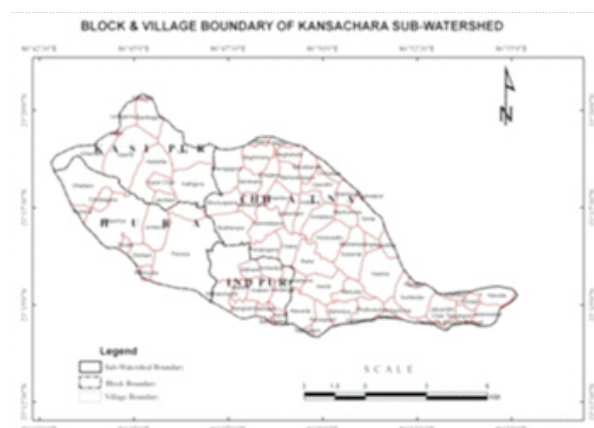


Fig.1

Soil of the study area shows that a major portion of the basin is covered with red and yellow soil; the rest part is composed of red gravel soil on the central part of the basin. Mostly the soil is infertile in type; mostly covering either forest or fallow land. The agriculture is a restricted practice here. The reddish yellow soil is not very fertile.

Geology of the study area comprises Archaean Dharwarian rocks and is an extension of peninsular mass of Chhotanagpur plateau:

- I. The Chhotanagpur genesis complex (cover most part of the district)
- II. Plutonic gabbro and anorthositic rocks
- III. Meta sedimentaries and meta basics of Singhbhum groups
- IV. Dalma group of basic volcanic rocks
- V. Intrusive granites (Kuilapal, Manbhum granites)
- VI. Gondwana groups of sedimentary with coal seam &
- VII. Quaternary sediment in order of decreasing antiquity

There are two shear zones:

1. South Puruliya shear zone WNW – ESE trending tectonically distributed shear zone.
2. North Puruliya shear zone, there are numerous lineaments picked up by remote sensing. Apart from the whole districts of my study area chiefly constitute of granite genesis migmatite, and amphibolites & hornblende schist.

As the area under study belongs to peninsular shield of India, it is constituted of oldest Precambrian or Archean formation from beneath the thin soil cover of recent period appears the granite genesis of the Archean age except where genesis basement is overlain, by the metamorphic rocks of Dharwar age and Gondwana deposits of Carboniferous Triassic age. The rocks of Gondwana system consist of glacial materials and fluvial sandstone and shale.

The older schistose rocks include phyllite, quartz schists, quartzites, Granitiferous sillimanite biotite schists. The granitic rocks include grey colored banded biotite granite gneiss or migmatites pink granite, perphyritic granite gneiss. All this granite rocks older schist and gneiss basic rocks have been indurated by pegmatite and quartz rocks the most common Archean rocks is gneiss which frequently shows great lack of uniformity in mineral composition but possess a constant more or less foliated or banded structure.

The Dharwar consists of quartzite slates, mica, and chlorite schist. The Gondwana form the main undoubted representative of subsequent sedimentation that continued throughout the Upper Carboniferous and Mesozoic periods, responsible for the structure. The deposition of these glacio-fluvial sediments in the gradually sinking trough is responsible for enormous thickness and also for the preservation of there valuable coal seams from Eocene and from the effect of crustal movement.

The geology shows that in upper most area granite granodiorite pegmatite igneous sandstone shale & conglomerate schist are present. The most part of the study area covered

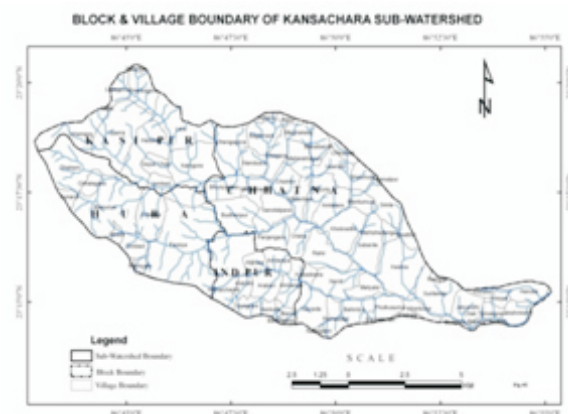


Fig.2



Fig.3

by gneisses rocks. On this region of low permeability through gneissic rocks and reddish soil the intensity of surface channel is high and thus tendency of branching of streams are also high which facilitates easy drainage of water. Thus availability of water is quite less on the surface as well as at sub subsurface.

Drainage originates from western upland of chhotonagpur plateau region to and flow almost parallel to each other carrying seasonal flow of water & meets Dwarakeswar. The river Kansachara drains from southwest to northeast of the study area. The study area drainage pattern in dendritic drainage pattern, here sub stream meet with mainstream at right angle .There are five sub watershed in the study area. The total area of watershed 25232.17 hectors and the length of river is around 80.2 km.

Slope shows that in few part of the study area slope is high, from upper to lower part slope is moderate & other area slope is level slope .In the high slope area runoff is high, so ground water availability is low & low slope area ground water availability is near the surface.

Climate of the district is of tropical dry sub humid with normal annual rainfall ranging from 1100 mm in the western part and 1400mm in the eastern part .The mean daily temperature ranges from 12c (in winter) to the maximum 46c (in summer) The variations in the number of rainy days & soil moisture limitations are common. Severe drought periods lasting for weeks adversely affect the crop growth & yields during main cropping kharif season.

Ground water availability chart shows (see Charts 1 & 2) that in some parts of the district minor irrigation facilities are available and are being developed. Studied on ground water indicate the presence of shallow aquifers in the western part, moderate in the middle part. In maximum part of the study area ground water level is more than 100 meters from sea level and even more than 200 meters also.

Land use/cover- Land use is the use actually made of any parcel of land, house, and apartments, are land use categories, where as the term residential, and agricultural refers to a system of land utilization implying roads,

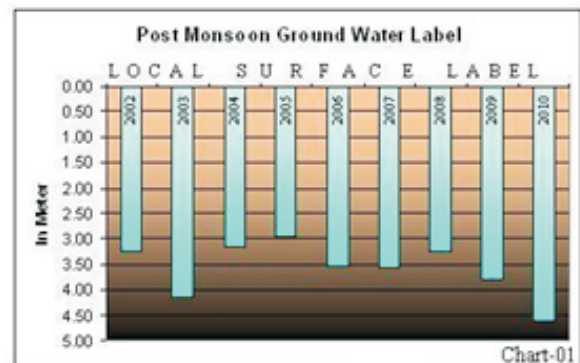


Chart-01

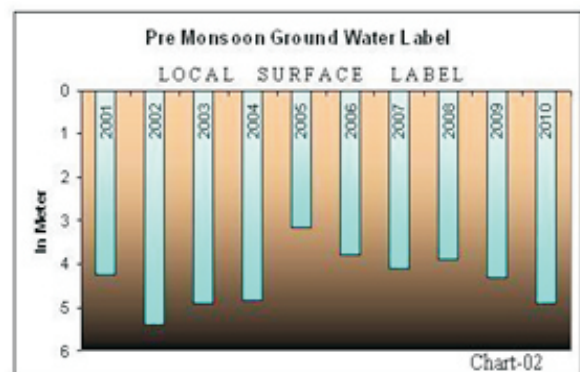


Chart-02

neighborhood retail and service activities as well as location of agricultural pursuits. In a rural areas tree crop and corn crop would identify the land use, where as orcharding, truck farming and grazing indicate a system of land utilization.

The land use study should be made in close connection with water resource management, flood protection scheme and irrigation utilities such study should include: (i) Survey of soil and land classification, (ii) Investigation of surface and underground water resource for irrigation, and (iii) Re-examination of soil after the beginning of irrigation from to time.

The most part of land use map we see the agricultural fallow land, here one time of year cultivation is occurred. The southwestern western and southeastern part thin forest are present. Here also shows existing agriculture, open fallow land. Here large part of land is prone to gully erosion is present. Southeastern rail way pass through the eastern part.

Materials and Methods

SOI topographical sheets on 1:50,000 scales were used to identify watershed. Satellite image (ETM+ and SRTM) were used for land use/land cover study and delineation of drainage and sub-watershed boundary. Maps of soil were taken from NBSS & LUP, geology from GSI and DPMS from NATMO. Rainfall data were obtained from IMD Kolkata. The ground water level data for 2001 to 2010 were collected from SWID, Kolkata and Well data from the field. Census data and political boundary of blocks & village, collected from District Statistical hand book. All the data set are inter-linkage.

ERDAS IMAGINE-8.5 and ArcGIS-9.2 software were used for digital image processing and generating thematic maps. Boundaries of sub-watershed, blocks, villages & drainage were digitized & attached in the form of the attribute table. This was followed by raster overlay based on weighted value for scarcity and ground water potential zone identification.

Socio-economic data: A standardized questionnaire was prepared to collect socio-

economic information for the water-shed management in Kansachara river. Stratified random sampling design was adopted. The list of respondents was prepared by backward class village and villagers of Kansachara Sub-Watershed. The village were selected based on the required information in each village i.e. river distribution and also socio-economic condition session wise (Kharif & Rabi). Every care was taken to give proper representation in the sample by making use of B.D.O office. Finally the collected information was compared with different data set.

Result and discussion

In study area of Kansachara rainy season is maximum four month, therefore needs appropriate planning or management for solving day to day problem. Ground water is the one of the factor. But high slope and other unsuitable factor caused less groundwater available. Annually ground water level ratio 00m (Monsoon) 00m (Permission) all those it varies year to year, due to amount of rainfall and time of rain fall.

Surface water flow/ river flow and ground water are not separate resources- they are parts of the same cycle and interchange many times. For example, infiltrated ground water may be available further down stream of a river as surface flow again surface water flow may in turn infiltrated and join ground water.

This is why it is suitable for surface water management on micro label at mini watershed level. Watershed characterization involves

Table 1	
Use Category	Area (in hectares)
Existing agriculture	4400.9
Forest	2699.1
Open fallow	3792.9
Water body	469.6
Agricultural fallow	6784.8
Wet fallow	1578.2
Sand	25.4
River channel	5481.1

Table 2			
Mini watershed Code	Mini watershed Under the Blocks	Number of Village	Number of Micro watershed
2A2C8F7	Chhatna block	51	7
2A2C8F8	Chhatna and Indpur block	19	5
2A2C8F9	Chhatna, Hura and Indpur block	12	4
2A2C8F10	Hura and Kasipur block	11	5
2A2C8F11	Kasipur block	08	3

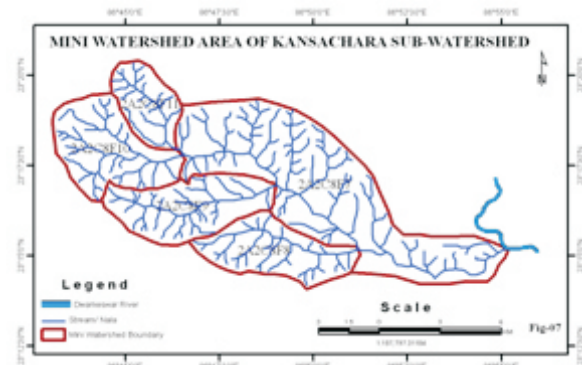


Fig.5

measurement of related parameters (geological, hydrological, Soil, geomorphology & land cover/land use). One the other hand ground water volume related almost same parameters.

In sub-watershed, there are five mini-watershed and 24 Micro watershed (Fig.5). Five mini watersheds clockwise numbering flowing AIS & LUS (All India Soil and Land use Survey) alphanumeric codifications are given in Table 2.

Scarcity zone: The scarcity map prepared primarily from geology, geomorphology, soil, drainage density, slope, rainfall and land use, reclassified by assigning weight value. The scarcity zone are classify in three classes: high, moderate, low. From the output (Fig. 6) it is observed that upper part is a zone of high scarcity. Against this, Kasipur, Hura and also some parts of Indpur and chhatna blocks fall in the low scarcity zone. Chhatna, Indpur, Hura and Kasipur blocks fall in the medium scarcity zone.

Potential zone- Potential zone map of ground water resources was prepared using

parameters like geology, lineament, soil, drainage density, slope, rainfall and land use, influencing the ground water potentiality. These factors are good for water potentiality and have higher ground water.

It is observed Chhatna block has good or high potential zone because of low slope, location of lineament, drainage density, infiltrated soil, and porous lithology. On the other hand, high slope, low drainage density, hard lithology and non pours and soil are responsible for low potential zone (Fig. 7).

Conclusion

Water is renewable natural resource. However, its availability is influenced by the physical and anthropological factors. Water resource management/ development require a comprehensive evaluation of both surface water and ground water conditions on watershed basis with regional perspective. On the other hand, water resources development needs a careful analysis of the upper catchments to the lower stretch of a watershed otherwise

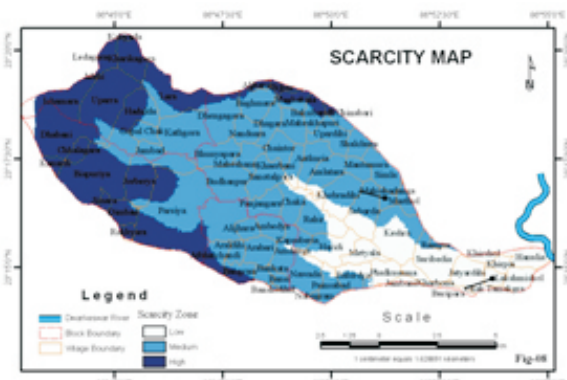


Fig.6

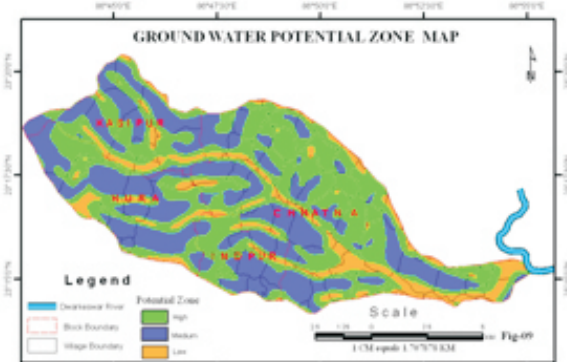


Fig.7

scattered local level surface/ground water management in the upstream affects negatively the recharge in the downstream of a river.

It emerges from the study that the ground water recharge zone is located mainly in the northern portion of the study area. Secondly, rain water is mainly responsible for the ground water recharging for the study area. Thirdly, small size nalas and dams are suggested for temporary storage for live save irrigation.

Acknowledgements are due to Dr. Parthasarathi Chakrabarti, Ex-Chief Scantest-DST Kolkata, West Bengal, and Prof. Susanta Kr. Chakraborty, Dean, Faculty of Science, Vidyasagar University for their kind help in preparation of this paper.

References

1. Chakrabarti. P, and Nat, S. (2002), **Geoinformatics: Spatio-thematic information for natural hazards/disaster management, Resource and Environmental Monitoring**, NRSA, Hyderabad pp.1198-1201
2. Chaturvedi, R.S. (1983), 'Integrating remote techniques in groundwater exploration – a typical cases study from Bundelkhand

region in U.P.', **National Symposium in Remote Sensing in Development and Management of Water Resources**, Ahmadabad.

3. Moullick B. (1996), 'Ground water scenario in West Bengal', **Seminar Proceedings Aquifer Characteristics and Groundwater Management in Eastern India**, Jadavpur University, Calcutta, pp. 18-26.
4. Rao V.V. and Raju P.V. (2010), 'Water Resources Management', **Remote Sensing Applications**, NRSC, Hyderabad, pp.133-164
5. Saha, A .K, (1996), 'Some problems of groundwater management in West Bengal', **Proceedings of Seminar Aquifer Characteristics and Groundwater Management in Eastern India**, Jadavpur University, Calcutta, pp. 126-127.
6. Saraf, A.K. and Choudhury, P.R. (1997), 'Integrated Application of RS & GIS in groundwater exploration in hardrock terrain', **Proceeding, Symp. on Emerging Trends in Hydrology**, Roorkee Department of Hydrology, Roorkee, pp.435-442.

(**Mr. Kartic Bera** is a Research Scholar, and **Dr. Jatisankar Bandyapadhyay**, Assistant Professor in the Department of Remote Sensing & GIS, Vidyasagar University Paschim Medinipur, Midnapore (West Bengal) E-Mail : 4kbrsgis@gmail.com)

Land Use/Cover in Rohtak City: A Comparison between Planned and Unplanned Residential Areas Using Geoinformatics (A Case Study of Sector 1, HUDA and Ramgopal Colony)

Parmod Bhardwaj, Sneha Nehra and Babita Bhardwaj

Abstract

Geoinformatics, composed of remote sensing, DIP, GIS including GPS and information technology, has emerged as a powerful and reliable tool for mapping and analysis. Remote sensing provides us satellite images of various resolutions, DIP helps to process them and GIS helps to map and analyze this spatial information along with non-spatial information. Thus geoinformatics provides us an output which makes understanding of spatial phenomena easy and it leads to better decision-making in planning of a spatial phenomena. The simultaneous development in sensor technology and information technology has led to better mapping of spatial phenomena in an accurate, real time and cartographically beautiful manner with a wide scope of experimentation. In the present study a comparative analysis of land use/cover of residential areas in Sector 1 HUDA (Planned) and Ramgopal Colony (unplanned) in Rohtak city of Haryana has been done. Major dependence of study in terms of data has been on SOI toposheet and the guide map of Rohtak city, LISS IV and Cartosat 1 satellite data alongwith Google earth images. ArcGIS 9.3, ERDAS Imagine 9.2 and M.S Office software have been used for analysis, mapping and final output of results.

Key Words: *Geoinformatics, Spatial Phenomena, Land Use/ Cover.*

Introduction

Geoinformatics, primarily remote sensing, digital image processing, geographical information system including GPS and information technology, has emerged as a

powerful and reliable tool for mapping and analysis in spatial studies. Remote sensing provides satellite images of various resolutions, DIP helps in their processing and GIS to map and analyze this spatial information with attribute data. Hence, the integration of RS, DIP, GIS, GPS and IT provides us the output, making the understanding of spatial phenomena easy for better decision-making in planning of spatial phenomena. The simultaneous development in sensor and information technologies have led to mapping of spatial phenomena accurately in near real time with a wide scope of experimentation.

In the present study an attempt has been made to compare residential land use/cover in Rohtak city of Haryana making Sector 1 HUDA (Planned) and Ramgopal colony (unplanned) case the case study.

The study area

Rohtak city, where are the two urban pockets of Sector-1 HUDA and Ramgopal Colony, is located



Fig. 1: Location of Study Area

on N.H.10, 77 Kms away from the National Capital of New Delhi. Sector-1 is extended between 76°37'36"E to 76°38'15"E and 28°53'34"N to 28°52'44". It is situated between N.H.10 and JLN Canal. Total area of sector-1 is 0.84 km² developed and planned by professional agency i.e. Haryana Urban Development Authority.

On the other side of the scale, Ramgopal colony which extends from 76°36'56"E to 76°37'36" E and 28°53'21"N to 28°53'46"N is situated between N.H.10 and Rohtak-Sonipat Road. Total area of Ramgopal colony is 0.52 Km². It is not planned by any authority but developed in the process of infilling between two roads i.e. N.H.10 and Rohtak-Sonipat Road; and is now in process of regularization (Fig.1).

Objectives

The main objective of this study is to demonstrate the advantages of Geoinformatics in urban land use/cover studies. Here our objectives are to-

1. make a comparative analysis of land use/cover of planned and unplanned urban area;

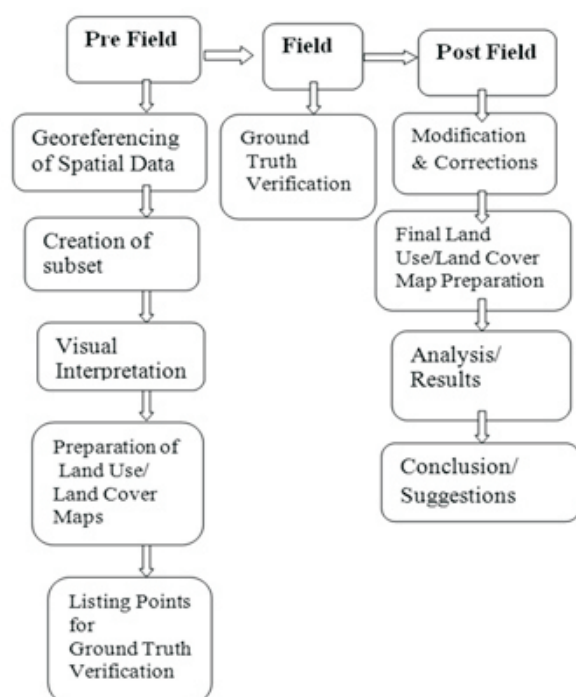


Fig. 2: Flow chart showing methodological steps

2. find out the types of gaps in land uses in a planned and unplanned colonies and factors working behind; and
3. Assess the present status of land use of sector 1 and Ramgopal colony with the help of Geo spatial data.

Data sources

The data for the present study have been picked up from the secondary sources. A brief description of data used is outlined below:

Tertiary Data Source:

- Cartosat-1 (Resolution 2.5 m)
- LISS IV (Resolution 5.8 m)
- Merged image of Cartosat 1 and LISS IV

Sr. No	Land Use Land Cover	Area m ² Sector-1	Area m ² Ram Gopal Colony	Area (%) Sector-1	Area (%) Ram Gopal Colony
1	Residential Area	518826.44	350792.7	61.78	67.26
2	Shopping Complex	15947.38	20819.5	1.90	3.99
3	Road and Street	37625.37	2445.4	4.48	0.47
4	Community Centre	1053.36	6324.15	0.125	1.21
5	School	Nil	9672.079	Nil	1.86
6	Major park	96256.17	Nil	11.46	Nil
7	Green Belt	20026.71	Nil	2.38	Nil
8	Park	32886.04	Nil	3.93	Nil
9	Water Works	117059	Nil	13.94	Nil
10	Vacant Land	-	131486.2	Nil	25.21
11	Total	839680.47	521540.1	100	100

Table -1 Distribution of Land Use/Land Cover
Source: Based on Map No 2 and 3

Ancillary data

- Top sheet No 53 D/9 (SOI)
- Guide map of Rohtak city (SOI)
- Map of Sector 1 from HUDA office.

Softwares Used

ERDAS 9.2 for import-export of image, subset creation, georeferencing and classification.

ArcGIS 9.3: For on screen digitization, and analysis using Arc GIS Toolbox, Map Making and GIS output. M.S.Office.

Methodology

It is the engine of research work which involves a series of steps. main dependence of work has been on satellite images and image processing and GIS softwares beside M.S.Office. Sequential development of methodology has been illustrated by flow chart given below (Fig. 2).

Results and discussion

By interpreting Fig. 3 & Fig. 4, statistics were derived (see Table 1). A comparison of the two urban pockets reveals sharp differences in land use/cover between the two pockets. There is clear a manifestation of impact of planning on land use/cover pattern. Notwithstanding the fact that both are residential pockets, there are interesting differences in land uses.

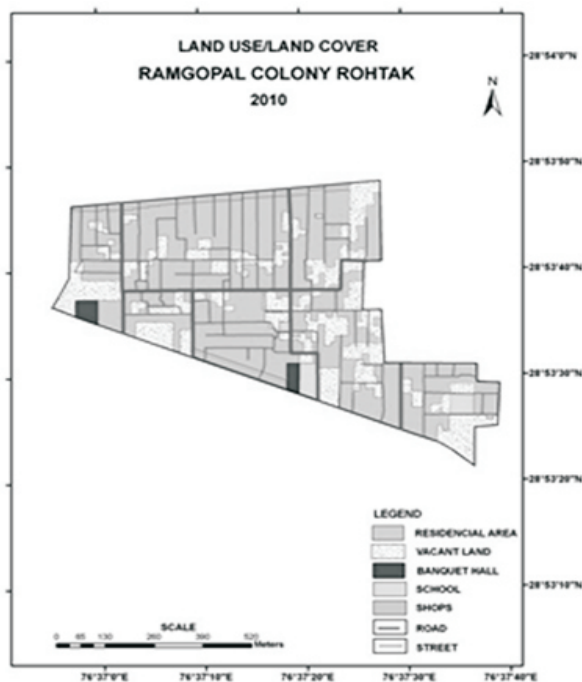


Fig. 3

In sector one, planned by the HUDA, about 62 per cent of the total is devoted to residential houses. Against this, the share of houses comes to 67.3 per cent in case of Ramgopal colony. In case of HUDA developed areas residential plots/flats are bound to follow floor area ratio (FAR) and other regulations of urban land use control as per planning norms. There is a well defined pattern of plot and road sizes as well, develop as per the plan. In contrast, no such regulations are

followed in the case of Ram Gopal Colony. There the owners of plots are making constructions as per their convenience, leading to more and more area is converted into the built up area, with adverse implication in environmental management and higher pressure on available facilities and amenities.

Shopping centre/Shops

Shopping complex/shops of Sector-1 covers 15947.38m² areas, while that in Ram Gopal colony covers 20819.5m² which is 1.90 per cent and 3.99 per cent, respectively.

Notably, Ram Gopal colony has more area in this category but the location of shops is along the road side. The services offered by the shops include building material, catering requirements not only of residents in the colony



Fig. 4

but also of whole city and surrounding areas. It is mainly because of the nodal location of the shopping area of Ram Gopal colony. On the other hand, shopping complex in Sector -1 is located in residential area only and it provides services catering to daily requirements of residents including grocery and stationary items,

medicine, fruits and vegetables, milk, and garments.

Roads and pathways

There is a marked difference between two colonies in this context. While in Sector-1 it occupies 37625.37 m², in Ram Gopal Colony only 2445.4 m² area, constituting 4.48 and 0.47 per cent area, respectively. It happens because that in Sector-1 roads are designed according to lay out plan of plots and other land uses but that is not the case in Ram Gopal Colony, leading to narrow and poor quality of roads.

Community centre/Banquet hall

Both the pockets have community centres or banquet halls for public functions, nevertheless, the community centre of Sector-1 has been developed for holding community functions of its residents, while that of Ram Gopal Colony have developed alone National Highway No 10 to cater the commercial requirements from any part of the city or even surrounding villages.

Parks/Green belt

There is a marked difference in land use in this category between the two pockets. In fact, it's a manifestation of impact of planned and unplanned development. While Sector-1 has 149168.92 m² area under major park, green park and small parks, constituting about 18.0 per cent of total area Ramgopal colony. There is complete absence of parks and green belt. It has serious implications with regard to environmental conditions and pressure on available facilities. In sector -1, the availability is not only adequate in terms of area coverage but also it caters the needs of all parts of the sector, creating a healthy urban living.

Vacant land

There is a remarkable difference in vacant land in two pockets. Since in Sector-1 zoning has been adopted and implemented so there is no vacant land as such but on the other hand there is no such planning in Ram Gopal Colony so a major part of area i.e. 25.21 per cent is still lying vacant. This land is generally misused by residents by

throwing their household garbage, converting it into a heap of garbage. Bad smell and flies lead to unhealthy conditions for living.

Conclusions/Suggestions

The up planned area shows imbalanced development in urban areas. This not only creates unhealthy conditions for residents but also put strain of existing utilities of planned areas in surrounding. Similar has been reported by present study, residents of Ram Gopal Colony use the facilities of Sector-1. It can lead to serious urban hazards in absence of implementation of rules regarding structural engineering and dense settlements in Ram Gopal Colony. The serious lack of parks/green belts creates unfavourable micro climatic effects on environment and health of residents. Hence, short term and long term planning perspective is the needed to make urban living healthy, peaceful and convenient. For any successful planning and implementation accurate and real time information on existing land use/ cover is required. This information can be generated and managed with the emerging technologies of Geoinformatics.

References

1. Ali, Akhter Mohammed (2004), "Remote Sensing and GIS a tool for urban studies-amenity pattern in Hyderabad (A.P, India)", **XX ISRS Congress**, 35(7), pp.498-502.
2. Mohan, M. (2005), "Urban Land Cover/Land Use Change Detection in National Capital Region (NCR) Delhi: A Study of Faridabad District", www.fig.net/pub/cairo/papers/ts24/ts24_05_mohan.pdf.
3. NRSA (1989), **Manual of Nationwide Land use/Land cover Mapping using Satellite Imagery**, National Remote Sensing Agency, Hyderabad.
4. Gupta, K and Jain, S (2005), "Enhanced capabilities of IRS P-6 sensor for Urban Planning", **Current Science**, 89 (11), pp.1805-1812.

5. Bhardwaj, Parmod and Kumar, Rajiv., (2009)
“Technological mapping of land use /land
cover transformation along Haridwar-
Roorkee transport corridor”, **Proceedings,**
CETAS-2009, pp 315-319

Acknowledgement

Authors are indebtedness to Department of
Geography, M.D.University Rohtak for providing
research facilities and the necessary help to
complete this study.

(**Dr Parmod Bhardwaj** is Associate Professor, and **Ms Sneh Nehra** and **Ms Babita Bhardwaj** are
students of M.Tech (Geoinformatics) IInd semester, Department of Geography M D University
Rohtak (Haryana) 124001

Email bhardwajpk95@gmail.com

An Integrated Approach to Predict Urban Growth of Hyderabad City using Sleuth Model, Remote Sensing and GIS Techniques

S.Indhira Gandhi, V.Madha Suresh, M.Stalin

Introduction

As the cities physically expand due to rapid increase in population and activities, the land use changes with the hitherto non-urban areas like forest, agricultural lands, other vegetative cover, water bodies etc., get replaced by concrete structures and black-topped roads (Strahler, 1975). The urban sprawl, known as the areal expansion of urban concentrations, puts intensive demand on environmental resources and poses problems by eating into valuable natural habitats of their hinterlands (OECD, 1990). Urban sprawl is associated with loss of natural wetlands along with loss of core forest habitat, loss of prime farmland and increase of impervious surface (Hasse and Lathrop, 2003). As urbanisation proceeds, the biological needs like water increase in complexity. As the local water resources like rivers, lakes and groundwater get increasingly polluted, the highly urbanized areas are forced to seek water from ever greater distances and expense (Detwyler and Marcus, 1972).

The rapid urbanization especially in developing countries like India is attracting people to urban areas. Prediction Models are perhaps the best way to understand the change in land use and take appropriate planning and development decisions. With availability of high resolution satellite imageries repetitively, remotely sensed data have an edge over the traditional data sources to predict urban growth more precisely; and plan the future developmental activities with the help of GIS technology.

The present paper attempts to apply sleuth model to predict growth in GIS environment making Hyderabad City as a case study with following objectives.

Objectives

The main objectives are to:

- i) examine population growth pattern and its impact on urban sprawl of Hyderabad city,
- ii) study change in land use/cover during 1988-2004,
- iii) apply SLEUTH Model to predict the urban growth from 2005 to 2055 and to simulate the spatial consequences of future urban growth under different planning scenarios so as to adopt the most appropriate growth estimate for future planning.

The study area

Hyderabad, the capital headquarters of Andhra Pradesh state, extends from 78° 22' to 78° 33'E and 17° 17' to 17° 30' N. Covers an area of 2,880 km² and a population of 1.25 million in 1961, it was the fourth largest city in India prior to independence, and has been the sixth largest ever since. It is a primate city of Andhra Pradesh. The decadal growth of Hyderabad Urban Agglomeration (HUA) was 43 per cent and 67 per cent during 1971-81 and 1981-91, respectively; to come down to 31.0 per cent during 1991-01. Its population grew: 2.55 million in 1981 to 4.3 million in 1991 and then to 5.7 million in 2001.

The HUA consists of Municipal Corporation of Hyderabad (MCH), Secunderabad cantonment, the ten surrounding municipal towns, Osmania University, some outgrowths (OGs), and a few smaller settlements. Much of the spatial expansion in the last two decades has occurred in the municipals towns in the surroundings. These towns recorded a growth of 71 per cent during 1991-01. Against this, the core city (MCH) recorded only 18.7 per cent increase during the same period. Several of these towns

have been growing fast since 1981-91 decade. Together, they shared 30 per cent or about one-third of the total population in the HUA at 2001, against about 23 per cent at 1991 (Table 1).

Land use/cover changes

The changes in land use/cover in Hyderabad city between 1988 and 2004 are highly revealing.

Component	Area (Sq. km)	Population (in Lakh)			Density/ km ² (2001)
		1981	1991	2001	
MCH	172	21.0	30.5	36.3	21048
Surrounding Municipalities	419	3.8	9.9	17	4102
Others	187	2.3	3.2	4	2147
HUA	778	27.1	43.6	57.5	7393
HUDA	1905	29.9	46.7	63.8	3351

Table 1: Area, Population and Density of Hyderabad Urban Agglomeration

Sources: Census of India, Andhra Pradesh, Final Population Totals, 1981, 1991 and 2001, and HUDA (2003).

The urban expansion is inversely proportional to forest land (see Table 2). The share of land under the settlements and barren land has increased by 14.81 per cent and 1.53 per cent, whereas forest land has decreased by 14.10 per cent. The rapid growth of population mainly due to massive rural-urban migration has resulted in the loss of forest land. The land under water bodies has gone down by about 1.0 per cent due to encroachment on the Nagarjuna Sagar lake.

According to the HUDA notification, a buffer zone of 30-metre width, on all sides of each of the lakes, must be kept free of any construction to prevent pollution of the lake and allow free flow of water into the water bodies. In spite of such notification, there are several instances of

S.No	Land use Category	Area (%)		Change (in %)
		1988	2004	
1	Built-up	39.94	54.75	+14.81
2	Forest	17.98	03.88	-14.10
3	Vegetation	01.50	0.08	-1.42
4	Water Bodies	23.19	22.39	-0.8
5	Barren Land	17.37	18.90	1.53

Table 2: Land use change detection of Hyderabad city

permissions given by the HUDA itself for residential colonies in lakebeds. A number of tourism-related beautification works carried by the HUDA (under the aegis of Buddha Purnima Project Development Authority) around Hussainsagar can be categorized as the serious violation of its own notification. This clearly explains a part of forest land and water bodies have been converted into settlements and commercial sites. The major conversion of land use takes place along the roads and the pattern of sprawl are found to be linear.

The Sleuth model

The urban growth model, the main component of SLEUTH, is tightly coupled with the land cover change transition model. The SLEUTH urban growth sub-model is characterized by grids of homogeneous pixels, with a neighborhood of eight cells of two-cell states (e.g., urban/non urban), and five transition rules acting in a sequential time steps (Silva and Clarke, 2002). SLEUTH simulating four types of urban land use dynamics, namely spontaneous growth, new spready center growth, edge growth and road influenced growth (Clarke et al., 1997). The growth rules are applied sequentially during each cycle, and are controlled by five coefficients (Diffusion, Breed, Spread, Slope Resistance and Road Gravity). Spontaneous growth simulates urbanized pixels randomly and controlled by diffusion coefficient. New spreading center growth determines whether any of the new spontaneously-urbanized cells will become new urban spreading centers by the breed coefficient. Edge-growth simulates growth that stems from existing urban centers. It is controlled by the spread coefficient, which influences the probability that a non-urban cell with at least three neighbors will become urbanized. Road-influenced growth simulates the influence of transportation network on growth patterns and is controlled by the breed coefficient. The application of SLEUTH model, based on raster images, offers several advantages in modeling urban growth and land cover changes. Because of its cellular data structure, it possible to integrate with raster-

based data from remote sensing (Jantz et al., 2003). Another advantage is that the future trajectory of urban morphology can be shown virtually during the simulation processes (Li and Yeh, 2000).

Silva and Clarke applied the model to Porto and Lisbon metropolitan areas in Europe, characterized by different spatial objects (Silva and Clarke 2002). Calibration result showed that the model adapted well to the European context as indicated by high regression scores which are close to the local characteristics. Candau (2002) applied the model to Santa Barbara in California to study urban growth. It was found that SLEUTH calibration was not scalable across image resolutions and data from the last 40 years proved more effective for calibration than including the entire historical profile available. Jantz et. al. (2003) applied the SLEUTH model in Baltimore-Washington metropolitan area in the United States, using a historic time series remote sensing imageries for assessing the impacts of alternative policy scenarios on declining water quality in the Chesapeake Bay estuary. In this case, future growth was projected to 2030 under three different policy scenarios (current trends, managed growth, ecologically sustainable growth). Result showed that SLEUTH has an ability to address several regional planning issues, but spatial accuracy and scale sensitivity must be considered for practical applications. Table 3 presents the summary of growth types simulated by the SLEUTH model.

Data sources and methodology

The present study utilized remotely sensed digital images and topographic maps, from NRSC, Hyderabad and Survey of India, Dehradun, respectively. Table 4 summarizes the spatial and temporal data from 1950 to 2004.

Data preparation

The input data required by the SLEUTH model include slope, land use, exclusion, urban extent; transportation and hill shade (see Fig. 3). Data preparation depends largely on GIS and remote sensing techniques: data conversion, reclassification and data import/export. The

Growth Cycle Order	Growth Type	Controlling Coefficients	Summary Descriptions
1	Spontaneous	Dispersion	Randomly selects potential new growth cells
2	New Spreading Center (Diffusive)	Breed	Growing urban centers from spontaneous growth
3	Edge (Organic)	Spread	Old or new urban centers spawn additional growth
4	Road-Influenced	Road-Gravity, Dispersion, Breed	Newly urbanized cell spawns growth along transportation network
Throught	Slope Resistance	Slope	Effect of slope on reducing probability of urbanization
hout	Excluded Layer	User-Defined	User specifies areas resistant or excluded to development

Table 3: Summary of growth types simulated by the SLEUTH model

software used for preparing the input data included ERDAS Imagine 8.5, ArcGIS 9.1 and Adobe Photoshop 7.0.

Slope map of Hyderabad area was created from the digital elevation model (DEM), developed from SRTM image at 90 metre resolution in ERDAS Imagine software, later resampled into 30, 60 and 120 metre resolutions before use in calibration process. The hill shade layer for each study area was produced directly from DEM, used as the background for model image output and visualization purpose.

The land use data was generated from satellite images; classified into five major classes: Vegetation, Barren land, Urban, Water and

Theme	Year	Source	Format
Urban Extent	1950	Classified from 1950 Satellite Image (Landsat TM 30m)	Raster
	1972	Classified from 1970 Satellite Image (Landsat TM 30m)	Raster
	1990	Classified from 1988 Satellite Image (Landsat ETM 30m)	Raster
	2004	Classified from 2004 Satellite Image (Landsat ETM 30m)	Raster
Roads	1950	Digitized from Topo Map of 1950	Raster
	1972	Digitized from Topo Map of 1972	Raster
	1990	Digitized from TopoMap of 1990	Raster
	2004	Digitized from 1/5000 Development Plan of 2004	Raster
Slope	2005	Computed from SRTM 90m DEM	Raster
Excluded	1972	Areas Digitized from 1/5000 Development Plan of 1972	Raster
Hill shade	2005	Computed from SRTM 90m DEM	Raster

Table 4: Model Inputs

Others. Land use with consistent classification for two periods is needed for the model. Exclusion is defined as the areas resistant to urbanization. Excluded areas, chosen for this analysis, are water bodies, public land, forestland and national park, extracted from the classified land cover data. Pixel values for excluded areas range from 0-255, but areas available for urban development have a value of zero.

The urban extent includes city/towns, institutional land, airport, rural residential land, and recreational land. Four time periods (e.g. 1950, 1972, 1990 and 2004) were used for calculating best fit statistics of the model (see also Jantz et al., 2003, Candau, 2002 and Clarke, 2002). Transportation layers were derived from digitization of topographic maps for 1972 and 1990. Roads layers were given weight in terms of their 'accessibility'; highways, the most accessible, assigned a weight of 100, provincial roads, second most accessible, of 50, and neighbourhood streets, the least accessible, of 25. Then, the weighted vector coverage was converted to a grid with the same resolution as other input data, giving the background a value of zero.

Input data for the study area was prepared at three resolutions to calibrate the SLEUTH model. The cell sizes of images 200m, 100m and 50m, corresponding to the resolutions of 120 m, 60m and 30m. The selection of these spatial resolutions is based on the works done by Dietzel (2003) and Candau (2002).

Calibration of SLEUTH model

The calibration was carried out on SLEUTH version 3.0 beta program. The code is written in C programming language, and supports three modes: test, calibration, and prediction. The study uses all the three modes viz. test calibration and prediction. The model was operated by a Linux Redhat version 9.0 on PC microcomputer.

Known historical data are compared with simulated land cover in an effort to find out the coefficient values that best modelled the urban

and related land cover changes over time. These are measured using several Pearson r^2 statistics, comparing measurements such as total number of urban pixels, edges, clusters and a spatial match comparison.

Running SLEUTH in calibrate mode will perform brute force Monte Carlo runs through the historical data using every combination of the model coefficient values indicated. Calibration requires several (often thousands) of single simulations of land cover change. Because of this, output requirements can greatly add to the total application time. Several options are available for log and image file output during calibration. However, fewer the output files written, the more efficiently will run the code.

Brute force calibration

Brute-force calibration involved fitting the model to historical data on land use, transportation, and urban extent. Three phases of calibration viz. coarse, fine and final corresponding to progressively higher spatial resolutions were carried out. As calibration proceeded to finer resolution the range of parameters explored was narrowed around the best values obtained at the previous level, and the number of Monte Carlo simulations for coefficient combinations increased from previous to final calibration phases.

Selection of the best fit statistics

Measurements of simulated data, such as the number of urban edges, clusters and urban pixels, are saved in the avg.log file. If in test or calibrate mode, for every year that real data exists (a control year) SLEUTH writes out a grid of urban extent (and land cover). Values are calculated from these grids and at the end of a run (a run begins with a single set of coefficient values and is executed n MONTE_CARLO_ITERATIONS). These values for each year are then averaged over the number of Monte Carlo iterations, and the result is written to the corresponding run number in control_stats.log. The standard deviations of the averaged values are written to the std_dev.log file. If in test mode, this process is performed for every year, not just the control years. The avg.log file may be used in

the final step of calibration to derive forecasting coefficients.

Control_stats.log is generated in test or calibrate mode. It contains r2 values of simulated data (found in avg.log file) compared to input urban (and land cover) data. Values for input urban statistics can be written to the LOG file by setting the LOG_BASE_STATISTICS flag in the scenario file to "YES". This is the primary file used to narrow coefficient ranges during calibration.

Coefficient Type	Prediction Best Fit Value
Diffusion	5
Breed	16
Spread	78
Slope	22
RG	84

Table 5: Coefficient values used to predict growth

Results and discussion

Results obtained from calibration phases are sorted, and parameters of the highest scoring model are used to begin the next and more refined sequences or permutations over the parameter space. Initial exploration of the parameter space uses a condensed, resampled and smaller version of the data sets, and as the calibration closes in on the "best" (final) run, the data are increased in spatial resolution. The highest scoring numeric results from each factor that control the behaviour of the system from each phase of calibration feed the subsequent phase, with user-determined weights assigned to the different metrics (Goldstein, 2004).

When calibration mode is completed, results are used for forecasting studies in prediction mode. SLEUTH forecasts rely on replicating growth trends from the past. Once a coefficient set is found that can best describe how urban change has occurred over time, these values are used to forecast future growth.

The calibration process produces initializing coefficient values that best simulate historical growth for a region. However due to SLEUTH's self-modification qualities, coefficient values initializing the model for a date in the past may

be altered by simulation end date. Therefore to forecast run initialization, coefficient values at simulation end date are used to initialize a new simulation in future date. Using the best coefficients derived from calibration to run a large number of Monte Carlo simulations will produce a single set of averaged coefficients for simulation end date. Using the BSS (Best Solution Set), the ending coefficient values, parameters derived from simulation end date, a forecast run may be initialized.

Calibration output was explored by using statistical methods (e.g. sort descending) to select the best fit values. It is observed that Lee Sallee measuring spatial fit by taking ratio of intersection and union of simulated and actual urban growth did not yield high score for Hyderabad (around 0.37 in coarse calibration phase). A perfect spatial match is 1. To obtain high values of the shape match for Hyderabad is hard due to scattered expansion of the city (see Lebel et. al., 2005); making hard for the model to fit actual shape. Increased spatial resolution and narrowed ranges of parameters have improved the calibration. The behaviour of study area differ on different growth coefficients values (see Fig. 1).

After processing the model, the parameters of best and fit coefficient data were obtained (see Table 5). The urban expansion in Hyderabad City is a mixture of spread and road gravity expansion. The urban expansion is mainly by spread, but resisted by slope. The reason for the urban expansion is IT industry, educational institutes and historical/tourist places. Figure 1 reveal that the spread coefficient value is high

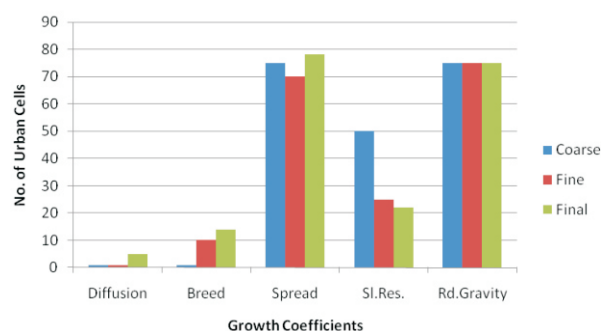


Figure 4. Growth coefficients after calibration

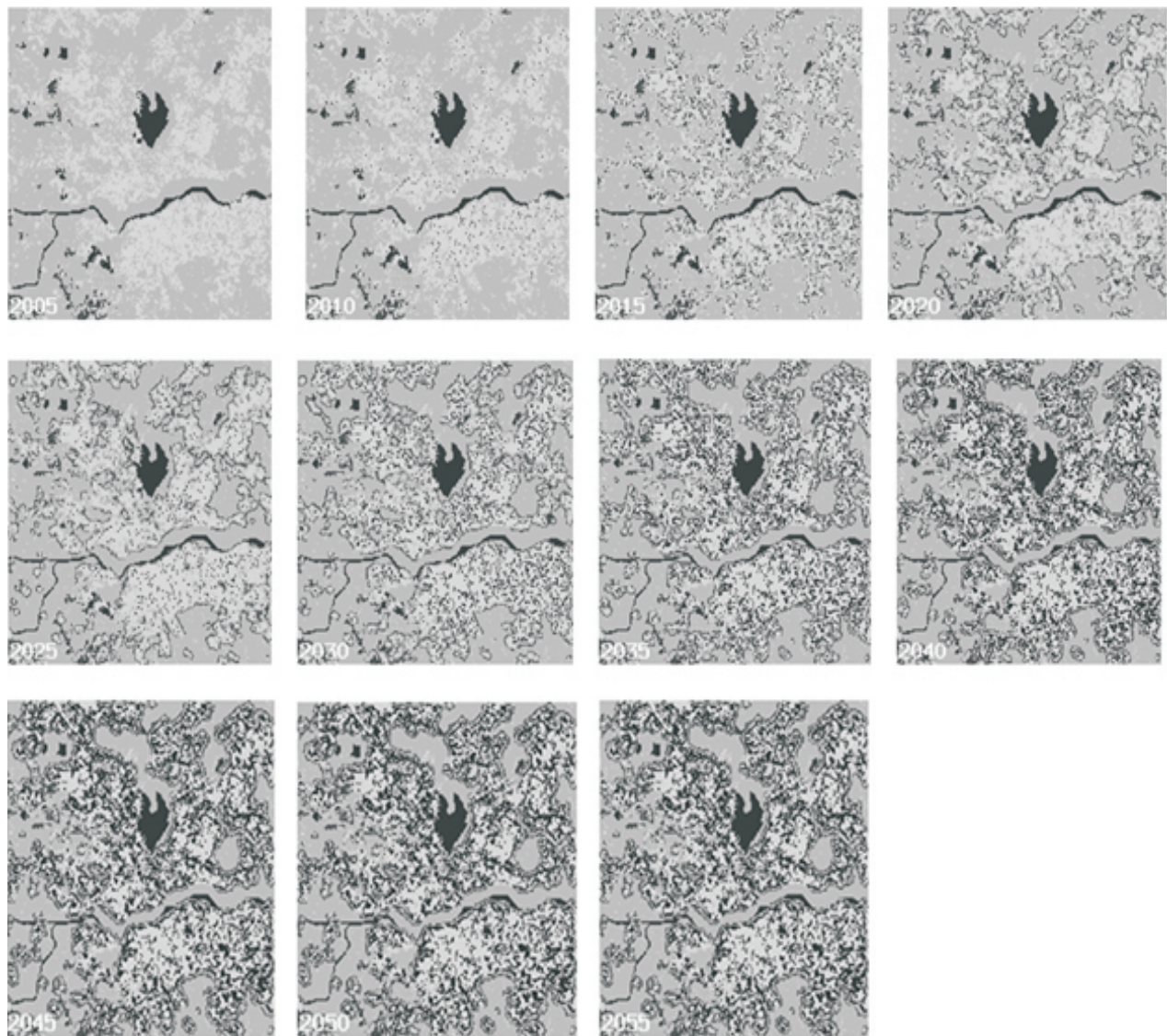


Fig.2 Predicted Urban Growth of Hyderabad City

(about 78) at the fine calibration, because of the development of transport network to spread urbanization. The high road gravity coefficient value (75) derived from final calibration may indicate the abundance of urban growth along the road side and as a result many new buildings or urban centers are being developed on road side.

The spread value adjusted to the local characteristics at the final calibration.

The predicted change in urban area of Hyderabad City between 2005 and 2055 reveals that the city continues to expand more and more rapidly (Fig. 2 and Table 4 for predicted urban area). Much of the growth in Hyderabad is now

due to the growth of the IT industry, business process outsourcing (BPO) and other software services, which are increasingly concentrating in the outer areas, planned for them by the State Government. Besides, large manufacturing and integrated Special Economic Zones (SEZs) are expected to come up in these areas. Film industry is also a major driver of the various services and of the employment generation. Recently, large real estate and construction activity has been playing a major role in the economic development and employment generation, and much of it is occurring in the areas outside the urban agglomeration. The city is continuing to grow organically.

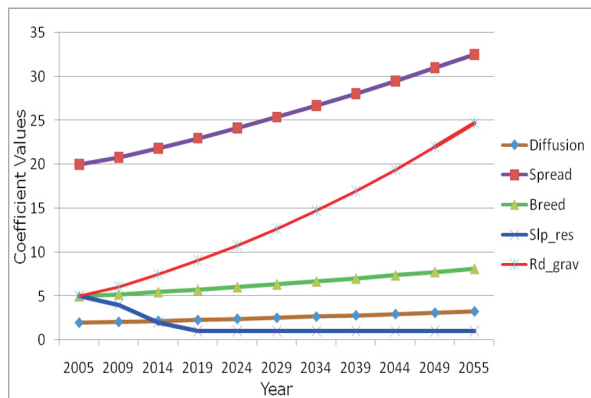


Fig. 3 Modelled Future Urban Growth Trends

In the same way, road gravity coefficient is also progressively increasing, indicating greater influence of road network on growth. However, the rate of increase of road gravity coefficient is more than that of spread coefficient. Therefore, the urban sprawl would be more influenced by the road than the organic growth of Hyderabad city beyond 2055 (Fig.3).

Conclusions

SLEUTH, which provides the key functionalities like interactive scenario development, ability to visualize and spatially quantified, is a highly potential model for certain applications. Empirical calibration of the model using Landsat TM images of past change aids the model predictions of future change. However, the calibration at high level of spatial detail remains a computationally intensive process, requiring sufficient use of a parallel computing environment and may prevent the use of the model by local or nongovernmental agencies where computing resources may be a limiting factor. Notwithstanding these considerations, we found SLEUTH to be a useful tool for assessing the impacts of alternative policy scenarios.

Calibration of the SLEUTH model for Hyderabad indicates a very high spread coefficient, which means that the predicted mode of growth in Hyderabad is “organic” or edge growth. Hyderabad has been experiencing “organic” or edge growth and road influenced growth due to very high coefficient of spread and road gravity.

Within Hyderabad Urban Agglomeration (HUA), municipal corporation of Hyderabad is the major area that drove the population and urban growth in HUA.

The quality of the input data and the selection of optimal parameter ranges should be considered carefully to improve

the calibration result. Since the calibration of SLEUTH is computer intensive, it should be implemented on a super computer or to be run on a parallel processing and high performance computing methods (e.g. cluster computer) in order to obtain the result in a timely manner. Finally, applying the SLEUTH model to Asian countries has just started, there is still a need to explore several others aspects to use this model. This calibration experience has provided us some insights to SLEUTH model and greater understanding of how the CA adapt to the urban environment in Asian countries.

References

1. Clarke, K. and L.J. Gaydos (1998), “Loose coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore”, **International Journal of Geographical Information Science**, 12: 699-714.
2. Chang, D. C. and Tsai, B. W. (2001), “Land use and land cover changes in Taiwan”, **Sustainable Development for Island Societies: Taiwan and the World**. Asia-Pacific Research Program, Taipei, 377-383.
3. Dietzel, C.K., and K. C. Clarke (2004), “Determination of optimal calibration metrics through the use of self-organizing maps”, **Integrated Assessment of Land System Workshop**, held at Institute for Environmental Studies, Amsterdam, , October 28-30, 2004
4. Gigalopolis (2007), **Project Gigalopolis: Urban and Land Cover Modelling**. Santa Barbara, University of Santa Barbara, Canada at <http://www.ncgia.ucsb.edu/projects/gig/>.

5. Jantz, C. A. et. al. (2003), "Using SLEUTH urban growth model to simulate the impacts of future policy scenarios on urban land use in the Baltimore-Washington metropolitan area", **Environment and Planning B: Planning and Design**, (30), 2512-271.
6. Silva, E.A. and K.C. Clarke (2002), "Calibration of the SLEUTH urban growth model for Lisbon and Porto, Spain", Computers, **Environment and Urban Systems**, (26), 525-552.
7. Torrens, P.M. and D. O'Sullivan (2001), "Cellular automata and urban simulation: where do we go from here", **Environment and Planning B: Planning and Design**, (28), 163-168.
8. Yeh, A.G. and X. Li (2002), "A cellular automata model to simulate development density for urban planning", **Environment and Planning B: Planning and Design**, (29), 431-450.

(**S.Indhira Gandhi** is a research scholar and **V. Madha Suresh** is a Reader at University of Madras, Chennai, and **M.Stalin** is the Director, Survey of India, Patna
E-mail: stalindigital@gmail.com)

Detection of Land Use/cover Changes Using Remote Sensing and GIS

(A Case Study of Bulandshahr District, Uttar Pradesh)

Mohd. Shahnawaz Khan and Mohd. Mazhar Ali Khan

Abstract

Land use/cover is an important component to understand the human intervention with the environment. Land, one of the basic and finite resources for human existence, is deteriorating with increased demand and intensive exploitation of land resources with the rapid growth of population. The present paper attempts to identify the land use/cover changes in Bulandshahr district of Uttar Pradesh during 2000-2010. Bulandshahr district, a part of the Upper Ganga-Yamuna doab in Uttar Pradesh, has close proximity to the national capital of Delhi to experience rapid urbanisation. Consequently, there has been large-scale land transformation from agriculture to non-agricultural uses. For identifying the land use/cover changes, remotely sensed data from the Landsat TM (cloud free), acquired for two periods of February 2000 and February 2010, have been pressed into service. Visual interpretation technique is employed to categorise the images into five class categories of land use /cover, namely built up land, agricultural land, forests, wastelands, and water bodies. Ground truth observations were carried out for testing the accuracy level of visually classified imageries.

Introduction

Land, is one of the most important assets and the basic resource, represents the solid part of the earth's surface. It also stands for ground or soil and provides food and water. With advanced technology and change living styles, the pressure on land resources is increasing day by day, resulting in land use/cover changes over time. The productive agricultural land is now converting into non agricultural uses. Hence, the information on Land use/ cover is essential for planning and sustainable development of agriculture. Land use/cover change has become an important tool for managing and monitoring natural resource and environmental changes. It provides accurate results.

Land use is a consequence of human interventions aimed at satisfying human needs, either material or spiritual or both, from the complex of natural and artificial resource (Vink, 1975). On the other hand, land cover refers to the bio- physical characteristics of the land surface, like the distribution of forest, vegetation, mountain, water, ice, soil and other

physical features of the earth (Erle, 2010). Generally the natural land cover is a good expression of soil and vegetation. Land cover is continuously changing. In the past two centuries, the impact of human activities on land has grown because of technological development, demographic pressure, changing landscapes and ultimately it impact on the biodiversity, nutrient and hydrological cycles as well as climate (de Sherbinin, 2002).

The three international conferences: Stockholm, 1972; Rio, 1992; and Johannesburg, 2002, called for substantive studies on Land use/cover changes and since then it has become a global issue. It is because the effects of land-use and land-cover are directly related to the livelihoods of people. Over the time, data from the remote sensing satellites have gained importance to map the Earth's features and infrastructures, managing natural resources and studying environmental changes. Remote Sensing (RS) technology and Geographic Information System (GIS) are efficient tools for analysis and planning and modelling of land uses (Prakasam, 2010),

for their reliability, accuracy, and baseline information for land use mapping. Conventional ground methods of land use mapping are labour intensive, time consuming and done infrequently (Zubair, 2006).

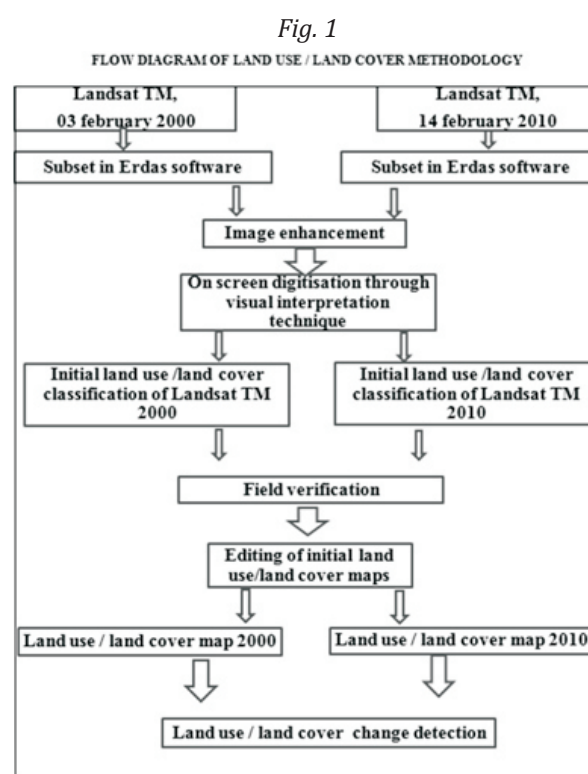
In the light of above statements, the present paper attempts to map and analyse the changing land use/cover of Bulandshahr district between 2000 and 2010 with a view to detect the land transformation and the changes in the agricultural land. To identify areas of change in Bulandshahr district over a period of ten years, land use/cover were categorized using visual interpretation classification technique with the help of temporal Landsat TM images; and then the classified images were overlaid in GIS. It has been found that Landsat TM data is adequate for general extensive synoptic coverage of large areas, reducing the need for expensive and time consuming ground surveys conducted for validation of data. Visual classification is preferred for interpreting land use and land cover in low and medium resolution satellite images (Puig et al., 2002).

The study area

Bulandshahr district, falling between 28° 04' N and 28°45' N latitudes and 77° 35' E and 78° 30' E longitudes in western Uttar Pradesh, is bounded by the districts of Ghaziabad on north, Aligarh on south, Moradabad and Badaun on east, and Gautam Budh Nagar on west. River Ganges forms its natural boundaries with Badaun and Moradabad districts. It covers an area of 3,717 km².

The district is a levelled plain interrupted by some uneven lands on river banks. The area is covered by alluvial deposits of Quaternary period. The only minerals of importance in the district are kankar and reh (District Gazetteer, 1980:9).

The general slope of the area is about 0.29 m/km, which is gentle. The land surface elevation varies from 207.4 metre above mean sea level at Gulaothi in the north-east to 193.8 metre above mean sea level in the south at a



place on its boundary with Aligarh district. Bulandshahr town, the district headquarters, is located almost in the centre of the district and has an elevation of 222 metre above mean sea level.

The soils are alluvium with the kankar embedded in abundance and surface occasionally bears saline efflorescence. Domat or loam, sandy loam, matiar or clay, bhur or sand is the different varieties of soil in the district. Domat is fertile loam which is soft; matiar is stiff clay suitable for paddy cultivation. In the tarai soils are classified as bhur. (District Census Handbook, 2001:7)

The climate is characterized by a hot summer, a cold winter and general dryness except during the southwest monsoon season; experiencing the sub-humid monsoon climate (Singh, 1971:133), that's why it is rich in agricultural land, and produces many crops, fruits and vegetables, generally there are three harvests, the kharif, rabi and zaid. The zaid is relatively of little significance.

With 2.91 lakh population in 2001, Bulandshahr ranks 22nd in terms of population size in the

state. It predominantly a rural district-76.8% population lives in rural areas (District Census Handbook, 2001).

Objective, database and methodology

The main objective of the paper is to detect changes in land use/cover in Bulandshahr district during 2000-2010.

For the purpose, geometrically corrected Landsat Thematic Mapper (TM) of path 146 and row 40, cloud free images of the study area were obtained from United States Geological Survey (USGS) for two points of time, 2000 and 2010. The map of district of Bulandshahr was obtained from the Survey of India. It was projected to Universal Transverse Mercator (UTM) projection in zone 43^o N and geographic coordinate system of WGS 1984 datum. Image enhancement was applied first to improve the appearance of images for visual analysis like needed FCC preparation through band combinations and contrast enhancements (see Fig. 1). Adopting the first level land use/cover classification provided by the NRSC, Hyderabad, the study area was classified into five land use/cover classes viz. built up land, agricultural land, forest, wastelands and water bodies. By using the attribute table the changes in land use/cover between 2000 and 2010 were worked out. This was accomplished through the digitization of the images and attributes in a GIS environment using ArcGIS and visual interpretation techniques. A table was developed showing the area of all categories of land use/cover in sq. km. and the calculated percentage of change there in from the two periods.

Results and discussion

While analysing with the Landsat TM data of 3rd February 2000 (Fig.2) and 14th February 2010 (Fig.3) it was found that the district Bulandshahr is agriculturally well developed. Built up area is unevenly distributed. Main concentration of built up land is found in the central and western part because of urban development. Forest is occupying a very little area in central, eastern and southern part of the image. River Ganga

flows in the eastern part and forms the eastern boundary of the image. Small tributaries and canals can also be seen flowing in north-south direction. Wasteland can be seen clearly on the eastern part of the image near Ganga and slightly on the central, southern and western part of the image.

To identify the land use/ cover change from Landsat TM of 2000 to 2010, post classification change detection method was applied. The twin images were overlaid and shown the change in land use/ cover map (Fig.4). The statistics of land use/cover distribution for 2000 and 2010 is derived from the maps (see Table 1).

A close examination of land use/cover changes map reveal that the area under built up category of land has increased. The increase is registered all over the area; however it is more in the central and western part of the image. This increase in built up land has taken place at the cost of agricultural and waste lands. That's why agricultural land and waste land has shown decrease to the tune of -2.12 % and -0.35 %, respectively. Forest cover has also decreased for the same reason. Water bodies have also registered a marginal decline.

Built up land excluding transport network of roads and rails is an area of human habitation and human activities. It has a cover of buildings and other civic amenities. While analysing the change detection, it was found that of all the five classes, only built up land has increased (108.19 sq. km. Or 2.9 %) during the study period, indicating to fast urban expansion.

Agricultural land is primarily used for the production of food grains, oil seed and other commercial as well as horticultural crops. In the study area agricultural land is the only class which spreads over the most part of the area. It is due to the fertile alluvial plain and developed irrigation facilities. Underground water level is also not very deep here, that is why tube well irrigation is quite common in practice. Major agricultural crops such as wheat, corn, rice, sugarcane, and some vegetable crops are grown here. Beside this, tree plantation and orchards of

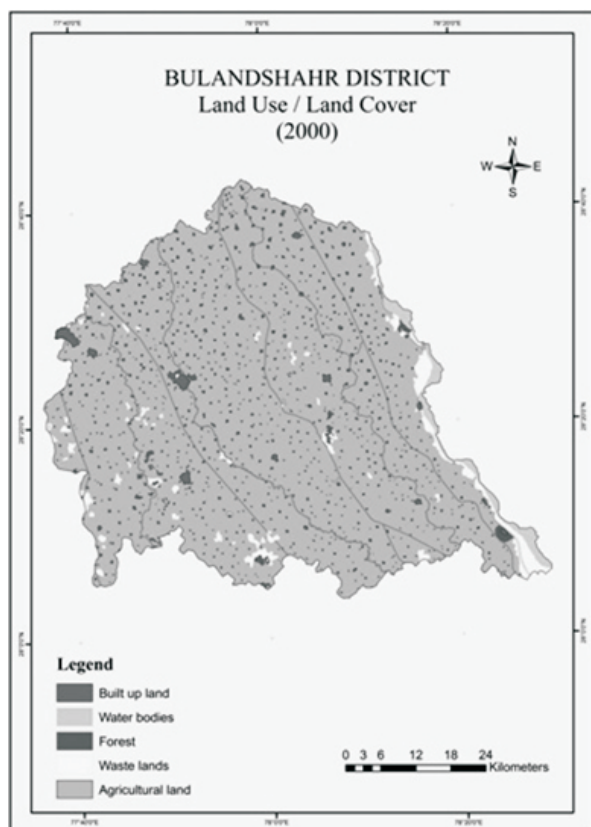


Fig. 2

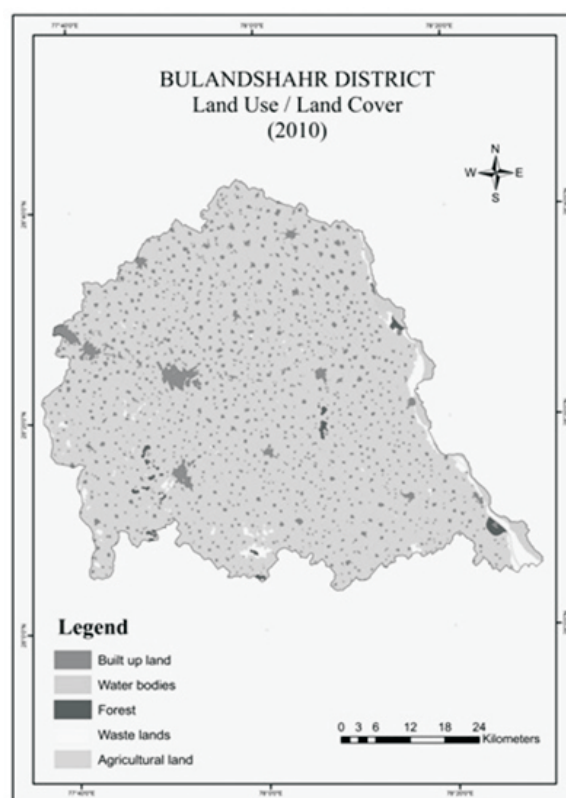


Fig. 3

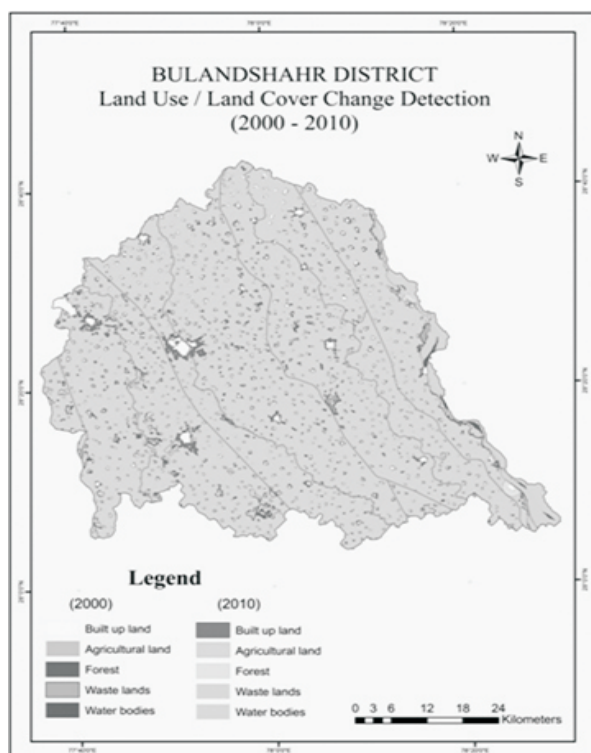


Fig. 4

Table 1.
Bulandshahr District: Changes in land use/cover during 2000-2012

	Land use/cover		Change
	2000	2010	
Land use/ cover classes	Area (sq.km.)	Area (sq.km.)	Area (sq.km)
Built up land	140.9 (3.8)	249.1 (6.7)	108.2 (2.9)
Agricultural land	3336.2 (89.8)	3257.8 (87.6)	-78.5 (-2.1)
Forest	49.2 (1.3)	37.5 (1.0)	-11.8 (-0.3)
Waste lands	93.9 (2.5)	80.9 (2.2)	-13.0 (-0.4)
Water bodies	96.7 (2.6)	91.8 (2.5)	-5.0 (-0.1)

Note: Figures in parentheses indicate to percentages

mango, guava, and other fruits are also found in some parts of the district. While analysing with the data of 2000 and 2010 it was found that the agricultural land has decreased by 78.47 sq. kms. (-2.12 %). It has happened due to the urban encroachment on the agricultural land (Table 1).

Forest is the land bearing vegetative association dominated by trees of any size, capable of producing wood or other forest products. The main trees in forest area are Acacia, (Kikar) Sesamum, (Sheesham) Azadirachta indica, (neem) Eugenia jambolana, (jamun) Mangifera Indica, (mango) and other various species. In the study area the presence of forest is very less and day by day it is decreases. In 2000 it was 49.23 sq. Km.s which accounted for about 1.32 % and in 2010 it decrease to 37.46 sq. km's. (1.01 %). Hence a negative change of 11.77 sq. kms. of (-0.31%) is recorded.

Waste lands, defined as currently unutilized or underutilized and can be brought under cultivation or can be used for social forestry with reasonable efforts, are of two classes: saline and alkaline lands, water logged land, land with or without scrubs, industrial waste lands and barren waste lands. It has been found that wastelands have also recorded a decrease of 12.97 sq. kms or -0.35 %. The analysis of land use/cover change shows that some part of land was transferred to the waste lands while most of it has been transferred to other uses.

Water bodies include rivers, canals, lakes, and ponds. The Ganga River flows along the eastern part of the district and some seasonal rives like Kali, Karwan, and Nim and thin lines of canals are also seen flowing through the district. Some small lakes and ponds can also be seen in the image. It was found that the area under water bodies have also decreased by about 4.98 sq. kms. or -0.13 %.

Conclusion

Remote sensing and GIS technology is a powerful tool for observing and analysing land use/cover. The multi temporal satellite data of Landsat TM has provided useful analysis of Land

use/cover changes during 2000-2010 in the study area. Results from the images shows that the area under built up land has increased to about 108.19 sq. km's. (2.19%). It is due to rapid urbanisation and industrialisation in recent decades. It is also found that agricultural land has decreases by about 78.47 sq. km or -2.12% and other class of land like forest, waste lands and water bodies have also decreased. Thus, the changes observed with the application of remote sensing and GIS technology indicates that a good amount of agricultural land has be converted to built up area with increased urbanisation. It calls for proper land use planning and sustainable land management so as fertile agricultural land is saved of urban encroachment.

References

1. Singh, R.L.,ed. (1971), India-A Regional Geography, Silver Jubilee Publication, N.G.S.I, Varanasi, p.133.
2. Vink, A. P. A. (1975), Land use in Advancing Agriculture, Springer, Verlag, Berlin Heidelberg, New York.
3. Erle E. (2011), "Land-use and land-cover change". In Cutler J. Cleveland ed. The Encyclopaedia of Earth.
4. de Sherbinin, A. (2002), "Land-Use and land-cover change," A CIESIN Thematic Guide, Centre for International Earth Science Information Network of Columbia University, Palisades, NY.
5. Prakasam, C. (2010), "Land use and land cover change detection through remote sensing approach: A case study of Kodaikanal Taluk, Tamilnadu", International Journal of Geomatics and Geosciences, 1, (2), pp. 150-158.
6. Muttitanon, W. and N.K. Tripathi. (2005), "Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data", International Journal of Remote Sensing, 26(11), pp. 2311-2323.
7. Fromard, F., C. Vega, and C. Proisy (2004), "Half a century of dynamic coastal affecting

- mangrove shoreline of French Guiana: A case study based on remote sensing data analyses and field surveys”, Marine Geology, 208, pp. 265-280.
8. Duncan, J., D. Stow and J. Franklin, eds. (1993), “Assessing the relationship between spectral vegetation indices and shrub cover in the Jornada Basin”, International Journal of Remote Sensing, 14(18), pp. 3395-3416.
 9. Puig, C. J. Hyman.G and Bolanos.S, (2002), “Digital Classification vs. Visual Interpretation: a case study in humid tropical forests of the Peruvian Amazon”. International Centre for Tropical Agriculture (CIAT), Colombia.
 10. Gazetteer of India, Uttar Pradesh (1980), District Gazetteer: Bulandshahr, Department of District Gazetteer, Govt. of Uttar Pradesh, Lucknow, p.9.
 11. Census of India (2001), District Census Handbook: Bulandshahr, Directorate of Census Operations, Uttar Pradesh Lucknow, p.7.

(**Mr. Mohammad Shahnawaz Khan** is a Research Scholar and **Dr. Mohd. Mazhar Ali Khan** is a Professor at Department of Geography, Jamia Millia University, New Delhi,
Email: m.shahnawazkhan@gmail.com)

Drought Insurance as a Disaster Management Strategy in Iran

Kiyanoush Ghalavand, Ashu Pasricha

Abstract

Agriculture is central to the livelihoods of the rural poor and in the attainment of the Millennium Development Goals (MDGs). Natural disasters cause heavy losses to farmers and forest owners. Insurance can assist in minimizing these losses, and disaster insurance is that branch of this financial mechanism that is especially geared to covering losses from adverse weather and similar events beyond the control of growers. Agriculture has always been a risky business. In recent years, natural disasters, particularly climate-related ones, have increased both in frequency and magnitude. Agriculture sector is likely to be affected most due to extreme weather events like cyclone, flood or drought. So, the farmers are hit hardest. For a drought prone country like Iran, structural measures for management of disaster risk and its consequences often were found less effective. Hence, non-structural measures like micro-insurance or crop insurance are being suggested as a risk management strategy. The rationale is that poverty and vulnerability to climate change feed each other, and this nexus warrants that climate change policies work in concert with poverty reduction policies. However, traditional micro-credits and savings are inadequate when poor farmers without security nets are exposed to risks beyond their coping capacity. Therefore, micro or Drought insurance customized to specific needs of the poor may be an effective instrument for the purpose. UN Climate Convention and the Kyoto Protocol have included the provision of insurance as a mechanism to address the risks from climate change.

Keywords: *Drought Insurance, Disaster management, Iran*

Introduction

Agriculture is central to the livelihoods of the rural poor and in the attainment of the Millennium Development Goals (MDGs). Natural disasters cause heavy losses to farmers and forest owners. Insurance can assist in minimizing these losses, and disaster insurance is that branch of this financial mechanism that is especially geared to covering losses from adverse weather and similar events beyond the control of growers. Agriculture has always been a risky business. In recent years, natural disasters, particularly climate-related ones, have increased both in frequency and magnitude. Agriculture sector is likely to be affected most due to extreme weather events like cyclone, flood or drought. So, the farmers are hit hardest. For a drought prone country like Iran, structural measures for management of disaster risk and its consequences often were found less effective. So non-structural measures like micro-insurance or crop insurance are being suggested as a risk management strategy. The

rationale is that poverty and vulnerability to climate change feed each other, and this nexus warrants that climate change policies work in concert with poverty reduction policies. However, traditional micro-credits and savings are inadequate when poor farmers with no safety or security nets are exposed to risks beyond their means to cope with. Agriculture production and farm incomes are frequently affected by natural disasters such as droughts, floods, cyclones, storms, landslides and earthquakes. Susceptibility of agriculture to these disasters is compounded by the outbreak of epidemics and man-made disasters such as fire, sale of spurious seeds, fertilizers and pesticides, price crashes etc. All these events severely affect farmers through loss in production and farm income, and they are beyond the control of the farmers. With the growing commercialization of agriculture, the magnitude of loss due to unfavorable eventualities is increasing. (Raju&Chand, 2008). Drought is one of the main natural disasters in

the Islamic republic of Iran, and has seriously affected people's daily lives, socioeconomic activities and environment, particularly in the poorer areas. Drought occurs annually in many parts of the Islamic republic of Iran. In 2008, the country suffered its worst drought in 50 years, causing water shortages to at least 20 million people and an economic loss of about \$1.24. The worst-hit area was the southwestern region including Khuzestan and 15 provinces, where about 35 million people (50 per cent of the region's population) experienced serious water shortages. Currently in the Islamic republic of Iran, policies and regulations to mitigate droughts have major shortcomings. These include (i) weak risk management strategies; (ii) inadequate long-term strategic plans; (iii) inadequate attention to private sector and NGOs' participation; (iv) ineffective interagency coordination due to unclear roles and responsibilities of different agencies; (v) ineffective information gathering and sharing mechanism; (vi) inadequate governments' support for drought management; (vii) lack of commercial insurance to mitigate drought risk; and (viii) inadequate attention to policies for the protection of ecosystems and environment. In addition, as drought impacts have become more severe, traditional approach for the construction of water conservation structures and irrigation system is no longer practical and economically viable. Thus, structural measures need to be combined with nonstructural measures such as drought monitoring, forecasting and warning, drought insurance, and water savings technologies. However, nonstructural drought management measures have yet to be fully developed. Furthermore, the Islamic republic of Iran has yet to initiate systematic and comprehensive studies on drought management. The international lessons and experience will be very useful for strengthening structural and nonstructural drought mitigation measures for a long-term national drought management strategy in the Islamic republic of Iran. One of the key findings of systematic and comprehensive drought management studies

conducted in the United States clearly revealed that the impacts of droughts can be alleviated through good management. As a result, the United States has shifted its approach from crisis management to risk management to minimize drought impacts by establishing drought preparedness plans, developing policies and regulations for mitigation, and advance forecasting. (EM-DAT, 2008). Agricultural activities are carried with different risks such as natural disasters. Crop insurance is one of the most mechanisms to reduce financial damage in agriculture. It is a new idea and innovation for rural areas especially in third world. Then, different factors influence adoption of crop insurance. Drought is a particularly troublesome hazard that has a documented adverse impact on agricultural Development. A long history of decision support tools have been developed to try help farmers of policy makers manage risk. The steps, ideas and philosophy of adoption process have been explained in different studies (Rogers, 1995). These studies view the innovation as a key issue related to technology changes and these studies have been focused on adoption rate and its level (Rogers, 1995). Various studies have explained the adoption process in the form of systematic models. The diffusion model was the most widely used pattern for adoption of innovations (Rogers, 1983). Based on this model, innovative farmers adopt the new ideas and these ideas transform to another farmers in time. The focus of this model is in relationship between awareness and adoption. Awareness is perceived as an essential condition for adoption of innovations in the diffusion model (Hooks et al., 1983). Another necessary condition for adoption is a favorable attitude toward innovation. The model says that knowledge gained through access to different information sources is posited to be an important determinant of adoption behavior (Rogers, 1995). Also, the diffusion model asserts that adopters' characteristics are important determinants of adoption process. It is hypothesized that farmers' education, age and farming experiences is related to adoption.

Bhende (2005) found that income of the farm households from semi-arid tropics engaged predominantly in rain-fed farming was positively associated with the level of risk. Hence, the availability of formal instrument for diffusion of risk like crop insurance will facilitate farmers to adopt risky but remunerative technology and farm activities, resulting in increased income. Some of the studies confirm the conventional view that moral hazard incentive lead insured farmers to use fewer chemical inputs (Smith and Goodwin 1996).

Babcock and Hennessy (1996), found that at reasonable levels of risk aversion, nitrogen fertilizer and insurance are substitutes, suggesting that those purchasing insurance are likely to reduce nitrogen fertilizer applications.

A study by Horowitz and Lichtenberg (1993) find that in the US Midwest, crop insurance exerts considerable influence on maize farmers' chemical use decisions. Those purchasing insurance applies significantly more nitrogen per acre (19 per cent), spend more on pesticides (21 per cent), and treats more acreage with both herbicides and insecticides (7 per cent and 63 per cent) than those not purchasing insurance. These results suggest that both fertilizer and pesticides may be risk-increasing inputs.

An analysis of data from US agriculture indicates that the producer's first response to risk is to restrict the use of debt. Price support programmes and crop insurance are substitutes in reducing producer risk. The availability of crop insurance in a setting with price supports allows producers to service higher levels of debt with no increase in risk (Atwood et al., 1996).

Mishra (1994) analyzed the impact of a credit-linked Comprehensive Crop Insurance Scheme (CCIS) on crop loans, especially to small farmers in Gujarat. It is observed that CCIS had a collateral effect as reflected through the increased loan amount per borrower and reduction in the proportion of non-borrowers among small farmers. The implications of credit expansion are that increased availability of credit can enhance input use and output and

employment that increased share of small farmers in the total loan can have desirable effects on equity and efficiency considerations.

Methodology

Wheat producer farmers who produce irrigated wheat crop in Khuzestan and Gorgan provinces were the statistical population of this study. Statistical population (wheat producer farmers) of northern Khuzestan were 1830 and statistical population of Gorgan were 3172 (Totally 5002 wheat producers). Proportional stratified random sampling was used to determine sample population. Each geographical division (Shahrestan) is assumed as stratify. Then, based on proportion of wheat producers' population in each Shahrestan, the sample size was determined according to Kucran sampling formula. Table 1 shows details of sampling process.

A questionnaire was prepared for data collection. Its validity was examined by face validity. A pilot study was operated. Chronbach Alpha test was executed in order to examine the questionnaire internal consistency and its reliability. The alpha parameter was equated 0.92. The data were collected by facial interview with the farmers.

Findings

In relation to sample group demographic characteristics, the education level of sample has been illustrated in Table 2. The distribution of education condition of wheat producers is approximately normal and seems appropriate. About 24, 24.5, and 20 percent of respondents have benefited from education in primary, secondary, and high school levels, respectively. Therefore, almost all of wheat producers have benefited from education.

Spearman correlation coefficient was executed to determining correlation between independent variables and farmers' acceptance of crop insurance (Table 3). Age had a significant negative correlation with insurance acceptance. It means insurance acceptance rate is higher among the young farmers. If we assume crop insurance as an innovation, it is natural that old

farmers to be the traditional. Whereas, farmers with higher education better understand the crop insurance advantages, their adoption increases with increasing education level, significantly.

Background of wheat cultivation variable had no correlation with drought insurance adoption. But the adoption rate increased with increasing wheat crop area, and farmers' income enhancement, significantly. These findings are justified with the reason that threat of unexpected factors is increased by increasing crop area and farmers expect to alleviate these threats by crop insurance. Besides, farmers with higher income have less difficulty to pay crop insurance charge.

Farmers' awareness of goals and advantages of drought insurance; consult with other farmers; participation in training classes and sessions toward necessity of insurance; amount of contact with insurance agents; participation in crop insurance workshops; and amount of contact with agricultural extension agent were significant correlation with crop insurance adoption variable.

Multiple regression analysis according to stepwise method was executed to determine independent variables' effect on Drought insurance acceptance changes, as dependent variable, simultaneously (Table 4). The variable of consult with other farmers could explain 81 percent of dependent variable changes ($R^2=0.81$). It shows the importance of farmers' negotiation with each other and their communication on decision making toward Drought crop insurance. Whereas, most of farmers in research area had similar condition, they believed that the experience of each farmer can be generalized to the others. Considering that the triability of innovation is one of the stages of the adoption of innovations, when one farmer examines crop insurance, his experience is a criterion for other farmers to decision making. Amount of contact with insurance agents explained 15 percent of dependent variable changes (Table 4). It reveals the

important role of insurance agents towards farmers' Adoption. Then, insurance agents are the second information source of farmers after the other farmers in relation to decision towards accept or reject crop insurance. These two independent variables explained 0.96 percent of dependent variable changes. Farmers' awareness rate of goals and advantages of Drought insurance could explain 2.3 percent of dependent variable changes (Table 4). Awareness especially about the advantages of an innovation is the first stage in adoption of innovations.

Finally, amount of land which the farmers allocate to wheat cultivation was the fourth and the last independent variable which has been interred in regression equation according to stepwise method ($R^2=0.004$). These four variables explained 98.7 percent of dependent variable changes. The multiple regression equation has been written in below:

$$Y=2.41 X^1+1.01 X^2+1.3 X^3-0.133 X^4+5.5$$

Khuzestan State			Golestan State		
Shahrestan	Statistical population	Sample size	Shahrestan	Statistical population	Sample size
Iezeh	182	14	Gonbade Kavuos	549	42
Shush	600	45	Gorgan	523	40
Shushtar	210	16	Bandare Torkaman	626	48
Dezful	320	24	Kordkooy	780	59
Andimeshke	312	24	Azad Shahr	282	21
Masjed soleyman	206	16	Agh Ghala	412	31
Total	1830	139	Total	3172	241

Factor analysis to understand factors network related to adoption of wheat insurance

According to factor analysis, Kaiser-Meger-Olkin (KMO) parameter and its Bartlet equated 0.74 and 9724.39, respectively. These were

significant at 0.99 level. It shows the correction of the factors entered for factor analysis. Kaiser method and percent of variance have been executed to determine number of factors. Only those factors have been selected that their Eigenvalues based on Kaiser Method have been higher than 1. Finally, nine factors extracted and they could explain 75.03 percent of total variance (see Table 5).

Variables' situation after factors rotation according to Verimax method and factors nominating have been illustrated in Table 6. It is to be pointed that 24 variables after Verimax rotation because of low factor loading (less than

Table 2
Education level of respondents

Education level	Frequency	Percent
Literacy	68	18.5
Primary school	88	23.9
Secondary school	90	24.5
High school	72	19.6
Diploma and higher education	50	13.5
Without any response	12	-
Total	380	100

1) and their insignificant correlation with other factors, were eliminated of analysis process. The reason for this elimination is that the common level of the variables was overlap with more important variables, before. Therefore, these variables could be integrated with the other variables.

Regarding to the results of factor analysis in Table 6, the factors affecting on crop Drought insurance acceptance have been classified in nine factors. They are: Extension-education; Economic; Communication channels; Motivate; Opinion leadership; Facility; Confidential; Supervision; and Diversity factors. They could explain 75.03 per cent of total variance, as mentioned before. Extension-education factor

with special amount (Eigenvalue) which is equated 7.48 could explain 22.67 percent of total variance. This factor is the more important in compare to the others. It includes the variables such as execute of training classes, bulletins, leaflets, workshops, newspapers, radio and TV programs, and so on in order to persuade farmers to taking action towards crop insurance.

Economic factor has been the second most important factor explaining 12.67 percent of total variance. It includes variables such as area of wheat cultivation by each farmer, land revenue system, income, insurance contract payment, and discount towards agricultural crops insurance (Table 6). Third factor, communication channels, explained 8.31

Table 3
Crop insurance: Association (statistical) between independent variables and farmers' acceptance

Variables	R value
Age	-0.265**
Level of education	0.508**
farmer's wheat crop area (Hectare)	0.213**
Background of wheat cultivation (Year)	-0.106
Income	0.219**
Farmers awareness of goals and advantages of crop insurance	0.598**
Consultation with other farmers	0.373**
Participation in training classes and sessions	0.888**
Amount of contact with insurance agents	0.626**
Participation in extension lectures	0.857**
Watching films and video clips related to crop insurance	-0.012
Study of extension bulletins and journals related to crop insurance	0.079
Visiting of crop insurance company's activities	0.855**
Participation in crop insurance workshops	-0.011
Contact with agricultural extension agents	0.678**

* Significant at 0.05 level of probability

** Significant at 0.01 level of probability

percent of total variance. It contains variables awareness of crop insurance advantages, contact with insurance agents, and deliver information towards insurance to farmers. Motivation, the fourth factor, explained another 7.45 percent of total variance, consists of three variables on time indemnity payment, discount considering for farmers who were without crop damage, and give present to farmers from insurance companies.

Opinion leadership, the fifth factor, explained 6.9 percent of total variance. Arrange group discussion towards crop insurance advantages, beneficiary of local leaders and local council role towards crop insurance encouragement were the variables in this factor. The sixth factor, facility, explained only 5.12 percent of total variance. It consists of four variables i.e. facility

toward indemnity payment; discount consideration for farmers who were without crop damage; insurance companies performance towards their commitments; and make facility in official process for contracting of crop insurance.

Confidential, the seventh factor, explained only 4.65 percent of total variance. It has two variables: satisfaction of insurer farmers of their crop insurance; and persuasion of farmers to insure their crops by insurance agents. Supervision factor with special amount equated 1.22 was the eighth factor that explained 3.71 percent of total variance. This factor consisted of two variables: on time indemnity payment to indemnity farmers; and continuous control of insurance process correctness by inspectors. Diversity was the ninth and the last factor with

Table 4
Results of multiple regression analysis according to stepwise method to determining independent variables' influence on Drought crop insurance Adoption

Independent variables	B	S.E.B	Beta	R2 Adjust	R2 change	T	Sig.
Consult with other farmers	2.41	.13	.58	.81	.810	19.15	.00
Amount of contact with insurance agents	1.01	.10	.36	.96	.150	9.95	.00
Farmers awareness of goals and advantages of Drought crop insurance	1.30	.21	.19	.98	.023	6.30	.00
Each farmer's wheat crop area	-.13	.04	-0.71	.99	.004	-3.017	.006
Dependent variable: Drought Crop insurance adoption							
F= 533.36 Sig: 0.000 Constant= 5.50							

special amount equated 1.15. It explains 3.51 percent of total variance and contains one variable which is diversification of crop insurance options.

Findings and recommendations

The insurance and disaster management industries are closely related -- both deal with the risk of natural disaster and managing the events following disasters. Climate change, although a natural phenomenon is accelerated by human activities. Reducing vulnerability is a

key aspect of reducing climate change risk. To do so requires a new approach to climate change risk and a change in institutional structures and relationships. A focus on development that neglects to enhance governance and resilience as a prerequisite for managing climate change risks will, in all likelihood, do little to reduce vulnerability to those risks. Findings revealed that the farmers with higher rate of drought crop insurance adoption were younger with higher level of literacy, had more crop area and more

Table 5

Extracted factors with their specification, based on factor analysis.

Factors	Special Amount (Eigen value)	Variance Percent of S.A.	Cumulative Frequency of Variance Percent
First	7.48	22.67	22.67
Second	4.18	12.67	33.35
Third	2.74	8.31	43.67
Fourth	2.45	7.45	51.12
Fifth	2.27	6.90	58.02
Sixth	1.69	5.12	63.15
Seventh	1.53	4.65	67.8
Eighth	1.22	3.71	71.52
Ninth	1.15	3.51	75.03

income, had higher degree of awareness of the goals and advantages of crop insurance, had consulted often with other farmers and had participated more in training classes and sessions. Also, their contact frequency with agricultural extension and insurance agents was higher, participated in extension lectures and visited more times the crop insurance company's activities. Multiple regression analysis revealed that four independent variables could explain about 99 percent of farmers Drought crop insurance Adoption changes. The variables consult with other farmers, amount of contact with insurance agents, farmers' awareness of goals and advantages of crop insurance, and each farmer's wheat crop area were interred in regression equation. The variables affecting drought crop insurance adoption (31 variables) were classified to nine factors according to factor analysis technique. This classification helped us to achieve higher theoretical level in relation to the factors which influence on crop insurance acceptance. Consequently, extension-education

Table 6

Variables of each factors and the coefficients which have been extracted of rotated matrix.

Factors	Variables	Coefficient
Extension-education factor	Execute of training classes towards crop insurance advantages	0.857
	Distribution of training bulletins and leaflets	0.707
	Execute of workshops	0.875
	Contact with agricultural extension agents	0.779
	Distribution of newspaper towards crop insurance affairs	0.699
	Use of radio for farmers' enlightenment towards crop insurance advantage	0.843
	Use of TV for farmers' enlightenment toward crop insurance advantage	0.834
	Use of propagator films towards crop insurance	0.573
Economic Factor	Area of wheat cultivation	0.902
	Land revenue system	0.768
	Farmers' income	0.803
	Primary insurance contract payment	0.735
	Discount toward agricultural crops insurance	0.859
Communication Channels Factor	Awareness towards crop insurance advantages	0.767
	Contact of farmers with crop insurance agents	0.897
	Information deliver towards crop insurance to farmers	0.819
Motivate Factor	On time indemnity payment to indemnity farmers	0.522
	Discount considering for farmers who were without crop damage	0.671
	Give present to farmers by insurance companies	0.603

Opinion Leadership Factor	Arrange group discussion toward crop insurance advantages	0.742
	Beneficiary of local leaders role towards crop insurance encouragement	0.877
	Beneficiary of local council role towards crop insurance encouragement	0.515
Facility Factor	Facility toward indemnity payment	0.877
	Discount consideration for farmers who were without crop damage	0.532
	Insurance companies performance towards their commitments	0.712
	To facilitate official process for contracting of crop insurance	0.591
Confidential Factor	Satisfaction of insurer farmers of their crop insurance	0.940
	Persuasion of farmers to insure their crops by insurance agents	0.943
Supervision Factor	On time indemnity payment to indemnity farmers	0.613
	Continuous control of insurance process correctness by inspectors	0.569
Diversity Factor	Diversification of Drought insurance options	0.825

factor, economic factor, communication channels factor, opinion leadership factor, facility factor, confidential factor, supervision factor, and diversity factor influence on crop insurance acceptance. They could explain about 75 percent of total variance. Based on the findings, some recommendations are presented in the following. In order to accelerate drought crop insurance adoption process, identifying the first adopters between farmers is very important. Accordingly, those farmers are younger with higher level of education, higher wheat crop area, more income and better

communication with other farmers, insurance agents and agricultural extension workers. They could affect decision making of the other farmers, because, based on the findings farmers' consultant with each other had very important role on their decision making towards crop Drought insurance adoption. Simultaneously, strength of extension educational programs towards crop insurance has a great effect on farmers' acceptance regarding to the research findings. Insurance agents can facilitate the farmers' acceptance process by use of some manners such as present motivate factors, facility factors, confidential factors, supervision factors and diversity factors.

Reference

Atwood, J.A. *et. al.* (1996), 'An examination of the effects of price supports and the federal crop insurance upon the economic growth, capital structure and financial survival of wheat growers in the northern high plains', **American Journal of Agricultural Economics**, 78(1), pp. 212-24.

Babcock, B.A. and D.A.Hennessy (1996). 'Input demand under yield and revenue insurance', **American Journal of Agricultural Economics**, 78(1): 212-24.

Bhende, M.J. (2005), **Agricultural Insurance in India: Problems and Prospects**, Occasional paper No. 44, Department of Economic Analysis and Research, National Bank for Agriculture and Rural Development.

EMD-DAT. The OFDA/CRED, (2008), **International Data base UCL-Brussels**, Belgium, A report annual.

Ghalavand, K. *et. al.* (2007), Factors effective in crop insurance in Khuzestan province Iran, **International Conference APEAEN**, Central State Luzhan State University Manila Philippine.

Hooks, G.M. *et. al.* (1983), Correlates of adoption behaviors: The case of farm technologies, **Rural Sociology**, 48, pp. 308-323.

Horowitz, J.K and E.Lichtenberg (1993), 'Insurance, moral hazard, and chemical use in

agriculture', **American Journal of Agricultural Economics**, 75(4), pp. 926-35.

Mishra, P.K. (1994): Crop Insurance and Crop Credit: Impact of the Comprehensive Crop Insurance Scheme on Cooperative Credit in Gujarat, **Journal of International Development**, 6(5), pp. 529-68.

Nowark, P.J. (1987). The adoption of agricultural Conservation technologies: Economic and diffusion explanation. **Rural Sociology**, 52, pp. 208-220.

Raju, S, S and R.Chand.(2008). **Agriculture crop insurance in India: Problems and Prospects**: Occasional Paper No. 8, National Centre for Agricultural Economics and Policy Research, ICAR, New Delhi.

Rogers, E.M. (1995). **Diffusion of Innovations**, 4th edition, New York: The Free press.

Smith, V.H. and B.K. Goodwin (1996), 'Crop insurance, moral hazard, and agricultural chemical use', **American Journal of Agricultural Economics**, 28(2), pp. 428-438.

(Mr. Kiyanoush Ghalavand is Ph.D. Research Scholar and Dr. Ashu Pasricha is Assistant Professor, Department of Gandhian Studies, Punjab University, Chandigarh,
E mail: kiyanoush1973@gmail.com, ashu.p2@gmail.com)

Micro Finance and the Role of Insurance in Disaster Management

Kiyanoush Ghalavand, Ashu Pasricha

Abstracts

Disasters in India do occur frequently causing immense loss of life, assets and livelihood. In the present executive structure of the country, the district administration is bestowed with the nodal responsibility of implementing a major portion of all disaster management activities. There has been a paradigm shift from a reactive response to a proactive prevention mechanism putting pressure to build a fool-proof system, including, within its ambit, the components of prevention, mitigation, rescue, relief and rehabilitation. Numerous studies have shown a strong link between risk, vulnerability and poverty. Poor households lack resource with which to absorb the shocks of natural hazards. Even small disruptions in the flow of income can have serious implications for poor households. A humane world where people can live in security with dignity, free from poverty and despair, is still a dream for many, which should be enjoyed by all. Insurance is the safeguard against probable danger. Insurance can be bought against a particular event for its possible occurrence. It is a prevarication tool used as a preventive measure against future losses. India lives in villages. And, about fifty per cent of the 5.76 lakh villages of the country are situated in different terrain characterized by poor socio-economic conditions. The paper discusses role of micro insurance in disaster management, calling for integrated conservation-disaster risk escaping regime. The paper is an attempt to illustrate, how micro insurance can be used to mitigate the economic effects of disaster resulting from covariant risks. Also, it highlights the approaches to product design, distribution mechanism, limitations and the various operational challenges faced by an insurance company in administering a Micro Insurance scheme.

Keywords: Insurance, Paradigm, Disaster management, Risk

Introduction

More than one-third of the total population in the world lack any form of formal social security. Poor people confront many of the same risks faced by the elite population, but these risks have greater financial impact for the poor. Key risks include illness, death, loss of property by theft, fire and natural disaster like earthquakes, drought. Moreover, the vulnerability of poor people is exacerbated each time they incur a loss, creating a vicious cycle that impedes economic welfare. Numerous studies have shown a strong link between risk, vulnerability and poverty. Poor households lack resources to absorb the shocks of natural hazards. Even small disruptions in the flow of income can have serious implications for poor households. Because they lack resources. Poor farmers

commonly avoid risk by using informal and self insurance measures. Disasters can wipe out years of hard-won development progress, devastate lives and livelihoods and cripple developing economies. In 2008, 321 natural disasters killed over 235 000 people, affected the lives of more than 211 million and cost over US\$181 billion. (Stephan, 2009) As the impacts of climate change worsen, the frequency and severity of natural disasters are likely to increase. But natural hazards, such as cyclones, earthquakes and tsunamis do not need to become natural disasters. While disasters are generally triggered by a natural hazard event, the impact on communities is a direct result of vulnerability related to complex development factors, such as poverty, disability and gender inequality. While these measures can help

survival, most studies conclude that they are not the best tools for risk management, as they reduce the impact of a hazard at the expense of more profitable activities. Since the second half of the twentieth century, natural disasters have been increasing in frequency, severity, and intensity. Today, disasters affect more than 200 million people every year. (UN World Conference on Disaster Reduction Secretariat [UNWCDR], 2004). For example, the global community suffered 150 disasters with a combined toll of 90,000 human lives and USD 220 billion in economic losses. (UN International Strategy for Disaster Reduction [UNISDR], 2006 b). The October 2005 earthquake in Asia injured 70,000 people and claimed the lives of another 73,000 (Brine, 2006). The 2005 hurricane season in Central and North America was the most active on record for the Atlantic, shattering numerous records, most notably with Katrina, which was by far the costliest hurricane in U.S. history and the most deadly since 1928 (NOAA, 2006a; ;2006b). Natural disasters present a major global concern. They strike worldwide and can overwhelm the capacity and resources of even the most developed nations. In the past fifteen years alone, the world has witnessed well over five thousand natural disasters and lost nearly one Million people and close to USD 1,200 billion as a result. The 2004 Indian Ocean earthquake triggered a series of the most deadly tsunamis in recorded history, which battered ten South Asian and East African countries, killing 2.83 lakh people and displacing 1,126,900 (U.S. Geological Survey, 2007). Since the 1990s, two-thirds of disasters have been floods and storms across all five continents, while earthquakes and tsunamis claimed more than 4lakh lives despite accounting for only 8.0 percent of recorded events (UNISDR, n.d.b; n.d.e). The period also saw the three warmest years on record, in which heat waves killed thousands in Europe and Asia (UNWCDR, 2004). The El Niño phenomenon alone has caused 20,000 fatalities and USD 35 billion in material damages (UNWCDR, 2004). Another 40 thousand lives have been lost to severe landslides, debris and Mudflows. When

examined in terms of lives affected, that is, the number of people requiring immediate emergency assistance for basic survival needs, the impacts are still more staggering: the number left homeless, hungry, or injured is nearly 3.5 billion (UNISDR, n.d.c). Floods, storms, and drought account for nearly all human impacts, affecting 2 billion, 435 million, and 950 million lives, respectively (UNISDR, n.d.c). In an average year, natural disasters will claim more than 60 thousand lives and affect more than 250 million people (UK Department for International Development, 2004). Though better known for the human impacts of lives lost and affected, natural disasters also present a formidable economic threat. Together, floods, storms, and drought also have the greatest impact in terms of economic losses, which encompass damage to infrastructure, crops, housing, revenues, employment, and market stability (UNISDR, 2006,a). Over the past fifteen years, storms have been the most costly at USD 443 billion, but are followed closely by floods, which have cost over USD 360 billion. The lesser financial impact of drought, over USD 106 billion, is more than made up for by the disproportionate USD 271 billion incurred from earthquakes and tsunamis respectively. In an average year, natural disasters will claim more than 60 thousand lives and affect more than 250 million people. Nowadays it is widely accepted that a disaster is multifaceted and open to a range of different interpretations.

According to one definition, disasters are, 'An unforeseen and often sudden event that causes great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins' 'The combination of hazards, vulnerability and inability to reduce the potential negative consequences of risk results in disaster'; etc. For a disaster to be entered into the database of the UN/ISDR, at least one of the Following criteria must be met:

- A report of 10 or more people killed,
- A report of 100 people affected,
- A declaration of a state of emergency by the relevant government,

- A request by the national government for international assistance.

Even though there is no common worldwide definition of 'disaster', there are some characteristics which are common to most definitions. A disaster is generally considered as: (i) being sudden, abrupt or unpredictable, (ii) causing human, material, economic or environmental losses, (iii) exceeding the ability of the affected community to cope with it. The economic impact of a disaster usually consists of direct (e.g. damage to infrastructure, crops, housing) and indirect (e.g. loss of revenues, unemployment, market destabilization) consequences on the local economy.

Natural disasters

Disasters triggered by natural hazards are killing more people over time and costing more. This is the trend revealed by data collected by the Center for Research on the Epidemiology of Disaster (CRED) in Belgium (EM-DAT, 2005) and by the worldwide re-insurance industry. The world's poorer nations are disproportionately affected (Munich Re Group, 2002; IFRC, 2003), and the most vulnerable and marginalized people in these nations bear the brunt.

Following the definitions of natural disaster by the UN office for the Coordination of Humanitarian Affairs, natural disasters can be divided into three specific groups: Hydro meteorological disasters, geophysical disasters and biological disasters. Hydro-meteorological disasters are natural processes or phenomena of an atmospheric, hydrological or oceanographic nature that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. These include floods and wave surges, storms, landslides, avalanches, and droughts and related disasters (extreme temperatures and forest/scrub fires). Geophysical disasters are natural earth processes or phenomena that may cause Loss of life or injury, property damage, social and economic disruption or Environmental degradation. These include earthquakes, tsunamis and volcanic Eruptions.

Biological disasters are processes of organic origin or those conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. These include earthquakes, tsunami and volcanic eruptions. Biological disasters are processes of organic origin or those conveyed by biological vectors, including exposure to pathogenic micro-organism, toxins and bioactive substances which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. These include epidemics and insect infestations. However, the European Commission includes in natural disasters only hydro meteorological disasters and geophysical disasters, considering biological disasters (diseases, pests, contamination in the food chain as by dioxins) a separate group. Recent events have shown that there is no country that does not stand the threat of a disaster, though they may be threatened at different levels. Therefore, disaster preparedness is no longer a choice; it is mandatory irrespective of where one lives.

Natural Disaster Risk Management

When a hurricane or an earthquake occurs not everyone has a total loss. Still, many losses do occur at the same time. Crop losses have similar characteristics. While events such as too little rain, too much rain, or widespread frost create widespread crop losses, not every farm experiences the same loss. The challenge for those insuring losses from hurricanes, earthquakes, and crop disasters is to have access to enough capital to cover worst-case scenarios. Since catastrophic risks are not independent, and in the classic sense are uninsurable, special global markets have emerged to share these risks. The traditional mechanism is to share catastrophic risk with another insurance entity by what is called reinsurance. Reinsurance can take many forms. The simplest form to consider is another insurance policy on the insurance losses for a local insurance provider. Such a

policy can be arranged as a 'stop loss' policy: The local insurance provider pays a premium to the Global re-insurer who agrees to pay for all losses beyond a certain threshold. As long as the reinsurer mixes this into a global book of business, then what were correlated risks at the local level become independent risks at the global level. While reinsurance markets are extremely effective and have grown in recent years, there are significant limitations. First, price discovery is difficult. There is no price transparency. The international reinsurance market is a classic thin market with few buyers and sellers. Second, transaction costs are high. Reinsurance contracts can be unique, requiring costly legal fees to tailor the contract to the special circumstances. The local insurance provider will know more about the risk they are writing than the international reinsurer can expect to learn. Thus, the hidden and asymmetric information problems that plague local insurance providers are also present between the local insurer and the global reinsurer. It is expensive for the reinsurer to attempt to balance the information and monitor the local insurer. Third, the prices that must be charged for reinsurance may simply not match the willingness to pay. In addition to covering the transaction costs, the price of reinsurance reflects extra "loading" to build reserves and account for the ambiguity of catastrophic risk (Jaffee and Russell, 1997). A lack of understanding about the risks and events being insured may cause insurers and reinsurers to set premiums too high (Camerer and Kunreuther, 1989).

Froot (1999) develops four explanations for the high price and low use of catastrophic reinsurance:

- I. Reinsurers have market power;**
- II. The corporate form for reinsurance is inefficient**
- III. Frictional costs of reinsurance are high, and**
- IV. Moral hazard and adverse Selection at the insurer level is high.**

Disaster management for local governments signifies a series of measures which include disaster prevention, emergency response, and recovery and reconstruction. Presumably these measures correspond to the measures described in the regional disaster prevention plan prepared by local governments. Natural disasters, by their very definition, overwhelm the capacity of the affected community. In poor countries, disasters commonly overwhelm the national government as well, often times erasing years of hard-won development gains. With lower coping-capacity thresholds, poor peoples and nations are the most vulnerable; "Disasters seek out the poor and ensure that they stay poor" (International Federation of Red Cross and Red Crescent Societies, 2003: II). International support for countries struck by disasters, therefore, is well warranted. Furthermore, the international system is best positioned to gather and facilitate the sharing of experiences from all over the world, thereby, contributing to the development of a global knowledge bank of primary challenges and best practices in disaster risk reduction. The ISDR full's this role with competence and compassion. What is needed is the political will to undertake strong commitments to the requirements identities, and the financial resources to fund their achievement. The Hyogo Framework for Action 2005–2015 and the ISDR guidance for its implementation identify the tools for achieving its objective of substantial reductions in lives and economic assets lost. Its greatest contribution, however, is not instruction on early warning, tele-communication, and information systems; rather, it is the recognition. That, so long as people remain powerless in slums, degraded ecosystems, and poverty, technology will never be enough. The test of the framework, and the international consensus and commitment from which it came, will lie in the development of a culture of prevention that extend to human livelihoods and sustainable development. On December 26, 2004, a 9.0 earthquake centered off the coast of northern Sumatra, Indonesia, shook the floor of the Indian

Ocean. This massive underwater earthquake triggered a tsunami that killed more than two lakh people, making it one of the deadliest natural disasters in modern history. The tsunami reshaped the physical characteristics of five Southeast Asian countries and permanently altered the way the world looks at the potential impact of natural hazards. The tsunami affected a total of twelve countries and 5,000 miles of coastline, causing more than ten billion dollars in damage. Major infrastructure was severely affected, with more than 3 thousand miles of roads and 118 thousand .fishing boats damaged or destroyed. Some four lakh houses were also seriously damaged or destroyed, displacing entire communities, and the economic well-being of many was threatened as 1.4 million people lost their source of livelihood.

The tsunami, traveling at approximately 500 mph, carried a brute force with the potential to cause irreparable damage. This force was intensified due to the lack of disaster prevention and reduction strategies, as well as an increase of human settlements in Coastal belts, vulnerability of poor communities, substandard housing and construction standards, lack of a regional early warning system, and environmental degradation. Immediately following the tsunami, there were discussions about how many lives could have been saved if there had been a regional early warning system. The discussion was not unwarranted: the tsunami did not hit Sri Lanka until almost two hours after its origin, and yet over 35 thousand people died there. An early warning system presumably would have saved many of those lives. Rarity and severity are typically associated with catastrophic risks: the more severe a risk, the rarer it usually will tend to be, and vice versa (Frohwein et al., 1999). Catastrophe events can thus inflict considerable losses on many stakeholders of private businesses (insurers, re-insurers, banks, et cetera) and society (government, tax-payers, households). In agriculture catastrophic risks result in heavy losses for farms. For example, arable farmers are exposed to extreme meteorological events, such

as heavy precipitation, excessive heat, drought, hail, storm and frost, which may result in potential damage to crops (Langeveld, *et al.*, 2003). In dairy farming, epidemic diseases, such as FMD (foot-and mouth disease) and BSE (bovine spongiform encephalopathy), cause severe economic losses. We assume that an event is catastrophic if a farmer may face cash flow problems or even go bankrupt. Somehow farmers need to manage catastrophic risks. By applying risk management strategies, such as insurance, diversification, self-insurance, forward contracting, options and futures contracts, losses associated with catastrophe events can be borne or transferred. Insurance is a frequently used instrument to cover catastrophic risks (Pritchett et al., 1996). However, not all farmers buy insurance to protect their business against several types of catastrophic risks. Thus it is important to analyze the factors that influence purchase of catastrophe insurance to provide insight for improvement of existing and development of enhanced insurance policies. In order to understand the use of insurance decisions to cover losses due to a catastrophe, main factors that influence catastrophe insurance purchase need to be addressed. In farming, these factors refer to farm characteristics and farmers' personal characteristics (e.g. Mishra and Goodwin, 2003; Sherrick et al., 2004). Effects of farm characteristics on insurance purchase were elaborated by Mishra and Goodwin (2003), Ogurtsov *et al.* (2007) and Sherrick et al. (2004). Farm variables, including farm size, proportion of rented land, region, net farm income, governmental compensations, operating costs, off-farm income and debt use were found to have a significant impact on catastrophe insurance purchase. However, the analysis of impacts of farmer-specific factors is essential to understand real-life catastrophe insurance decisions.

Role of Insurance in Economic Development

Droughts, floods, and other natural disasters lead to severe income losses for rural people, especially farmers and poor people. Given their

limited ability to offset these losses, many rural people suffer extreme hardship, lose assets, and default on their debts in disaster years. The economic development literature increasingly links poverty and shocks (Dercon, 2005). Studies find that a large portion of the poor in developing countries are transitory moving in and out of poverty as they encounter shocks to household income. These poverty traps justify some type of public intervention for equity and efficiency enhancement. As Dercon (2005) concludes, “social protection may well be good for growth.” The prevalence of natural disasters is not new, and farmers, rural institutions, and lenders have, over generations, developed ways of reducing and coping with risk (e.g., crop diversification, farm fragmentation, kin support networks, storage, and asset accumulation). Although the virtues of these traditional risk management instruments are widely recognized. They can be costly in terms of the income opportunities that rural people forego (e.g., crop diversification is typically less profitable than specialization). They can also discourage investments and technological changes that, while risky, enhance long-term productivity growth. Also, risk exposure can reduce access to credit because of greater risk of debt default in bad years. And finally, shocks that accompany extreme events also create the poverty traps described above. Traditional risk management methods have limited capacity to spread covariate risks, like droughts, that affect most people in a region at the same time. In theory, these limitations would not exist if capital and insurance markets were perfect and could pool risks over wider regions and over time, but the reality in many developing countries is quite the opposite: relevant capital and insurance markets are poorly developed and weakly linked across regions and with urban areas.

Seminal works by Arrow (1964) and Debreu (1959) have addressed the value of risk sharing markets for society. Failures in insurance markets provide a rationale for governmental intervention, but only if government can fix the

problem at a lower cost than the social benefits derived. Many governments have intervened with a range of risk management programs for rural people (e.g., crop insurance, livestock feed subsidies and debt forgiveness). Such programs have often been an expensive drain on the public purse, and there is little evidence to show that these interventions have generated any sizeable social benefits or that the benefits exceed their costs (Hazell, 1992; Hazell, *et al.*, 1986). Given these failings, many governments turn to various forms of direct disaster assistance to relieve the problems of stricken areas. Such assistance is costly, and costs may escalate in the future as more people live in vulnerable areas and as global climate change increases the frequency and severity of many natural disasters. Moreover, once disaster assistance has been institutionalized and taken for granted, it can lead to many of the same perverse incentive problems as an insurance subsidy, inadvertently worsening future problems by encouraging people to increase their exposure to potential losses. For example, assured compensation for flood or hurricane damage to homes can lead to the building of more houses in flood and hurricane prone areas than prudent investors would otherwise build. Similarly, assured compensation for crop losses in drought prone areas may encourage farmers to grow more of the compensated crops even when they are more vulnerable to drought than alternative crops or land uses. More effective risk management instruments are needed to enable rural people to better manage their own catastrophic risks. While some disaster assistance should never be ruled out, new developments in insurance raise the possibility of substantially reducing the financial burden on governments.

The emergence of Micro Insurance is an important development within the field of microfinance. Micro insurance being available at affordable prices is an important financial service providing protection to the poor in the event of disasters. Hence, it challenges the

previously held belief of the non-insurability of the poor.

Concluding remarks

In the process of disaster management, there is a need to decide and translate the measures into action which are to be executed in each stage of disaster prevention, emergency response, and recovery and construction. Disasters can wipe out years of hard-won development progress, devastate lives and livelihoods and cripple developing economies. Disaster risk reduction programs aim to reduce the vulnerability and enhance the resilience of communities to the adverse effects of natural hazards. Investing in disaster risk reduction protects lives, livelihoods and property and is critical for sustainable development, including the achievement of the Millennium Development Goals. Since the adoption in 2005 of the Hyogo Framework for Action, a global blueprint for disaster risk reduction, there has been growing international conviction that response alone is not enough. The paramount concern of disaster risk management is to advise partner countries in developing an efficient risk management system of their own focusing on issues, such as: (i) political awareness, (ii) role of civil society, (iii) place of disaster risk management in development cooperation sectors, (iv) role of private sector in disaster risk management, (v) effective implementation of disaster risk management strategies, and (vi) role of bilateral technical and financial cooperation at international level.

References

- Arrow, K. J. (1964). 'The Role of Securities in the Optimal Allocation of Risk Bearing', **Review of Economic Studies**, 31, pp. 91-96.
- Braine, T. (2006), Was 2005 the year of natural disasters? **Bulletin of the World Health Organization**, 84 (1), pp. 4-8.
- Camerer, C. F. and H. Kunreuther (1989), "Decision Processes for Low Probability Events: Policy Implications." **Journal of Policy Analysis and Management**, 8, pp. 565-592.
- Debreu, G. (1959). **Theory of Value: An Axiomatic Analysis of Economic Equilibrium**, New York: Wiley.
- Dercon, S. (2001). **Income risk, coping strategies and safety nets. The center for the study of African Economics working paper**, CSAE.WPS/2003-01. Oxford University. Available at: <http://www.wiwi.fu-berlin.de/w3/w3collie/socpolws03/dercon.survey.pdf>. 37pp. accessed 27 March 2006.
- (Data Base) (2005) '**EM-DAT: the International Disaster Database**'. Center for Research on the Epidemiology of Disasters (CRED), Ecole de Santé Publique, University Catholique de Louvain, Brussels. <http://www.em-dat.net/index.htm>.
- EM-DAT (Emergencies Disasters Micro insurance: A Risk Management Strategy- Donor Brief, No. 16, December 2003).
- Frohwein, H.I. *et. al.* (1999), Alternative measures of extreme Events in decision trees. *Reliability Engineering and Safety Systems*, 66: 69-84.
- Jaffee, D. M. and T. Russell (1997), "Catastrophe Insurance, Capital Markets, and Uninsurable Risks." **Journal of Risk and Insurance** 64: 205-230.
- Hazell, P. B. R. *et. al.* (1986). **Crop Insurance for Agricultural Development: Issues and Experience**. Baltimore: The Johns Hopkins University Press.
- Hazell, P. B. R. (1992). "The Appropriate Role of Agricultural Insurance in Developing Countries." **Journal of International Development** 4: 567-581.
- IFRC (2003) **World Disasters Report 2003**. IFRC, Geneva. <http://www.ifrc.org/publicat/wdr2003/>.
- Langeveld, J.W.A. *et. al.* (2003), Coping with increasing extremes in agriculture: an

exploration for the Netherlands. **World Resource Review**, 15(4): 446-461.

Mishra, A.K. and B.K. Goodwin (2003), Adoption of crop insurance versus revenue insurance: a farm-level analysis. **Agricultural Finance Review**, fall: 144-155.

Munich Re Group (2002) **Annual Review. Natural Catastrophes**. Munich Re Group, Munich. http://www.munichre.com/publications/302-03631_en.pdf.

NOAA(2006b). **Noteworthy Records of the 2005 Atlantic Hurricane Season**. Retrieved August 4, 2007, from www.noaa.gov/stories2005/s2540b.htm.

Ogurtsov, V.A. *et. al.* (2007), Insurance decisions by Dutch dairy and arable farmers. **Journal of Farm Management**, 13(2): 95-106.

Pritchett, S.T. *et. al.* (1996), **Risk Management and Insurance**, 7th ed. West Publishing Co.

Sherrick, B.J. *et. al.* (2004), Factors influencing Farmers' crop insurance decisions. **American Journal of Agricultural Economics**, Feb. 2004: 103-114.

UK Department for International Development (2004). **Disaster risk reduction: A development concern, a scoping study on links between disaster risk reduction, poverty and development**. Norwich, England: Overseas Development Group.

United Nations Inter-Agency Task Force on Disaster Reduction (2001). **Framework for action for the implementation of the international strategy for disaster reduction (ISDR)**. Geneva:

United Nations Inter-Agency Task Force on Disaster Reduction (2007) **United Nations International Strategy for Disaster Reduction (n.d.a). Disaster occurrence, trends-century**. Retrieved August 1, 2007, from www.unisdr.org/disaster-statistics/occurrence-trends-century.htm.

UNISDR(2004). **Living with risk: A global review of disaster reduction initiatives**. Geneva: United Nations. Retrieved August 1, 2007, from www.unisdr.org/eng/about_isdr/bd-lwr-2004-eng.htm.

UNISDR (n.d.b). **Disaster Occurrence, Type of disasters 1991-2005**. Retrieved August 1, 2007, from www.unisdr.org/disaster-statistics/occurrence-typedisas.htm.

UNISDR(n.d.d). **Disasters Impact, Economic Damage**. Retrieved August 1, 2007, from www.unisdr.org/disaster-statistics/impact-economic.htm.

UNISDR(n.d.e). **Disasters Impact, Killed**. Retrieved August 1, 2007, from www.unisdr.org/disaster-statistics/impact-killed.htm.

UNISDR(2006b). **NGOs and disaster risk reduction: A preliminary review of initiatives and progress made**, Background paper for a consultative meeting on a "global network of NGOs for community resilience to disasters." Retrieved August 1, 2007, from www.unisdr.org/eng/partner-netw/ngos/meeting1-october-2006/NGOs_and_DRR_Background_Paper.pdf.

United Nations (2004a). **International Strategy for Disaster Reduction (A/RES/58/214)**. Retrieved August 9, 2007, from <http://daccessdds.un.org/doc/undoc/gen/n03/507/36/pdf/n0350736.pdf?OpenElement>.

United Nations (2004b). **Review of the Yokohama Strategy and Plan of Action for a Safer World: Note by the Secretariat (A/CONF.206/L.1)**. Retrieved August 9, 2007 from www.unisdr.org/wcdr/intergover/official-doc/L-docs/Yokohama-Strategy-English.PDF.

UNISDR(n.d.c). **Disasters Impact, Affected**. Retrieved August 1, 2007, from www.unisdr.org/disaster-statistics/impact-affected.htm.

United States Geological Survey (2007), **Most Destructive Known Earthquakes on Record in the World**. Retrieved July 27, 2007, from http://earthquake.usgs.gov/regional/world/most_destructive.php.

World Bank (2000). **Managing Catastrophic Risks Using Alternative Risk Financing and Insurance Pooling Mechanism**, The World Bank, Available: <http://wb1n0018.worldbank.org/external/lac/lac.nsf/c3473659f301161e852567ec0054ee1b/>.

(**Mr. Kiyanoush Ghalavand** is Ph.D. Research Scholar and **Dr. Ashu Pasricha** is Assistant Professor, Department of Gandhian Studies, Punjab University, Chandigarh,
E mail: kiyanoush1973@gmail.com, ashu.p2@gmail.com)

Landscape appreciation of Neyyar River Basin, Thiruvananthapuram, Kerala

Chandrasekar. M and R. Anilkumar

Abstract

Landscape appreciation is important in obtaining a synoptic view of geographic and geomorphic characteristic of an area. The Neyyar River basin constitutes one of the major river systems in the Trivandrum district and falls between the latitudes $8^{\circ}15'N$ & $8^{\circ}41'N$ and longitudes $77^{\circ}E$ & $77^{\circ}20'E$. The Neyyar river basin, the southernmost basin in the state, has an area of 498 km^2 . The present study attempts to study geomorphic characteristics of Neyyar river basin. Top sheets on the scale 1:50000 and Satellite images used for the investigation. To delineate and quantify landscape parameters, the potentialities of GIS were resorted to.

Introduction

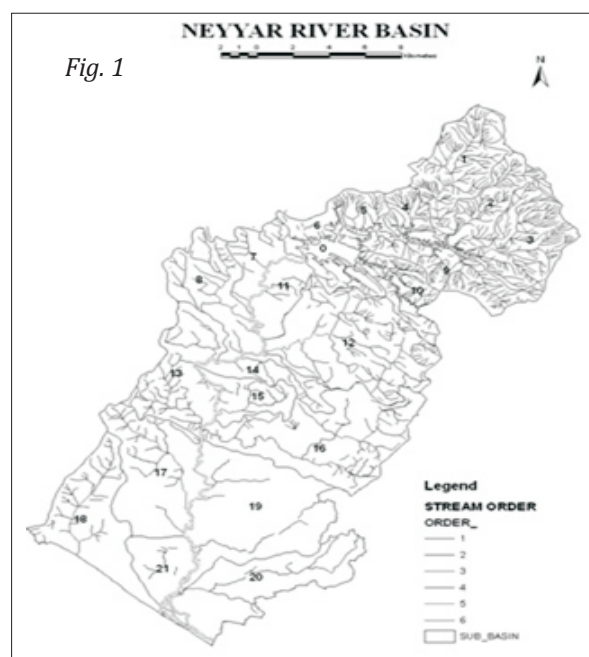
The land classification entails an appreciation of varying types of terrain and the best uses that may be made of them. An appreciation of geomorphic features is important but it should be sufficient to show that a thorough understanding of geomorphic principles along with knowledge of the geomorphic history of specific area may contribute significantly to the solution of a problem.

A better understanding of geomorphic landforms and its evolution is essential for the evaluation of land and water resources of any area. Development of streams from the crenulations of hills, erosion and deposition patterns, occurrence of mudflow, rock falls, landslides and other parameters like climatic variation and soil characteristics, land use and land cover patterns, etc. are dependent largely on the shape, slope, elevation and litho logical stratification of a landform unit.

The Neyyar river basin, southernmost basin in Kerala, is one of the major river systems; lying between the latitudes $8^{\circ}15'N$ & $8^{\circ}40'N$ and longitudes $77^{\circ}E$ & $77^{\circ}20'E$. The Neyyar River originates from the Agasthya malai at an elevation of 1866 m. The Neyyar river is a 6th order basin (Fig.1). The basin, with an area of 498 km^2 , has estimated water resources of 229Mm^3 , and the watershed region marks the

boundary of the Trivandrum district with the Tirunelveli district. The Neyyar river basin being part of the Indian Peninsular Shield has suffered intense tectonic activity the effect of which is imprinted in the form of dislocation of stream orientation. The straight courses of the Neyyar river and its right angled bends indicate that the river is controlled by these faults and or fracture systems.

From the highest elevation (1866 m) the river takes a NNE-SSW course and meets the Kall Ar at an elevation of 103 m, the dam site is constructed. For this sudden drop-in elevation



the river travels only 9 km, comparatively negligible when considered the drop. This indicates a sudden steep slope and a cascading effect. Thereafter the river flows into the Neyyar dam reservoir (constructed in 1959)

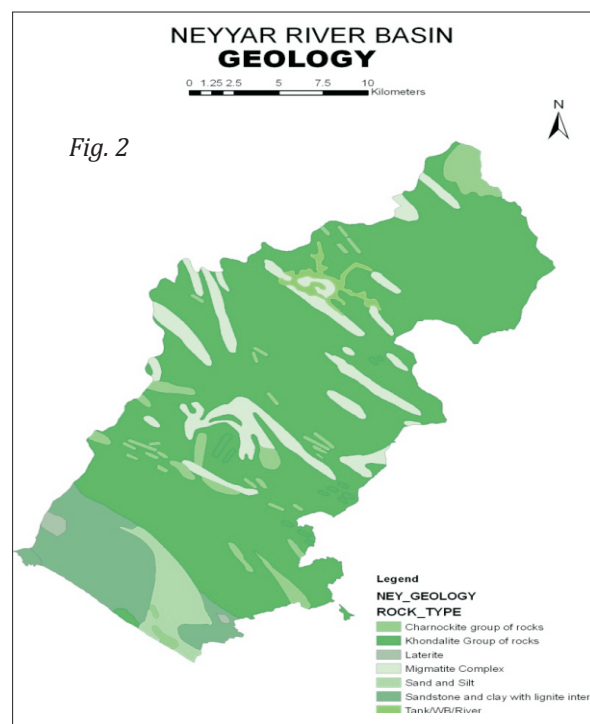
The present study attempts to study landscape characteristics of Neyyar river basin. Toposheets in the scale 1:50000 & Satellite images were used for the investigation. To delineate and quantify the geomorphic characteristics, the potentialities of GIS were resorted to.

Geology of Neyyar Basin

A large part of the Neyyar basin is made up of crystalline rocks of Achaean age comprising of gneisses of charnockite-khondalite suite blanketed by fairly thick laterite capping with lenses, of graphite, alluvium and soil (Fig.2). The thickness of laterite capping increases from higher altitude to lower altitude. The main rock types are charnockite, khondalite with veins of pegmatite, pyroxene granulites, garnet-biotite gneiss, garnet- sillimanite gneiss, Talc-granulites and quartzite. Dykes of dolerite and gabbroic composition following major structural trends were reported. At the foot of Agasthya malai and the place where the Neyyar and Kall Ar confluences the minor tributaries and the adjacent rivers like Edamalai todut takes a straight course indicating a major structural control. When this feature is further extended north-eastwards through the reservoir and to the adjacent Karamana river basin, it corresponded to a major lineament approximately trending NW-SE. This could be the major lineament about which the structural upliftment of Agasthya malai could have taken place giving rise to its present position thereby explaining the sudden drop in the elevation. In the highlands the major rock types khondalite and charnockite are very fresh as the rate of erosion is greater than that of weathering, due to heavy rain fall in this area. No laterite cover is observed capping the crystalline rocks.

Physiography of Neyyar Basin

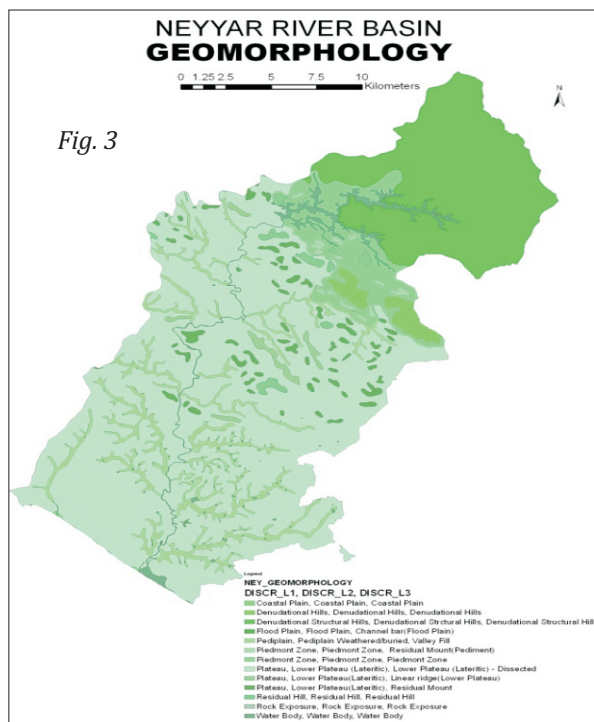
Physiographically with reference to the altitude the Neyyar basin embodies four major



physiographic divisions viz., the highlands, midlands, lowlands and the coastal lands. The highlands (600 m represent the high hill ranges and the catchment area of the Neyyar basin. In the midlands (600-200m) the highly resistant rock outcrops with laterite capping are observed. The lowlands (200-20m) represent a region of low relief and subdued topography, indicating a late mature stage of the river. In the coastal strip braided channels are observed.

From Agasthya malai the contour descends rapidly up to Erinja malai (300 m) beyond which it takes a near plain surface with alternating hillocks. These alternating hillocks in the midlands may either represent the hard resistant rocks as a result of the erosion or the consequence of the periodic upliftment of the area in conjunction with the uplift of Agasthya malai. This type of topography can be expected in regions of tropical weather conditions under high rate of sheet erosion.

Another lineament trending ENE-WSW is noticed at the confluence of the Chit Ar with the Neyyar. Here the straight course of the Neyyar and Chit Ar extends up to 8 km. The above observations of the river being controlled by structure are further corroborated by plotting



918 streams orientation of streams of all orders in the Neyyar basin. The major flow direction of the Neyyar basin is approximately NW-SE followed by minor flow direction NNW-SSE and NE-SW.

Downstream of the darn, the river takes a ENE-WSW course and turns in a NNW-SSE direction with conspicuous sinuous courses up to Aryankad. Beyond Aryankad it takes a right angled bend up to Pulimuttom. This can be attributed to a major fault/fracture which extends to the Chit Ar basin. Beyond Pulimuttom the river takes a N-S course with slight deflection and meanders profusely cutting its own plain by constructing flood plains. Beyond Ulloorakonam it flows in an entirely relief less plain and finally debouches into the sea at Puvar.

Methodology

The map of geomorphic features of Neyyar River basin was prepared based on SOI Toposheets on a 1:50000 scale (No: 58H/2, 58H/3 and 58H/6) and Satellite data were used to map the landform units based on image characteristics like tone, size, shape, pattern, texture, location, association, etc. and ground truth data was generated, based on extensive field checks in the area for the present study. For digitization,

computation and output generation, the GIS software was used.

Geomorphic characteristics

A better understanding of geomorphic landforms and evolution is very essential for the evaluation of land and water resources of any area. Development of streams from the crenulations of hills, erosion and deposition patterns, occurrence of mudflow, rock falls, landslides and other parameters like climatic variation and soil characteristics, land use and land cover patterns, etc. are dependent largely on the shape, slope, elevation and lithological stratification of a landform unit.

The Geomorphic units in the Neyyar river basin are demarcated from the satellite remote sensing data based on the spectral reflectance characteristics of each landform unit and with the help of the top sheets. Broadly the entire basin can be classified into four major geomorphic units based on its physiography—High lands, Midlands, Low Lands and Coastal lands (Fig. 3).

High lands: The area between 500m-1866m contour covers 33.12 sq.km (or 6.17 per cent), representing the high hill ranges and denudational structural hills. The Thalakkethodu, Kall ar, Mull ar are in this division. From the highland the Neyyar river descends fast in the form of rapids and falls due to the steep westerly slope of the highlands. From the Agasthyamalai the relief descends rapidly up to Erinja Malai (300m) and then it takes the shape of near plain surface with alternating hillocks. These hillocks may either represent the hard resistant rocks as a result of the erosion or these may be the result of periodic upliftment of the area in conjunction with the upliftment of Agasthya malai. The highlands are characterized by uncapped crystalline rocks with steep slopes; hence the rate of erosion is higher as compared to surface weathering which results into the youth stage in highlands area. In the Western Ghats there might be upliftments that may lead to the second stage of denudation. This sort of phenomena can be expected in a region with

steep slopes (the fall in elevation is 1163m in 9 Km) and high rate of rainfall, as propounded by Penck (1924).

Mid lands:The midlands are between 200m–500m contour and covers 124.76 sq.km (or 25.76 per cent of the total basin area). Midlands represent highly resistant rock outcrops with laterite capping. Demarcating features of the midlands from the highlands is the major NW-SW lineament passing through Edamali thodu. The midlands are differentiated from lowlands by appearance of Monadnocks where as the latter has a nearly plain topography. A flood plain deposit of local occurrence was noticed near Valliankod. The alternating hillocks in the midlands may either represent the hard resistant rocks as a result of the erosion or the consequences of periodic upliftment of the area in conjunction with upliftment of Agasthyamalai. Lower plateau (lateritic– dissected), pediplain (weathered/ buried), valley fill residual hills and linear ridges are the other important features in the midlands.

Low lands:The low land (200m- 20m) represents a region of low relief and subdued topography indicating a late mature stage of the Neyyar river basin. Lateritic capping with lenses of graphite (Aruvipuram) was observed in the low lands. These laterites are found capping the Khondolite and other rocks are Quartzite and Chanokite. The tropical weather and evergreen forest give a thick chemically weathered soil. In course land has been worn down to a low land of faint relief and subdued topography. In low lands the river might attain mature to old stage and slope may be moderate to gentle. Isolated river terraces were noticed in the low lands. The river terraces represent valley floors abandoned by river as they start to cut down to new and lower base level. The lowland and coastal land cover an area of 330.08 sq.km (67.08 per cent).

Coastal plains- is composed of marine sediment characterized by the presence of plain, mud flat and swales. In the coastal strip braided channels are observed

Conclusions

Physiographically, with reference to the altitude the Neyyar basin embodies four major divisions. viz., the highlands, midlands, lowlands and the coastal lands. The highland (600 m-1866m) represents the high hill ranges and the catchment area of the Neyyar basin. In the midlands (500-200m) the highly resistant rock outcrops with laterite capping are observed. The lowlands (200-20 m.) represent a region of low relief and subdued topography, indicating a late mature stage of the river. In the coastal strip braided channels are observed.

References

1. Abrahams, A.D (1984) Channel Network: A geomorphological perspective **Water Resources Research**, 34, pp. 2751-2764
2. Smith K.G, (1950) standards for grading texture of erosional topography. **American Jour. Science**, 248 pp 655-668.
3. Horton, R.E (1945) Erosional development of streams and their drainage density: hydrophysical approach to quantitative geomorphology. **Geo. Soc. Amer. Bull.**, 56, pp. 275-370.
4. Horton, R. E (1932) Drainage basin characteristics. **Trans. Aeri. Geophys. Union**, 13, pp 350-361
5. M.Samsuddin (1980) Quantitative Geomorphological analysis of Neyyar river basin, Trivandrum district, Kerala State, **CESS, Professional Paper**, 9, pp 1-28
6. Strahler, A.N., (1952) . Dynamic basics of geomorphology. **Geol. Soc. Amer. Bull.** 63.

(Mr. Chandrasekar.M, is Research Scholar and Dr.R.Anilkumar is Associate Professor, Department of Geography, University College, Thiruvananthapuram.
Email: chandru26oct@gmail.com)

SECTION V

GEO-SPATIAL TECHNOLOGIES AND DISASTER MANAGEMENT

Mapping Vulnerability Along Kalka-Shimla Highway Using Fuzzy Logic Technique in GIS Environment

Gaurav Sapra, Preetika S. Sapra

Abstract

Landslide susceptibility mapping helps in identifying strategic points and ecological sensitive areas prone to landslides. The main objective of this paper is to prepare landslide susceptibility map of landslide prone areas falling along the Kalka-Shimla Highway using fuzzy logic technique in GIS environment. For identifying landslide prone areas, surrogate indicators such as slope, aspect, elevation and geology have been used. After using fuzzy membership function assigned for each maps on the basis of landslide hazard evaluation factor (LHEF) rating scheme, a weighting factor was then considered for each map depending on the threat posed by each category on final susceptibility map. All maps were superimposed by a fuzzy gamma (γ) operator. A fixed value of $\gamma=0.95$ was chosen as critical brake point to produce the most reliable susceptibility map for landslide. Depending on the output value of membership function, final susceptibility map divide the study area into five zones of Very High, High, Moderate, Low and Very low susceptible to landslide hazard were earmarked on the map.

Keywords: Landslide Hazard Evaluation Factor (LHEF), Fuzzy Logic, Geographic Information Systems (GIS), Digital Elevation Model (DEM)

Introduction

A natural hazard may be defined as an unforeseen disaster. It comprises of floods, cyclones, landslides, volcanic eruptions, desert locusts and earthquakes. In hilly regions, landslides constitute as one of the major hazards causing loss to life and property. Landslide analysis is quite complex, involving multitude of factors and needing to be studied systematically in order to locate areas prone to landslides. The landslide susceptibility and hazard maps can be produced either by direct mapping or by indirect mapping technique. Direct hazard mapping is a technique in which degree of hazard is determined by the mapping geomorphologist's experience and his knowledge about terrain conditions. Another technique is an indirect hazard mapping in which either statistical or deterministic models are used to predict landslide prone areas based on information obtained from interrelation between landslide factors and landslide distribution. With the development of GIS, it is now possible to produce a landslide susceptibility map employing

indirect mapping technique such as combination of index map, statistical analysis, probabilistic approach and fuzzy logic approach. Here, fuzzy logic approach has been adopted for the preparation of landslide susceptibility map of area falling along Kalka-Shimla highway in North Western part of India, as a case study.

The study area: An area falling on both sides of Kalka-Shimla national highway (NH-22) starting from Kalka town of Haryana state and ending with Shimla City (Himachal Pradesh) has been selected for the present study. The altitude of study area from mean sea level varies from a low of 580 meters at Kalka to a high of 2067 meters at Shimla.

Data base and methodology

To prepare the landslide susceptibility map of Kalka-Shimla highway two separate input data sets are required. They are topographic data and geological data.

For topographic data, three topographic map sheets of number 53 B/13, 53 F/1 and 53 E/4 prepared at 1:50,000 scale available from

Survey of India, Dehradun. The geological data were obtained by using a previously published geological map of Shimla hills.

The methodological steps involved in this study are-

- i) Choice of casual factors affecting landslides,
- ii) Creation of DEM,
- iii) Generation of factor maps,
- iv) Assignment of fuzzy membership functions and weighting factor, and
- v) Choice of gamma operator and generation of final susceptibility map.

While making a choice of the casual factors affecting landslides in the study region, it was noted that the four factors namely, slope, elevation, aspect and geology are mainly responsible for the occurrence of landslides.

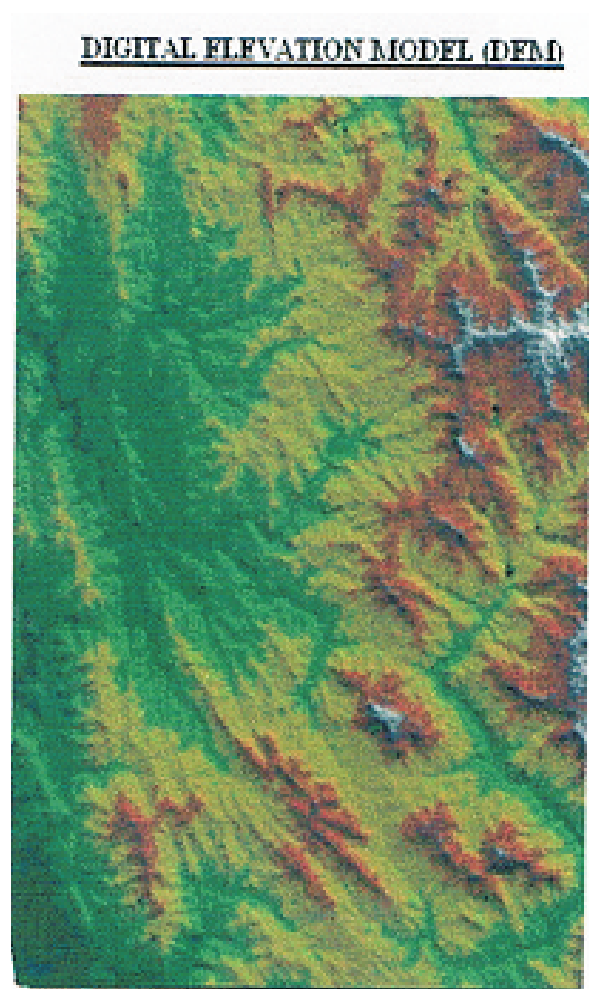


Fig 1: Digital Elevation Model of Kalka-Shimla Highway

Creation of DEM

DEM is the digital representation of topographic surface of earth in the form of raster or regular grid of spot height. In order to generate DEM, contour lines at 10m interval in the merged three topographic sheets which covered study area have been digitized using Arcview GIS (version 3.2 a) software. It provides information to map slope, aspect, elevation and information on geological parameters were obtained and mapped from the geological map of Shimla hills (Fig. 1).

Generation of factor maps

From DEM, three factor maps namely slope, aspect and elevation have been obtained.

i) Slope map: Slope forms one of the important parameter in any landslide hazard zonation mapping. Higher the slope greater are the chances of landslides. In the study area, change of slope is gradual and it varies from 0 degree to more than 45 degree. The entire slope map of study area is divided into four categories (Fig. 2) i.e. gentle, moderate, steep and very steep slope. Landslide susceptibility increases from gentle to very steep slope.

Aspect map: It is defined as the angle of slope. It is the angle at which two slope meet. It has a significant effect over the occurrence of landslide. In this study area aspect map has been categorized into nine categories (Fig. 3). From the figure it is clear that patches falling between 136-180 and 181-225 degrees are highly susceptible to landslide and aspect in the range 0-45 and 316-360 degrees are least susceptible

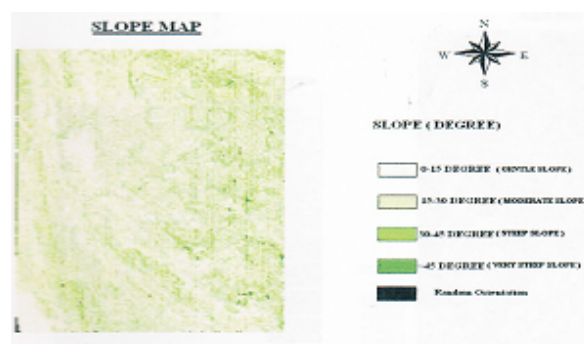


Fig. 2: Slope map of Kalka-Shimla Highway

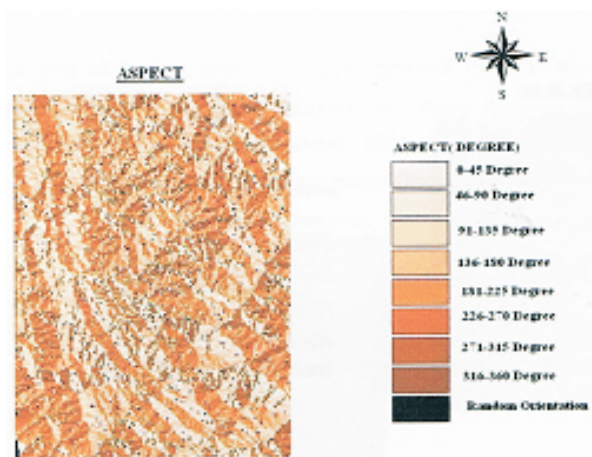


Fig. 3: Aspect map of Kalka-Shimla Highway

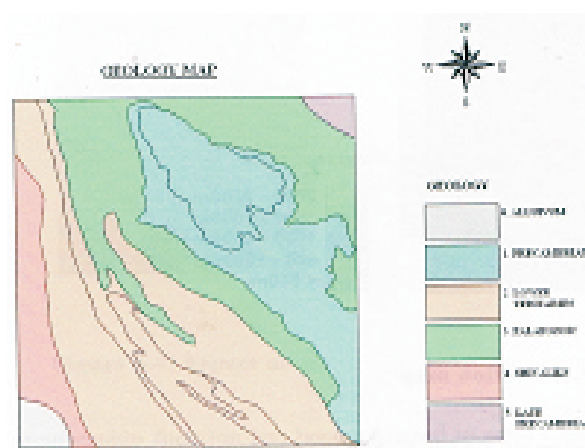


Fig.5: Geology of Kalka-Shimla Highway

to landslide. While aspect in the range 46-90, 90-135, 226-270 and 271-315 degrees are moderately susceptible to landslide hazard

iii) Elevation map: Elevation is a good indicator for landslide susceptibility mapping. There exist a direct relationship between elevation and occurrence of landslide i.e. if there is higher elevation than there is higher chance of occurrence of landslide .In this study area elevation lies in the range of 580 meters to 2500 meters. The elevation map is divided into five categories (Fig. 4).

iv) Geology map: The geological map provides information on lithological and structural setting of the area. The geology of Shimla hills is

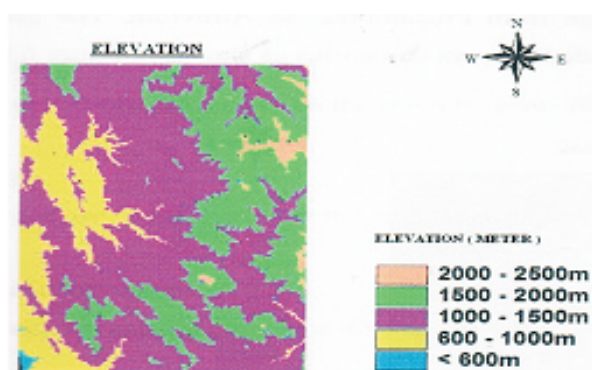


Fig.4: Elevation map of Kalka-Shimla Highway

formed of a thick pile of most unfossiliferous sediments ranging in age from Precambrian to Alluvium. The geology map of study area has been divided into six categories (Fig. 5) i.e.

Alluvium, Precambrian, Lower Tertiary, Palaeozoic, Shivaliks and Late Precambrian.

Assignment of fuzzy membership functions and weighting factors

In this study area, landslide depends on slope, aspect, elevation and geology. Fuzzy membership function was assigned to each class in all the four factor maps (Zaden, 1965). Two approaches have been followed for the assignment of fuzzy membership function. One has been on the basis of Landslide Hazard Evaluation Factor (LHEF) rating scheme (Anabalan, 1992).

It is a numerical system which is based on major inherent causative factors of landslide. The maximum LHEF rating for different categories are determined on the basis their estimated significance causing instability. Another factor known as weighting factor has been evaluated for each factor maps (Foumetis, et. al., 2004). It value has been assigned on the basis of expert's opinion about the estimated significance of each factor in causing landslides. The value of weighting factor, evaluated in case of each and every factor ranged between 0 to 1. Different values of fuzzy membership function and weighting factor were assigned to each factor map (Table 1).

Choice of gamma operator and generation of final susceptibility map

After assigning the fuzzy membership function and weighting factor to each factor map, the next

step is to combine all these maps using fuzzy gamma (γ) operator in order to generate a final susceptibility map. In this paper, a fixed value of $\gamma=0.95$ has been chosen. The effect of choosing different values of γ has been discussed in Tangestani, .The value of γ has been divided into two ranges:i) range of $\gamma > 0.8$ result in accelerating effect, and ii) range of $\gamma < 0.35$ result in decelerating effect.

Assigning a value of $\gamma=0.95$ increases the output fuzzy membership function, therefore locating areas with high and very high susceptibility to landslides. The γ operation has been done by using equation (1)

$$\mu\gamma(x) = [\mu\text{SUM}(X)]^\gamma * [\mu\text{PRODUCT}(X)]^{1-\gamma} \quad (1)$$

Where $\mu\text{SUM}(X)$ is the algebraic sum and $\mu\text{PRODUCT}(X)$ is the algebraic product (Marcelo and Carrol, 2000).

Table 1: Assigned fuzzy membership function and weighting factor to each of the four factors affecting landslide.

Factor	Class	Weighting Factor	Fuzzy value
Slope	0-15° (Gentle Slope)	1.0	0.2
	15-30° (Moderate Slope)		0.5
	30-45° (Steep Slope)		0.7
	>45° (Very Steep Slope)		1.0
Geology	Alluvium	0.8	0
	1Precambrian		0.2
	2Lower Tertiary		0.1
	3 Palaeozoic		0.5
	4 Shivaliks		0.7
Aspect	5Late Precambrian	0.6	1.0
	0-45°		0.1
	46-90°		0.4
	91-135°		0.4
	136-180°		0.6
	181-225°		0.5
	226-270°		0.4
Elevation	271-315°	0.4	0.4
	316-360°		0.2
	2000-2500 M		1.0
	1500-2000 M		0.7
	1000-1500 M		0.5
	600-1000 M		0.3
	<600 M		0.1

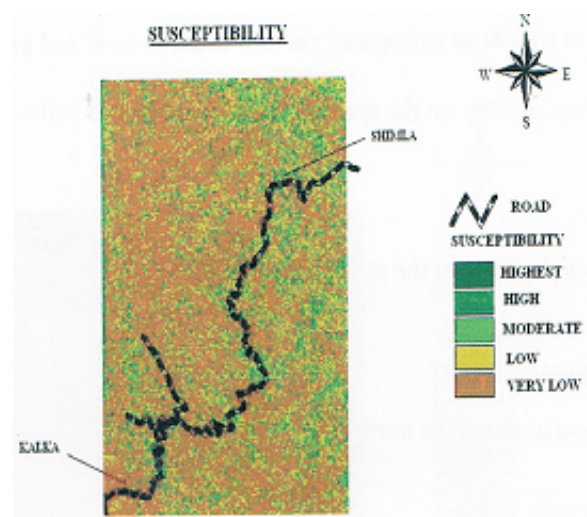


Fig. 6: Final susceptibility map of Kalka-Shimla Highway

On the basis of output fuzzy membership function susceptibility map has been classified into five zones: Very Low, Low, Moderate, High and Highest susceptibility to landslides (Fig. 6).

Conclusion

It is clearly depicted from final susceptibility map that in region near Kalka, brick red and yellow color patches are more dominated indicating the region of very low and low susceptibility to landslides respectively. The next major portion of map is covered by light green and green color patches, which indicates the region of moderate and high susceptibility to landslides respectively. It is evident that on moving upwards from Kalka to Shimla light green and green color patches goes on increasing and they are found to be more prominent on both sides of the highway and also in region near to Shimla. There are only few dark green spots in the map, which indicates the region of highest susceptibility to landslides. These spots are found to be more prominent at the road near to Shimla and also in some portions of Shimla.

References

Anabalgan R.(1992), "Landslide hazard evaluation and zonation mapping in mountainous terrain", **Engineering Geology**, 32,pp.269-277.

Bonham-Carter, G.F. (1994), **Geographic Information Systems for Geosciences: Modelling with GIS**. Pergamon Press, p. 398.

Fourmetis, M. et. al. (2004), "Landslide susceptibility mapping by GIS based qualitative weighting procedure in Corinth area". **Bulletin of Geological Society of Greece**. 36, Proceedings of the 10th International Congress, Thessaloniki.

Kakar, R.K.(1984):"Geomorphological and geological development of the Shimla Hills". In **Geographic Curriculum Project**, University of Georgia, Athens, U.S.A., pp.145-164.

Kwang-Hoon Chi et. al. (2002): "Fuzzy logic integration for landslide hazard mapping using

spatial data from Boeun, Korea". **Symposium on Geospatial Theory: Processing and Application**. Ottawa, Canada. July 9-12.

No-Wook Park et. al. (2003):"Predictive spatial data fusion using fuzzy object representation and integration: Application to Landslide Assessment ", **Korean Journal of Remote Sensing**. 19(3), pp.233-246.

Tangestani, M.H., (2003):"Landslide susceptibility mapping using fuzzy gamma operation in GIS , Kakan Catchment Area, Iran. **Australian Journal of Earth Science**. 51, pp. 439-450.

Wang, Huabin et. al. (2005): GIS based landslide assessment-an Overview". **Progress in Physical Geography**. 4, pp.548-567.

(Mr Gaurav Sapra and Ms. Preetika Sharma, are Assistant Professors, Electrical and Electronics Department, U.I.E.T, Panjab University, Chandigarh.

Email:gaurav_sapra2001@yahoo.com , pretikamadhav @yahoo.co.in)

Landslide Vulnerability Mapping: with GIS-based Fuzzy Logic Relations (A Case Study of Upper Tons River Valley, Garhwal Himalaya)

Radha Raman, Milap Punia and Ranjeet Kaur

Abstract

Landslides, one of the most destructive phenomena in Himalayan region that cause every year an extensive damage, both to property and life. Preparation of landslide susceptibility maps is important for planning future developmental activities and implementation of disaster management programmes in hilly terrains. This paper presents landslide susceptibility mapping using fuzzy logic relations and their cross application of membership values in the Upper Tons river valley of Garhwal Himalaya using remote sensing and geographic information system (GIS). Fuzzy logic relation for mapping landslide susceptibility is one of the techniques that allows to describe the role of landslide-conditioning parameters and their optimal combination. The study also establishes statistical relationship between landslides and geo-environmental parameters of landslide and analyze the accuracy in classification of landslide susceptibility map. Using total nine geo-environmental variables such as geomorphology, lithology, land use, slope, aspect, slope morphology, lineament, drainage density the landslide susceptibility models were developed using the fuzzy logic approach. The results indicated that about 72 percent of existing active landslides occurred in very high to high landslide susceptibility zones. Lithology, geomorphology, land cover and slope were found to be the most important in the study area. The result obtained from landslide map of the study area appears to be quite validated and established a relation with the geo-environmental condition of Himalayan regions. This landslide susceptibility zonation map helps to understand the spatial distribution of slope failure probability in an area and hence it is useful for effective landslide hazard mitigation measures.

Keywords- landslide hazard susceptibility, geographical information systems (GIS), remote sensing, Himalaya, fuzzy logic

Introduction

The hilly terrain of Himalaya is highly vulnerable to landslides due to its fragile terrain, complex geological setup, tectonically active belt (Shroder Jr. and Bishop 1988; Jade 2004). Moreover, population pressure and rapid development have led to expansion of construction activities have triggered the frequency of landslides in recent decades. In India, approximately 490 thousand sq. km or 15% of land area is vulnerable to landslide hazard. 98 thousand sq. km. is located in north, 80% is in hill areas including Himalayas, Nilgiris in south, Vindhya in Central parts and Eastern and Western Ghats (GSI, 2005). The natural and anthropogenic factors contribute to landslide tragedies every year in the Garhwal and Kumaun

region of Himalaya (Rautela, *et. al.*, 1999).

Geographic information system (GIS) integrated with earth observation systems is very helpful to create spatial landslide inventories and related attributes for the assessment of landslides hazard and susceptibility mapping. The earth observation data can be applied to inaccessible terrains to assess the impact of hazards in remote areas (Rao, 1997). The data handling capabilities of GIS can successfully be applied over mountainous areas of Himalaya to delineate the zone of hazards and risk (NRSA, 2001). A landslide susceptibility map has classified the land surface into different susceptibility zones by correlating some of the geo-environmental factors that contribute to

landslides with the past distribution of slope failures (Brabb, 1984; Guzzetti, *et. al.*, 1999; Ayalew, *et. al.*, 2005). This approach is quite useful for areas where it is difficult to access and collect the adequate information pertaining to the past record of landslide events, meteorological records of rainfall and the magnitude/intensity of earthquakes.

The landslide susceptibility mapping involves handling, processing and interpreting a large amount of spatial data. Thus, Geographical Information Systems (GIS) proved to be very important in susceptibility mapping (Aleotti and Chowdhury 1999; Ayalew *et al.* 2005). Generally, GIS based landslide susceptibility mapping broadly divided into two categories (i) Direct hazard mapping, in which the degree of hazard is determined by the experience and knowledge of the terrain conditions, and (ii) Indirect hazard mapping, in which either statistical models or deterministic models are used to predict landslide prone areas (Van Westen 2000). Indirect hazard mapping is based on information obtained from the interrelation between geo-environmental factors and the landslide distribution. The objectives of the present work envisages the remote sensing and GIS based landslide hazard susceptibility mapping by using fuzzy logic relations and their cross application of membership values in the Upper Tons river valley in Garhwal Himalaya.

Study area

The study, the upper Tons river valley is located at the western end of the Central Himalaya in northern India. The area extends from 30° 30' N to 31°25' N Latitude and 77°30' to 78°35'E Longitude and covers an area of approximately 1378 km². The elevation within this watershed varies between 1300 m to 6323 m above the mean sea level. The river originates from the Jamdar glacier in the Higher Himalaya and flow in steep and narrow valleys often resulting in excessive erosion and collapse of the banks. The valley of Tons river is highly rugged and intersected by a dense network of streams flowing down the steep slopes of the mountains

which are perpetually snow covered at higher elevations. The area lies in the Himalayan stratigraphical zone and in the vicinity of main central thrust (Valdiya 1988). This part of Himalaya is geologically unstable with large part of geographical area under greater slope instability and represents very fragile ecosystem threatened by erosion and landslides hazards (Fig. 1).

Materials and Methods

The landslide hazard mapping is done with the preparation of an inventory map of landslides and mapping of geo-environmental factor maps of the study area. The remote sensing image of high spatial resolution IRS P6 LISS-IV, dated 15th December 2005 (spatial resolution 5.8m) and IRS P6 LISS-III, dated 15 Oct, 2006 (spatial resolution 23.5m) were used to map the landslide distribution and field work was carried out in 2006. Survey of India topographic map on 1:50,000 scale formed the base layer of the satellite data. A total of 240 landslides of varying dimensions have been demarcated in the study area. The area of the landslides ranges from 158.2 mt². (0.001 hectare) to 101067 mt². (0.939 hectare). There are four main type of landslides categorized in the study area, such as rock fall, rock slides, debris slides and debris flow.

Thematic data layer preparation

In the present study nine landslides influencing factors were produced, and considered for the landslide susceptibility analyse. First of all, vectors format of all thematic layer were converted into raster format for further analysis in GIS. The raster data sets were divided into a grid with 10m × 10m cell size. Factors such as lithology, geomorphology, lineament density, land use/ land cover, soil type, slope aspect, slope degree, slope morphology and drainage density have been used to landslide susceptibility zonation.

Geomorphology

The geomorphological map (Fig. 2) has been prepared on the basis of dissection and

geomorphic feature interpretation using remote sensing data. It consists of seven geomorphic units which have been identified depending on the terrain characteristics i.e. elevation, character of the composed material and degree of dissection. The study area has three types of dissected hills; low dissected hills, moderately dissected hills and highly dissected denudo-structural hill. In the case of the relationship between landslide occurrence and geomorphology unit, landslide density values were higher in highly dissected denudo-structural hills and moderately dissected denudo-structural Hills.

Lithology

Lithology is one of the main factors influencing the type and the intensity of the landslides. The study area occupied by Higher Himalayan Crystallines is the most susceptible areas to landslide (Valdiya, 1980). The lithostratigraphic

units of the study area are Jaunsar Group, Berinag Formation, Damta Group, Dudhatoli Group and Barkot crystalline. The dominant lithological units constituting these lithostratigraphic units are phyllite, slate, quartzite, limestone, dolomite and shale, gneiss, granites, dolomite/marble, schist and unconsolidated sediments (Fig. 3). The dolomite and quartzite are dominant lithological unit in the study area.

Land use/cover

The landuse map of the study area was prepared by supervised classification scheme of satellite data of IRS- P6 LISS IV by using the Erdas Imagine software. There were eight landcover and landuse classes could be identified in the study area (Fig. 4). Landslides occurs in more in barren slopes and fallow land which are more prone to landslide activity. Scrub/Grassland have also shown high landslide distribution.

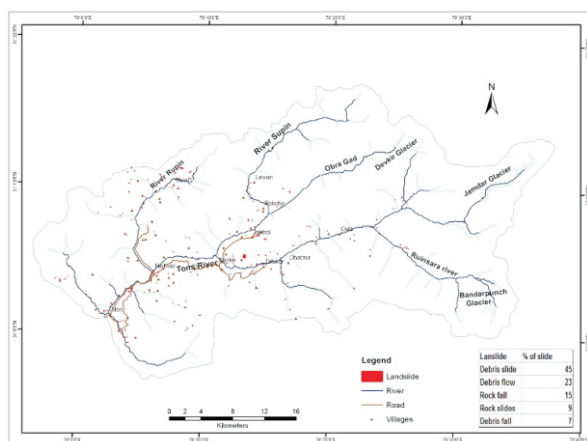


Fig. 1 Landslide Inventory

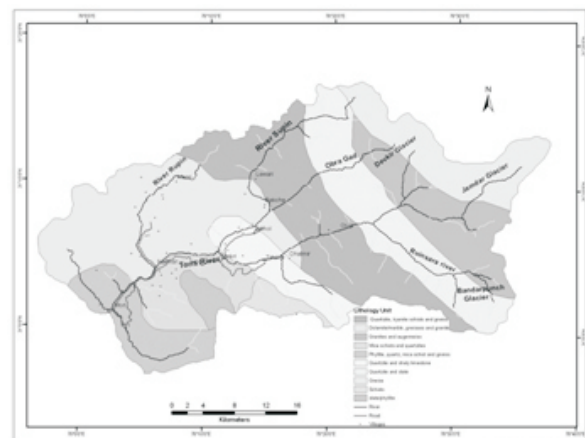


Fig. 3 Lithology

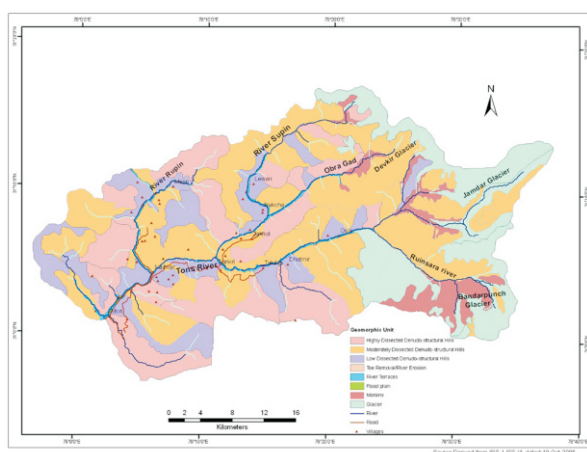


Fig. 2 Geomorphology

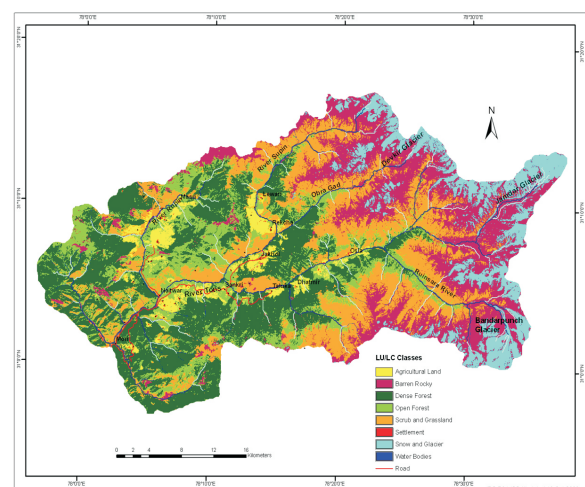


Fig. 4 Land Use/ Cover

321

north west (92.5°-337.5°). Landslides were most abundant on south-facing slopes. It is also indicated that the north east facing slope has highest percentage of area (15.4%) but having less landslide distribution.

Slope Morphology

Slope morphology is represented by the profile curvature values of the topography. Convex profile curvature indicates areas of erosion. Conversely, in areas of concave profile curvature, the flow rate decreases, the stream loses energy, and deposition occurs. Convex parts of surfaces, like ridges, are generally exposed and drain to other areas. Concave parts of surfaces, like channels, are generally more sheltered and accept drainage from other areas. A positive curvature indicates that the surface was upwardly convex. A negative curvature indicates that the surface was upwardly concave

and a value of zero indicates that the surface was flat (Lee and Min, 2001).

Lineament density

Lineaments are the structural features which describe the zone of weakness, fractures and faults along which landslide susceptibility is higher. All the geological lineaments have been mapped from the satellite data with the help of appropriate digital image processing techniques. These approaches include directional filters, principal component analysis, edge enhancement algorithms and line detection (Jensen, 1996; Philip et al. 2003). A lineament density map was generated for the purpose of a landslide susceptibility analyses based on the lineaments in the study area (Fig. 8). It has been observed that the presence of significant lineaments is one of the most important factors governing the stability of slopes in the study area.

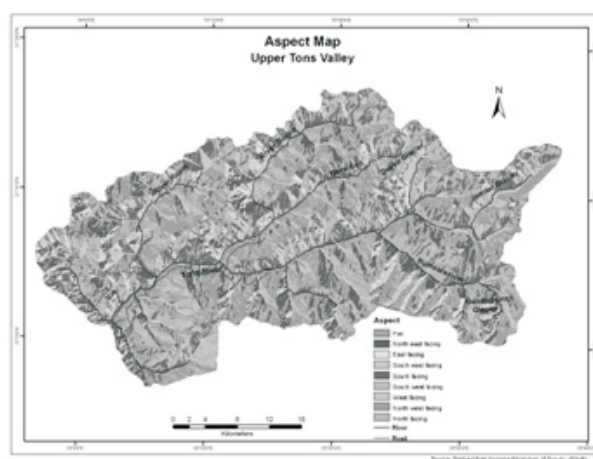


Fig. 7 Aspect of Slope



Fig. 8 Lineament

Fuzzy logic method

In the present study, the fuzzy set theory has been applied to determine the membership values for each category of the thematic layer using the cosine amplitude method (Ross, 1995; Ercanoglu and Gokceoglu, 2004; Kanungo et al., 2006). These membership values have been used to determine the relationship between the landslide occurrence and the categories responsible for such activity, which were then integrated in GIS by considering the weight of each thematic layer as one (or constant) to generate the Landslide hazard map. Cosine Amplitude Method is the ratio of total number of landslide pixels in the category to the square root of the multiplication of total number of pixels in that category and the total number of landslide pixels in the area. The membership value of a thematic layer is computed by the following equation with its values ranging from 0 to 1.

$$r_{ij} = \frac{\left[\sum_{k=1}^p x_{ik} \cdot x_{jk} \right]}{\sqrt{\left(\sum_{k=1}^p x_{ik}^2 \right) \left(\sum_{k=1}^p x_{jk}^2 \right)}}$$

Where,

r_{ij} is strength of the relationship,

i is thematic layer,

j is landslide distribution layer.

Values of r_{ij} close to 0 indicate dissimilarity, whereas values close to 1 indicate the similarity between the two datasets. The data layer represented by membership values is integrated by Fuzzy Gamma operation using fuzzy algebraic sum and fuzzy algebraic product.

Fuzzy algebraic product

The combined membership function is defined as:

$$combination = \prod_{i=1}^n r_{ij}$$

The individual maps are multiplied and this results is very small combined membership functions, due to the effect of multiplying several numbers less than 1.

Fuzzy Algebraic Sum

The combined membership function is defined as:

$$combination = \sum_{i=1}^n r_{ij}$$

The result is always larger (or equal to) the largest contributing membership value. The effect is therefore "increasing".

Gamma Operation = (Fuzzy Algebraic Sum) γ * (fuzzy algebraic product) $1-\gamma$

Gamma values assigned for each gamma combination operation play the most important role on the output of fuzzy membership functions (Bonham and Carter, 1994). For this study Set value of gamma is 0.95 has been chosen for giving an increasing possibility value to the hazard map. Finally, performing fuzzy gamma operation, the landslide susceptibility map was prepared using raster. The landslide susceptibility map (Fig. 9) has been first divided into five classes based on standard deviations (Ayalew et al., 2005) and the study area is categorized by very high, high, moderate, low and very low susceptibility classes.

Table 1: Distribution of landslide susceptibility zones

Landslide Susceptibility Zones	Area (%)	Area (Km ²)
Very Low Hazard	12.2	216.9
Low Hazard	28.8	355.3
Moderate Hazard	30.7	389.9
High Hazard	17.9	263.1
Very High Hazard	10.4	116.8

The landslide susceptibility map was cross tabulated with the landslide distribution map in GIS environment. The area covered by different landslide hazard zones and the area of landslides occupied per landslide susceptibility class are given in Table 1 and Table 2, respectively. The result shows that about 10.4% of the area is in very high hazard zone, which constitutes about 31.7 % of actual landslide. The high and very high susceptibility zones contained 71.7% of the active landslide of the study area. Approximately 16 % of the active landslide zones coincide with the moderate susceptibility class. The low hazard class contains less than 10% of the active landslide zones. Only 3% of the active landslide comes into the very low susceptibility class. The result validates that about 28% of the total area is occupied by high and very high hazard zones are able to predict 71.7% of the total landslide area.

Results and discussion

According to landslide susceptibility map, 10.4% and 17.9% of the total study area is found



Fig. 9 Landslide Susceptibility

Table 2

Landslide Susceptibility Zones	Landslide (%)
Very Low Hazard	3.0
Low Hazard	9.5
Moderate Hazard	15.8
High Hazard	30.0
Very High Hazard	41.7

to be very high and high hazard zone respectively (Table 1). Moderate and low hazard zones make up 30.7% and 28.8%, respectively. The very low susceptibility class has 12.2% of the total area. Landslide occurrence had a positive relationship with geomorphology and land use and land cover. Geomorphology is a natural factor to evaluate landslide probability, while land cover is a key environmental factor. Generally, landslides in the study area occurred in bare ground having low vegetation cover. However, some landslides have been reported in densely vegetated areas. Agricultural land was more prone to landslide because the topsoil was easily eroded. Thus, any disturbance in natural vegetation has eventually increased the occurrence of landslides events. The results show that the settlement and agricultural land cover types had the highest probability of landslides. Relation with slope and landslide hazard layer showed that landslides mostly occurred in areas where slopes vary between 10° and 40°. The research indicated that the proximity to faults/lineament and drainage are the major influences factors for slope instability.

The results show that the very high landslide susceptibility zone contains 41.7% of the existing landslides and covers only 10.4% of the study area. The high landslide susceptibility zone, which occupies 17% of the total area, contains 30% of the landslides. Very high and high landslide susceptibility zone occurred in the western and central part of the main Tons valley where most of the areas have covered by scrub, open forest and cultivable land. The region of active fault systems such as Main

Boundary thrust has come under very high susceptibility classes. It is also observed that many landslides are located along the road and nearby villages.

About 86% of the total existing landslide distribution in the study area were classified in moderate to very high landslide susceptibility zone. Thus, the landslide susceptibility zonation map using the fuzzy logic has been considered in providing a satisfactory result. Therefore it is imperative to work out the remedial and preventive measures which are needed to be designed to protect life and property from future landslides.

Conclusions

Landslides are natural prophone and pose a threat to affected communities and environment. In the Himalayan region, landslides occurred regularly in monsoon season. Precipitation as a triggering mechanism of landslides is strongly influenced by the landscape dynamic and lithology. This study focused on the Upper Tons valley in Garhwal Himamalya, the most geo dynamically and unstable zone in the Himalayan region. The areas occupied by Higher Himalayan crystallines are the most susceptible areas to landslide. In this study fuzzy logic method and landslide influencing factors were applied for landslide susceptibility zonation in GIS environment. It delineates the area of probable landslide for very high hazard and high hazard zone, which can be more meaningful for practical applications.

In Fig. 7, the landslide hazard susceptibility map based statistical approach has been found to be significant, about 72% of the total actual landslide area is found to be under very high and high hazard zone and it contains 28% of the study area. Thus, result obtained from landside susceptibility map of the study area appears to be quite validated and it has established a relation with the geo-environmental condition of Himalayan region.

Hazards zonation approach is quite useful way

for planning future developmental activities and implementation of disaster management programmes in hilly terrains. Thus, remote sensing techniques and GIS greatly aid in the investigations of landslides, on both local and regional scale. Most importantly, they greatly help in the prediction of future landslide occurrences, which is very important to those who reside in areas surrounded by unstable slopes.

References

1. Aleotti, P. and Chowdhury, R. (1999), "Landslide hazard assessment: summary review and new perspectives", **Bulletin of Engineering Geology and Environment**, 58, pp.21-44.
2. Ayalew, L., Yamagishi, H. (2000), "The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda-Yahiko Mountains, Central Japan", **Geomorphology**, 65, pp. 15-31.
3. Ayalew, L. et al. (2005), "Landslides in Sado Island of Japan: Part II. GIS-based susceptibility mapping with comparisons of results from two methods and verifications", **Engineering Geology**, 81, pp. 432-445.
4. Barredo, J. et al. (2000), "Comparing heuristic landslide hazard assessment techniques using GIS in the Tirajana basin, Gran Canaria Island, Spain", **Journal of Applied Geology**, 2(1), pp. 9-23
5. Brabb, E.E. (1984), "Innovative approaches to landslide hazard and risk mapping", *Proceedings, Fourth International Symposium on Landslides, Vol I*, Canadian Geotechnical Society, Toronto, Canada, pp. 307-324.
6. Cevik, E. and Topal, T. (2003), "GIS-based landslide susceptibility mapping for a problematic segment of the natural gas pipeline, Hendek (Turkey)", **Environmental Geology**, 44, pp. 949-962.
7. Dai, F.C., et al. (2001), "Assessment of landslide susceptibility, Garhwal Himalayas", **Environmental Geology**, 36, pp. 325-334.
8. Ercanoglu, M. and Gokceoglu, C. (2004), "Use of fuzzy relations to produce landslide susceptibility map of a landslide prone area (West Black Sea Region, Turkey)". **Engineering Geology**, 75 (3&4), pp. 229-250.
9. Greenway, D.R. (1987), "Vegetation and slope stability", In: Anderson, M.G., Richards, K.S. eds., **Slope Stability**. Wiley, New York, pp. 187-230.
10. Gupta, S.K. ed. (2005), *Inventory of Landslides of Northwest Himalaya: With Available Data From Eastern Himalaya*, Geological Survey of India, Kolkata, p. 209.
11. Guzzetti, F. et al. (1999), "Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, central Italy", **Geomorphology**, 31, pp. 181-216.
12. Jade, S. (2004), Estimates of plate velocity and crustal deformation in the Indian subcontinent using GPS geodesy. **Current Science**, 86, pp. 1443-1448.
13. Jensen, J.R. (1996), **Introductory Digital Image Processing: a Remote Sensing Perspective**, Prentice Hall, Upper Saddle River, NJ.
14. Kanungo, D.P. et. al. (2006), A comparative study of conventional, ANN black box, fuzzy and combined neural and fuzzy weighting procedures for landslide susceptibility zonation in Darjeeling Himalayas, **Engineering Geology**, 85, pp. 347-366.
15. Lee, S., and Min, K. (2001), Statistical analysis of landslide susceptibility at Yongin, Korea. **Environmental Geology**, 40, pp. 1095-1113.
16. NRSA (2001). Landslide hazard zonation mapping along the corridors of the pilgrimage routes in Uttaranchal Himalaya. Technical Document, NRSA, Department of Space, Govt. of India, Hyderabad.

17. Philip, G. et. al. (2003), Mapping the Nidar Ophiolites of the Himachal Himalaya (India). **International Journal of Applied Earth Observation and Geoinformation**, 2, pp.153-160.
18. Rao, D. P. (1997), A note on recent movement and origin of some piedmont deposits of Dehradun valley, **Photonirvachak: Journal of the Indian Society of Photogrammetry**, 5(1).
19. Rautela, P. and Pande, R.K. (2006), Non-monsoonal landslides in Uttaraanchal Himalaya (India), Disaster Prevention and Management, 15(3), pp. 448-460.
20. Ross, T.J. (1995), **Fuzzy Logic with Engineering Applications**, McGraw-Hill, New York.
21. Shroder Jr. J.F., Bishop M.P. 1998. Mass movement in the Himalaya: new insights and research directions, *Geomorphology*, 26, pp.13-35.
22. Styczen, M.E. and Morgan, R.P.C. (1995), Engineering properties of vegetation. In: Morgan, R.P.C., Rickson, R.J. eds, **Slope Stabilisation and Erosion Control: a Bioengineering Approach**. E&FN Spon, London, pp. 5-58.
23. Suzen, M.L., Doyuran, V. (2004), Data driven bivariate landslide susceptibility assessment using geographical information systems: a method and application to Asarsuyu catchment, Turkey, **Engineering Geology**, 71, pp. 303–321.
24. Valdiya, K.S. (1980), **Geology of Kumaun Lesser Himalaya**, Wadia Institute of Himalayan Geology, Dehradun, p. 291.
25. (1988), Tectonics and evolution of the central sector of the Himalaya. *Philos. Trans. R. Soc.*, 326, pp. 151–175.
26. Van Westen, C.J. (2000), The modelling of landslide hazards using GIS, **Survey in Geophysics**, 21, pp. 241–255.
27. Van Westen, C.J. (1997), Statistical landslide hazard analysis. ILWIS 2.1 for Windows Applications Guide, ITC Publication, Enschede, pp. 73–84.

(Mr. Radha Raman and Ms Ranjeet Kaur are Research Fellows and Dr. Milap Punia, is Associate Professor at Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi- 110067

Email: Milap.punia@gmail.com)

Geospatial Technologies for Developing Rain Water Harvesting Model to Solve Water Problem in Twin Villages of Neb Sarai and Maidan Garhi NCT of Delhi

Satya Raj

Abstract

Neb Sarai is a big village located in South Delhi. It has a population of 13,272 persons living in about 2896 households. Maidan Garhi is another village located near Neb Sarai and has a population of about 9383 persons living in around 1880 households. It is the combination of two villages, Maidan and Garhi. It got combined in early 1940's. The location of these villages is strategically important as it is near to Indira Gandhi National Open University (IGNOU) and is connected to Mehrauli-Badarpur Road only through the IGNOU Road which also serves as the only communication path to the University from the highway or Mehrauli-Badarpur Road. This road has a lot of unauthorised constructions on both sides making it narrower and all the more difficult during the rainy season. As the University is on a higher terrain and IGNOU Road slopes downwards towards the highway all the rainwater accumulates at the entrance of IGNOU road making the situation worse for daily commuters. Apart from this, the village also has acute water shortage for drinking and other domestic purposes. Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. It is of 3 types depending on the types of catchments. Catchments can be in the form of rooftops, roads or open spaces like forests. The main objective of this paper is to calculate the rainwater harvesting potential of Neb Sarai and its adjoining areas with the help of GIS techniques especially for roof catchments and how it could solve diverse problems related to water in these areas.

I. Introduction

Water is the lifeline of any society. Right from ancient times, civilisations have flourished in the vicinity of water bodies. Availability of drinking water and provision of sanitation facilities are the basic requirements for a healthy society. With the ever increasing population, water has become a scarce resource, especially in urban areas. It has become big challenge for the government and the policy makers to provide safe drinking water for the urban masses. This calls for sustainable and judicious use of water resources. Among the various technologies to augment freshwater resources, rainwater harvesting appears to be a promising, simple, economic and eco-friendly method of water conservation and an ideal solution to recharge groundwater. The rainwater collection system is known to have existed for over 4000 years. The technique is being revived today to give back to nature what we take from it. Rain is the first

form of water that we know in the hydrological cycle. Hence it is a primary source of water which is nearly pure. Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. The augmented resource can be harvested in times of need. Artificial recharge to ground water is a process by which the ground water reservoir is augmented at rate exceeding that under natural conditions of replenishment.

Rainwater harvesting is of three types depending on the types of catchments. Catchments can be in the form of rooftops, roads or open spaces like forests. Rainwater harvesting also depends on the area of catchments which directly accounts for the amount of rain collected. Thus bigger the area, larger is the amount of water collected. The quality of water that gets collected from the

catchment also depends on the location of the catchment. Roof catchment provides purer water compared to catchments situated in areas where they are open to contamination or are chemically treated. The water collected from such catchments must be treated before being used for any purpose.

There are numerous studies in this regard. Liaw and Tsai (2004) found out the optimum storage volume of rooftop rainwater harvesting systems for domestic use in Taiwan. Jasrotia and Singh (2006) have tried runoff and soil erosion modelling in a catchment area in the Himalayan region, using remote sensing and GIS techniques. Varma and Tiwari (1995) elaborated on the current status and prospects of rain water harvesting. Xu and ZhangQ (2007) did the modeling of surface runoff in Xitiaoxi catchment in China. Bhattacharya and Rane(2003) have developed a rainwater harvesting model for South and South-west Delhi. Kumar *et. al.* have discussed the potential of Rain Water Harvesting for water scarce regions of India. Centre for Science and Environment (CSE India), Delhi is a pioneer in campaigning about the benefits of rainwater harvesting techniques to the common public. The centre has identified 16 model projects in Delhi, from among those that have been designed by it. CSE has helped in the process of implementation of these and has been monitoring their impact on a regular basis. These Sixteen model projects have been constructed by enterprising citizens who sought CSE's help to setup rainwater harvesting structures in their colonies and institutions. The structures have a distinctive geographical and geological characteristic. They also feature different forms of rainwater harvesting-rooftop harvesting and surface water harvesting.

The Study Area

Neb Sarai is a big village located in South Delhi. It has a population of 13,272 persons living in about 2896 households. Maidan Garhi is another village located near Neb Sarai and has a population of about 9383 persons living in

around 1880 households. The location of this village is strategically important as it is near to Indira Gandhi National Open University (IGNOU) and is connected to Mehrauli-Badarpur Road only through the IGNOU Road which also serves as the only communication path to the University from the highway. The village and its adjoining areas suffer from acute shortage of water. Altogether the national capital territory, (NCT), of Delhi receives 611 mm of rainfall on an average annually and the number of rainy days is as low as 20-30. (A rainy day is specified as a day with more than or equal to 2.5 mm of rainfall). The geology of Delhi comprises Alwar-quartzites and alluvium whose vertical hydraulic conductivity or permeability, is high compared to the horizontal permeability. This makes the conditions favourable for artificial recharge. These rocks are also designated as Delhi Ridge. The ridge occupies the south central part of Delhi (although it extends up to western bank of Yamuna River as seen near Okhla in south and Wazirabad in north-east). The village of Neb Sarai, IGNOU and adjoining villages of Maidangarhi come under south central part of Delhi Ridge. The ridges rise 40 to 50 m above the plains. Thus the rainwater slopes down from higher areas in Maidangarhi and IGNOU and accumulates at the junction of the Mehrauli-Badarpur Road and IGNOU Road which is relatively at a lower altitude. Thus it becomes an utmost necessity to utilise rainwater harvesting techniques for solving these problems related to water in the region.

Objectives

The main objectives of this paper are to:

- 1) Demonstrate the enormous potential of rainwater harvesting techniques in solving the water problem in the study area.
- 2) Develop a geospatial database of the rainwater harvesting potential for the study area.
- 3) Assess the actual volume of water collected through rain water harvesting technologies with special emphasis to rooftop catchments.

II. Material and Methods

Satellite images were downloaded from Google Earth having the extent as follows:

Left Longitude download=77.1871948242188

Right Longitude
download=77.2270202636719

Top Latitude download=28.5230026527189

Bottom Latitude
download=28.4880052015033

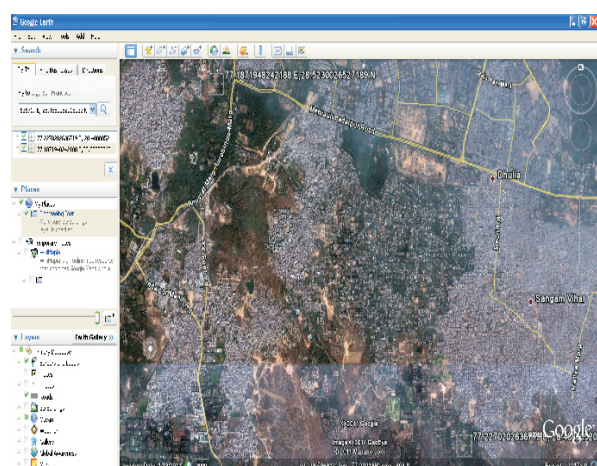


Fig. 1. Extent of Downloaded Images from Google Earth

It can be well understood with the help of above Fig. 1, where the red rectangle denotes the extent of downloaded images from Google Earth. The images were further combined and georeferenced in Arc GIS 9.2 version. Then the georeferenced image was opened in AutoCAD map 2000i and digitised. The rooftops were captured as polygons. Only proper rooftops were captured as polygons and the dilapidated and uneven rooftops were ignored. In Neb Sarai we also have houses in continuity without any spaces between them. So in such cases roof of houses were captured in the form of one big polygon consisting of all the connected houses. After digitization, the map was further cleaned and polygon topology was constructed in AutoCAD map 2000i itself. Then the polygon layer was exported to Arc GIS 9.2 and area of all the polygons were calculated thus giving the total rooftop area available in the villages. This information was useful in calculating the rooftop

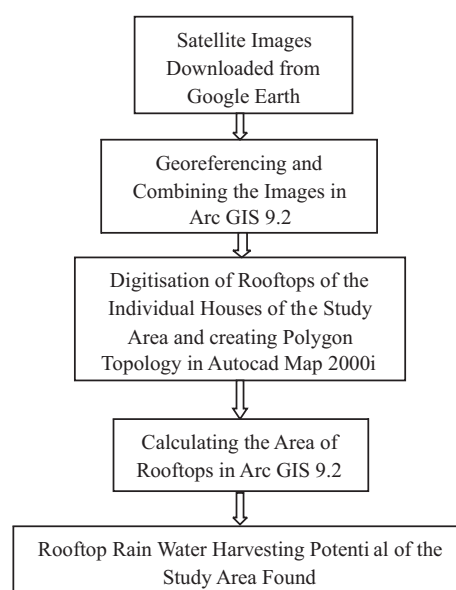


Fig. 2. Methodological steps

rainwater harvesting potential of the area.

For methodological steps in details see Fig.2,

III. Results and Discussion

Suitability of Rooftop Rainwater Harvesting System-

In a typical domestic roof top rainwater harvesting system, rainwater from the roof is collected in a storage vessel or tank for use during periods of scarcity. Such systems are usually designed to support the drinking and cooking needs of the family and comprise a roof, a storage tank and guttering to transport the water from the roof to the storage tank. In addition, a first flush system to divert the dirty water, which contains debris, collected on the roof during non-rainy periods and a filter unit to remove debris and contaminants before water enters the storage tank are also provided. Therefore, a typical Roof top Rainwater Harvesting System comprises following components:

- 1) Roof catchment-the roof of house is used as catchment for collecting rainwater
- 2) Drain pipes-they are made of PVC or stoneware and are of suitable size to drain off rooftop water to storm drains.

- 3) Gutters-these are channels fixed to the edges of roofs all around so that water is smoothly collected and transferred to storage tank. They can be rectangular or semicircular.
- 4) Down pipe-it is the pipe that collects rainwater from gutters to the storage tank.
- 5) First flush pipe-it is incorporated in rooftop rainwater harvesting systems to dispose of the first flush water which could contain debris, dust or polluted water which could have otherwise entered the storage tank, thus rendering it unfit for drinking and cooking purposes. After the first rain is washed out through this pipe, the valve is closed in order to enable relatively clean water to enter the storage tank.
- 6) Filter unit-it helps in removal of suspended or colloidal impurities present in rainwater by allowing it to pass through a filter media that is sand. The sand used for this purpose should be of uniform size and should be devoid of clay, sand, or any organic matter. Sometimes anthrafil (made of anthracite) is used in place of sand as a filter medium.
- 7) Storage tank-it is used to store water collected from rooftops and can be cylindrical, rectangular or square made up of brick, cement or concrete.
- 8) Collection sump- A small pit is normally dug in the ground beneath the tap of the storage tank and constructed in brick masonry to make a chamber, so that a vessel could be conveniently placed beneath the tap for collecting water from the storage tank.
- 9) Pump unit- It facilitates lifting of water from the storage tank to the user.

It can be well understood with the help of a following figure:

Altogether 797 rooftops were captured as polygons in Neb Sarai and adjoining areas of Maidan Garhi and Freedom Fighters Complex. The total area of rooftops was calculated to be 172892.921 sq. mt.. Apart from this 47 polygons

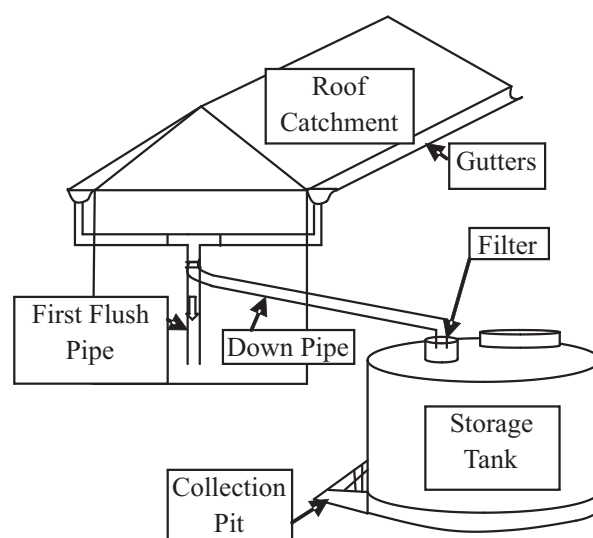


Figure.3: A Typical Rooftop Rainwater Harvesting System Rooftop Rainwater Harvesting Potential in Neb Sarai and Adjoining Areas

were captured from the residential areas at IGNOU complex having a total area of 14772.124 sq. mt. 40 polygons were captured as Academic and Administrative buildings at IGNOU Complex which had a total area of 5104.285 sq. mt. (Fig.4). Buildings with impervious roofs form the most effective catchment for rainwater harvesting. Collection of water from a single house may not be of much significance, but when there are hundreds of houses then the potential of harvesting rainwater from rooftops may be enormous. Thus grand total of digitised polygons in the area were found to be 884 having a total area of 192769.33 sq. mt.

The formula for calculating the amount of rain water collected in any area is as follows:

Rain Water Collected= Rainfall (mm) x Area of catchment (m²) x Runoff coefficient

Runoff coefficient is the factor which accounts for the fact that all the rainfall falling on a catchment cannot be collected. Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner, and more impervious roofing material contributes to better water quality and greater quantity. While loss is negligible for pitched metal roofs, concrete or asphalt roofs average less than 10 per cent loss, and built up tar and gravel roofs average a

maximum of 15 per cent loss. Table. 1 gives the run-off coefficient of different types of roofs. Since most of the rooftops in the study area were made of concrete or tiles, so run-off coefficient was taken to be 0.7. So the total rainwater that would be collected from rooftops was calculated to be 82.4 million liters.

Volume of Water Collected from Rooftops= 611 (mm) x 192769.33 (m²) x 0.7=82447442.441 litres

TABLE 1

Runoff Coefficients of Common Types of Roofs [15]

Roof Material	Runoff Coefficients
GI Sheet	0.9
Asbestos	0.8
Tiled	0.75
Concrete	0.7

The total population of Neb Sarai and its adjoining areas is 22,655 persons. If we consider the average drinking water needs of a person to be 6 litres per day. So the total drinking water needs of the total population of the study area per day would come to about 135930 litres (22,655*6). If we divide the total amount of water collected from rooftops (82447442.441 litres) by per day drinking needs of the population of Neb Sarai (135930 litres), we get 606.54 drinking water surplus days.

Even if we consider that only 60 percent of collected rooftop rainwater gets effectively harvested, then we get about 49.47 million litres of water available. Even that water would be sufficient for drinking purpose of the population for about 363 days or almost one year which is really commendable.

Conclusion

Thus it is obvious that harvesting water from roof tops appears to be the simplest and the most appropriate methods to meet immediate domestic needs of people of our study area due to the following reasons: Due to rapid growth of population and built-up area in Neb Sarai, the

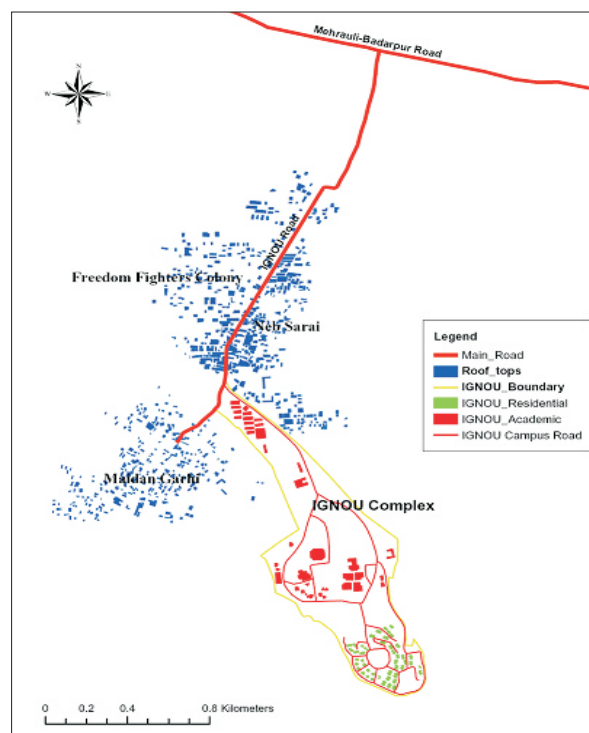


Fig.4: Digitised Rooftops of Neb Sarai, Maidangarhi and Adjoining Areas Along with IGNOU Complex

surface area for infiltration of rain water into the ground has decreased drastically, thereby, diminishing the recharge of ground water.

The figure shown above is taken from www.changematters.esri.com and just reflects the vegetation change in Haus Khas district of Delhi from 1975 to 2005. The highlighted

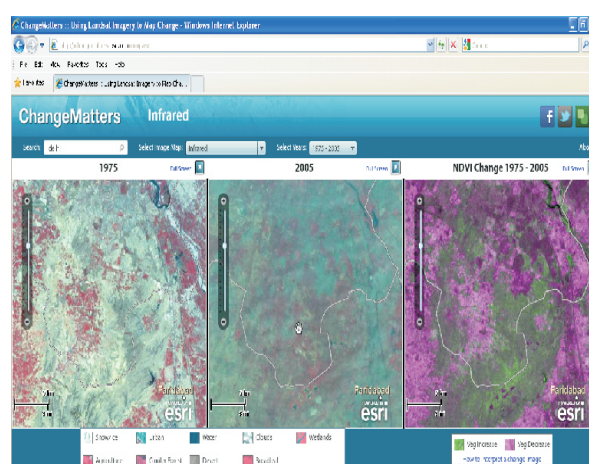


Fig.5 : NDVI Change in Haus Khas District of South Delhi (1975-2005)

(www.changematters.esri.com)

rectangular part reflects the IGNOU ridge and its adjoining areas (Fig. 5). It was very densely vegetated (red portion) in 1975 imagery. However in the 2005 imagery it can be seen that the same vegetated portions are reflected in cyan, which means urban built up area has come up in place of vegetation. The last image shows NDVI change in the rectangular area which shows greater portion of vegetation decrease (shown in pink). So rooftop rainwater harvesting could be the most suitable method to augment groundwater as there is paucity of the surface area for infiltration of rain.

Rainwater is bacteriologically safe, free from organic matter and is soft in nature. So it would also improve the quality of ground water through dilution.

The structures required for harvesting rooftop rainwater are simple, economic and eco-friendly.

Roof catchments are relatively cleaner and free from contamination compared to the ground level catchments.

Losses from roof catchments are much less when compared to other catchments and greater amount of water can be harvested from it.

It would help in reducing the frequent drainage congestion and flooding during heavy rains in the study region where there is paucity of open surfaces and surface runoff is quite high.

There is a water logging at the entrance of IGNOU Road from Mehrauli-Badarpur Road. This could be curtailed to a large extent if rooftop run-offs are utilised. The situation could be improved further if run-offs from roads and open spaces would have also been utilized. However that requires a detailed study of terrain and availability of lineaments in the study area.

Further researches can be taken up in this respect.

References

1. Rain Water Harvesting: An Ideal Solution, http://www.delhi.gov.in/wps/wcm/connect/DOIT_DJB/djb/home/rain+water+harvesting/harvesting2 (accessed September 21, 2011)
2. Rain Water Harvesting: Step by Step Process, <http://www.cseindia.org/node/1162> (accessed September 21, 2011)
3. Liaw, Chao-Hsien & Yao-Lung Tsai, Optimum Storage Volume of Rooftop Rain Water Harvesting Systems for Domestic Use, **Journal of the American Water Resources Association** (JAWRA), 40(4), pp.901-912, 2004
4. Jasrotia, A.S. and R. Singh (2006), Modeling runoff and soil erosion in a catchment area, using remote sensing and GIS, in the Himalaya region, India, **International Journal Geoscience Environmental Geology**, 51, pp. 29-37.
5. Varma, H.N. and K.N. Tiwari (2005) **Current status and prospects of rain water harvesting**, Indian National Committee on Hydrology (INCOH), National Institute of Hydrology Roorkee, India.
6. Xu, L. et. al. (2007) Modeling of surface runoff in Xitiaoxi catchment, China, **Water Resource Management** 21, pp.1313-1323.
7. Bhattacharya, A. and O. Rane (2003). Harvesting rainwater: catch water where it falls, **Centre for Civil Society**, pp. 422-439.
8. Kumar, M. D. et. al., Rainwater Harvesting in the Water-scarce Regions of India: Potential and Pitfalls.

(Dr. Satya Raj) is Assistant Professor in Geography, School of Sciences, IGNOU, Maidangarhi, New Delhi-110068

Email: satyaraj@ignou.ac.in)

Development and Conservation of Archaeological Sites Using Geomatics

Raj Gaurav, D. Gowtham Sai

Abstract

Application areas of Remote Sensing and GIS technology are growing over the period. In this paper an attempt has been made to examine the role of remote sensing and GIS technology in conservation and development of archaeological monuments, focusing on new techniques that can be useful for archaeology in conservation and development of existing and finding of new sites. Archaeological monuments are the glimpse of entire humanity, and the unique creature of humanity. Finding of innovative and better methods and techniques is the right way to save these from man-made and/or natural disaster.

Geomatics has a vital role to play in Archaeology. By using advance surveying, photogrammetry, remote sensing and GIS we can perform several tedious tasks in lab itself. Some of the major task, which can be performed include conservation, preservation and development of new sites. These have been discussed in details in the paper in context of the role geomatics play in this context.

Introduction

The "archaeological heritage" is that part of the material heritage in respect of which archaeological methods provide primary information. It comprises all vestiges of human existence and consists of places relating to all manifestations of human activity, abandoned structures, and remains of all kinds (including subterranean and underwater sites), together with all the portable cultural material associated with them. The protection of this heritage cannot be based upon the application of archaeological techniques alone. It requires a wider basis of professional and scientific knowledge and skills. Geomatics is one of them. It is the discipline of engineering for gathering, storing, processing, and delivering geographic information/spatially referenced information. It consists of Geodesy, Photogrammetry, Surveying & Mapping, Remote sensing and Cartography. There is a huge application of the Geomatics in archaeology and it can be used for conservation of archaeological heritage as well.

Conservation

Geomatics can be applied in following areas for conservation of archaeological heritage.

As per the Archaeological Survey of India Act, it is highly required to set a 200 metre boundary around an archaeological site. Land Survey is very useful in this area. One of the most important aspects of a land survey is the marking of corners and boundaries. Total-station and GPS is highly recommendable instrument for its capabilities to provide highly accurate coordinate for boundary demarcation. It prevents the site from local human made activities.

GPS (Global Positioning System) is a satellite based radio positioning system which provides high positioning accuracy on Global (WGS-84) datum. It is able to allocate every visible part of earth in terms of latitude & longitude. Hence it can help to allocate the heritage sites those are at inaccessible areas and direction & distance is unknown from the nearest township.

In archaeological fieldwork, GPS may also be used for mapping find-spots, earthworks and other archaeological features without the need of conventional techniques (i.e. Triangulation, off-set grids). GPS has proved to be a highly effective method of producing an accurate map

of the archaeology in digital format, allowing feature type to be layered in the same way as on terrain. The GPS technique utilises a rapid automated sampling procedure along regularly-spaced transects. In this manner, subtle changes in the landscape may be recorded. The results may be produced graphically as contour image or 3D Digital Terrain Model (DTM), an increasingly popular tool to assist in archaeological site analysis.

Aerial Photograph is very powerful source for landscape analysis & modelling. Aerial photograph is a unique source of detailed historic landscape information. It has the potential to provide baseline data by using photographs, texture information, and terrain data. Several elements of heterogeneity extracted using these approaches are common in landscape ecology, including patch compaction, shape, size, texture, and neighbouring characteristics (context). However, new elements of spatial element were also identified, representing tonal, textural, topographic, and positional variability over multiple spatial scales. We also explored differences in heterogeneity between landscape types of contrasting structure and ecology. Few quantitative differences were identified between landscapes, despite obvious ecological and biophysical differences. The results of this analysis provide an alternative description of baseline landscape.

It is always a tedious work to visit the site and examine each and every changes in the monuments. In this case airborne photographs or imagery can play a vital role. By processing these images every changes in pattern e.g. - shape, size, tone, texture etc. can be finding out. And inspection of the sites on a certain interval will keep a proper tracking of that site and hence it will increase life of the heritage sites.

The satellite imagery will allow us to survey the surrounding of the heritage inside the lab. For example nature of the site e.g.- hilly, plain etc. It will show the terrain changing pattern. And hence the effect of that change on the heritage

sites can be obtained. Further an appropriate action for prevention can take place.

Knowledge base is a collection of data representing related experiences; their results are related to their problems and solutions. It can be used for storing and searching archaeological sites and cultural heritage information. Archaeological, Social/Historical, Environmental information can be used as an input for a knowledge base and further analysis & processing of these information will give a model on which decision can be taken.

Detection of archaeological sites: Lidar & GPR

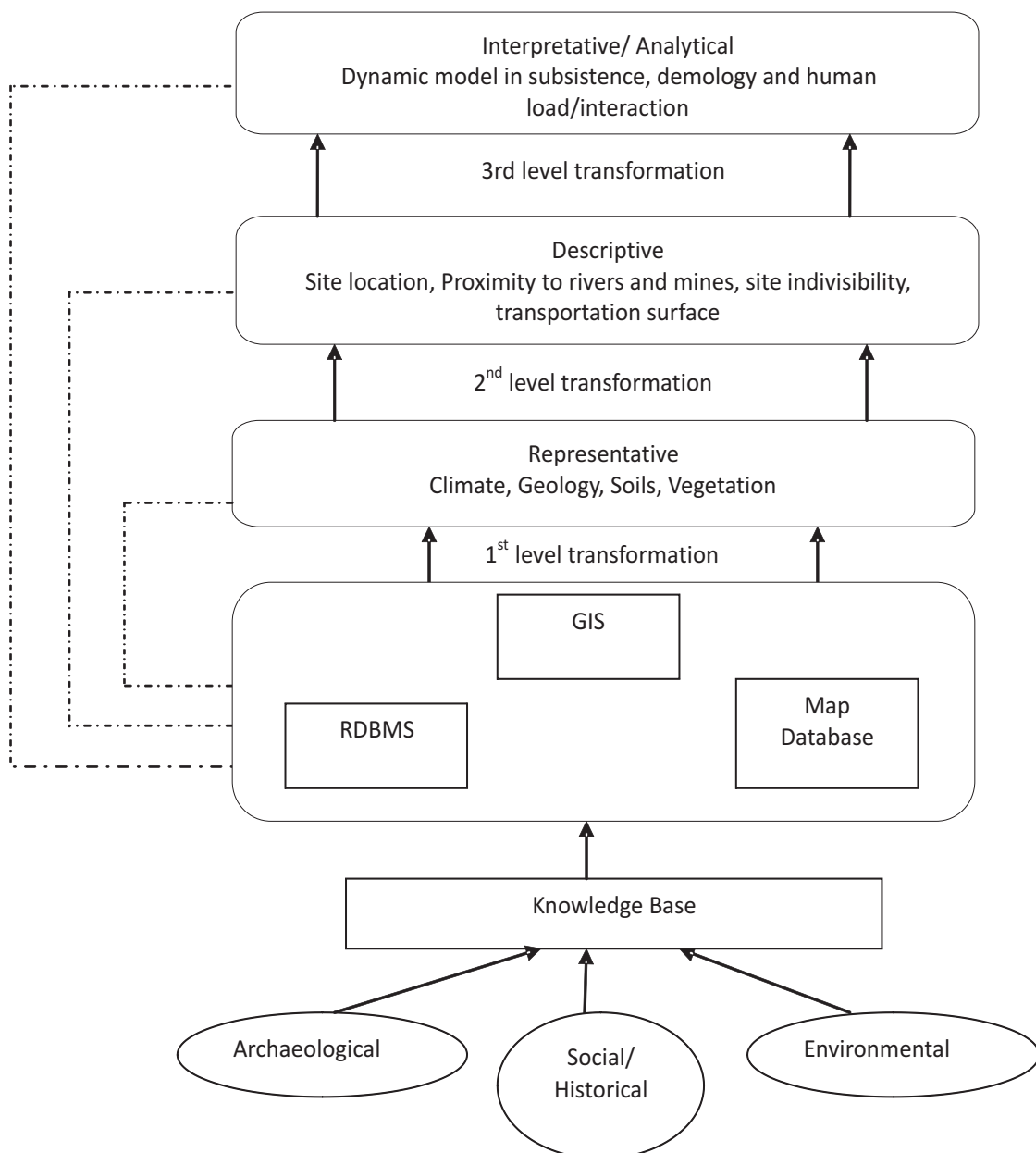
LIDAR is the acronym for light detection and ranging which describes the method of determining three-dimensional data points by the application of a laser. It is a active remote sensing method which is possible to detect the underground presence of structures such as walls, foundations, floors, roads, kilns, hearths, tombs, graves, pits cavities, mounds and filled ditches. The location of archaeological sites can be used as a guide for politicians, administrators and town planners in carrying out territorial projects, avoiding the risk to destroy important remains from the past.

LIDAR data is unique as it can produce point data and feature data from under the ground. In basic terms airborne LIDAR consists of an active laser beam being transmitted in pulses from a fixed wing or rotary aircraft and the returning reflection being measured the precise location of the sensor array is known due to a combination of Global Positioning System (GPS) and the Inertial Measurement Unit (IMU) in the aircraft. Using the principle of measuring distance through the time taken for a pulse of light to reach the target and return it is possible to record the location of points on the ground with a very high degree of accuracy, typically 100–150mm in both plan and height. The majority of laser sensors operate by sending out a laser beam that scans across the ground surface by means of a mirror or alternatively by a fiber optic scanner whatever is the means of

emitting the beam, the calculations that enable the creation of Digital Terrain Models (DTMs) etc are based on the returning (reflected) pulse to the sensor.

The core part of the building detection is based on a morphological filter for distinguishing between terrain and non-terrain segments. Aiming at a vector representation of buildings, the roof faces are obtained by further segmentation of the building segments into sub-segments. The 3D geometrical properties of each face are obtained based on plane fitting

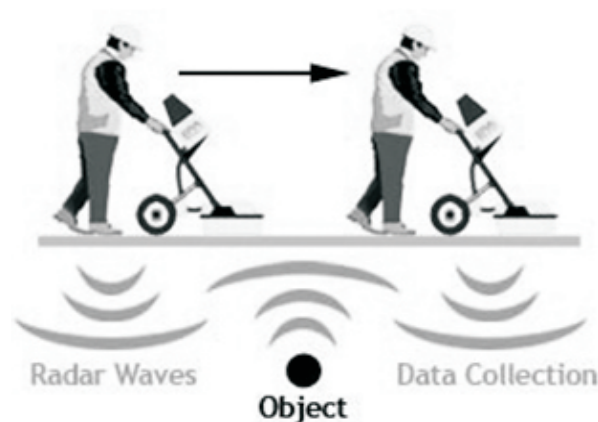
using the least squares technique. The reconstruction part of the procedure is based on the adjacency among the roof faces. Seresht and Azizi describe a strategy for automatic building extraction from aerial imagery and digital elevation models. The first step is a coarse recognition of building regions from DEM. Then some filters are applied on the selected regions based on their shape, size and content to enhance the detectability of the buildings. Further object recognition is then achieved based on image features that include points,



Spatial Decision Support System

edges, and lines. Selection of type and level of feature extraction is related to the desired accuracy and method of reconstruction. Also, straight lines are usually a basic characteristic of conventional buildings with regular edges. Buildings are then reconstructed from the listed features.

GPR (Ground Penetration Radar) can be used to detect and map subsurface archaeological artefacts, features, and patterning. The principle of GPR is simple; an electromagnetic pulse is sent into the ground and when the pulse hits an object it will cause reflections which are received by the receiver. The depth of the object is calculated by the time travelled by the electromagnetic pulse. Unlike traditional archaeological excavations GPR is unique in detecting some spatially small objects at relatively great depths and in its ability to distinguish the depth of anomaly sources. GPR can be used to study the structures without damaging it. Uniform sandy soils are ideal conditions for a GPR to work as a powerful tool.



LIDAR data in Archaeology

There are several uses of LIDAR data but it is determined by the nature of survey and equipment being used. The use of data can be sub classified into following types: Visualization, Interpretation, Mapping and Field use.

Visualization determines the usefulness of lidar data and how they are used in relation to archaeology is the question of how the data are viewed.

Interpretation refers to the quality of determining the concepts of features and points present in the data and matching them to the ground.

Mapping is the essential part of archaeological survey while using lidar; in order to adequately record the results of interpretation of lidar data it is necessary to map the features identified.

Field use refers to marking of obtained data on the field with the available data.

GIS and Archaeology

A common application of information technologies to cultural heritage is GIS, invented in urban planning for creating and managing spatial data and associated attributes. The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship.

The archaeological research of the study area consists of a heterogeneous data-set that contains three major categories of data types: vector data, raster data, and multimedia data

Vector data describe administrative boundaries, the coast line, urban limits, buildings (structures), soil data, coverage data and archaeological traces.

Raster data include aerial photos, satellite images, scanned historical maps, scanned topographic maps, scanned topographic diagrams and scanned geological maps.

Multimedia data traces, declared archaeological places and the places of unknown historical settlements, for their complete representation are followed with specific multimedia documentation (Video, Sound, Images).

Lidar and photogrammetric data into GIS

Filtering and processing of LIDAR data with subsequent use of GIS enabled to generate realistic 3D terrain models, a large scale visualization providing even a realistic view of the ancient landscapes. It is possible not only to detect buildings and their approximate outlines, but also to extract planar roof faces and, thus, to create models that correctly resemble the roof structure.

Photogrammetry is concerned with deriving measurements of the size, shape and position of the objects from the measurements made to photographs. Photogrammetry has been applied to the planning, recording, reconstructing, and revitalizing the world heritage sites. Digital object enhancement and 3D modelling techniques are also possible and usually give clear presentation of heritage sites. In brief, Photogrammetry offers a rapid and an accurate method of acquiring three-dimensional information regarding cultural monuments.

Conclusion

It is important join different items like archaeological studies and Information Technologies. This joining allows a better management of cultural heritage. Not only in knowing phase. In the way to preserve the archaeological heritage Geomatics represent useful instrument. It allows to monitory archaeological evidences and so to define recovery and preservation action.

(**Raj Gaurav** and **D. Gowtham Sai** are students in M.Tech(Geomatics), Indian Institute of Surveying & Mapping, Survey of India, Uppal, Hyderabad.

Email: rajgaurav.jsr@gmail.com)

High Resolution X-Band SAR Data for Snow Studies in Manali Area of Western Himalayas

P. K. Thakur, S.P. Aggarwal, Snehmani, P. K.Garg, R. D. Garg

Abstract

State-of-the-art high resolution active remote sensing imaging radar, TerraSAR-X, is having all-weather and all-time data acquisition capability. It is a promising tool for mapping snow and glaciers in mountainous region. The present study uses dual polarization (HH/VV) Synthetic Aperture Radar (SAR) data of TerraSAR-X (TSX), to estimate the snow physical properties (snow cover, snow wetness), in Manali sub-basin of Himachal Pradesh, India. A modified snow wetness inversion algorithm is implemented on space borne imaging radar-X-band 1 m high resolution spotlight mode SAR data of TerraSAR-X. This inversion algorithm has been successfully implemented in Matlab and Mathematica. Mask for forest, built area, layover and shadow has been considered in estimating snow parameters. Overall accuracy in terms of R2 value comes out 0.85 for snow wetness based on ground truth data for subset area of Manali sub-basin. Also, it is generally difficult to visually interpret the SAR images of lower resolution, but high resolution (1 m) of TSX give high quality SAR images for visual interpretation. Inferences were drawn by visual interpreting the SAR image along with texture analysis of SAR images, especially in identifying forests, glaciers, river, bridges and settlements.

Keywords- High resolution X-band, Image processing, Polarimetric SAR, Snow wetness, Inversion model, Manali.

Introduction

The Himalayas, one of the largest reservoirs of fresh water in form of glaciers and snow outside the Polar region, have nearly one-tenth mountain area covered with glaciers and another about one-third support the snow cover. There are 9575 glaciers, covering an area of about 38000 km² in the Indian part of the Himalaya. These snow cover and glaciers are the largest source of fresh water outside polar caps. The physical properties of snow such as snow wetness, showing the degree of liquid water content in snow pack, along with snow density and Snow Water Equivalent (SWE) are most important parameters for several water resources related studies such as snow melt runoff and snow avalanche modeling. The traditional methods to survey these parameters is not only very expensive but also difficult in rugged Himalayans Mountains. The optical remote sensing has been used effectively to map the snow cover area (Rott, and Mätzler, 1987; Dhanju, 1983; Dozier and Painter, 2004),

qualitative snow wetness (Gupta et. al, 2005) and snow grain size with hyperspectral data (Dozier and Painter, 2004). The mountain shadow, clouds and retrieval of physical properties of snow using optical data still remains a gap area and in these cases SAR offers a better alternative as discussed in next sections.

SAR for snow study

The potential of Synthetic Aperture Radar (SAR) imagery for monitoring snow cover was discussed as early as 1980's (Goodison et al, 1980; Shi and Dozier, 1995), recognizing its advantages of high spatial resolution, insensitivity to cloud, and operability at night. SAR can overcome the problem of cloud cover and mountain shadows (Nagler and Rott, 2004; Bartsch, et. al. 2007). However, the relation between the image and the actual snow map is difficult to distinguish with SAR than with optical sensors. Dry snow does not change the backscattering from ground significantly in comparison to bare ground. In addition SAR

images are hampered with the effects of speckle and geometric distortion due to layover, foreshortening and shadowing. Different scholars (Baghadi, 1997; Nagler and Rott, 2004; Koskinen, et. al., 2010) have demonstrated that wet snow may be mapped appropriately with SAR due to the reduction in backscattering. SAR data has demonstrated the capabilities of detecting the extent of wet snow cover in mountainous areas (Rott and Mätzler, 1987; Shi, et al. 1994). Recently (Luoju, 2009) improved SCA estimation approach to monitor wet SCA in boreal forest. Enhanced snow cover mapping accuracy has been obtained by using coherence in addition to SAR intensity information (Rees, 2006). In context of Indian Western Himalayas, limited research has been done using polarimetric SAR data to infer snow cover and its properties, except for the recent work reported in (Singh and Venkataraman, 2010; Thakur, et. al. 2009). None of these works have used high resolution polarimetric data as well as X-band SAR data, for inferring the snow properties. Finding the research gap, the present study is an attempt to address this gap area in the part of Western Himalayas using TerraSAR-x data.

Backscattering from Snow

According to wetness, depth, substrate, surface roughness and density, the backscattering coefficient of a snowpack is highly variable. Dry snow is highly transparent to radar, with penetration depth of about 4 m for X-band. The backscatter return from soil, slopes are dominated by surface scattering therefore radar back scattering from a snow surface largely depends upon the dielectric constant of the surface, its roughness properties, and the geometry of the scattering. Several mathematical models of surface scattering have been developed, some based on physical laws, some on empirical data fitting, and some on a combination of the two (Rees, 2006). Backscattering from a typical snow pack can be appropriately modeled by a sum of contributions from the snow surface the volume scattering from the snow layer and the

contribution from the ground. The total backscatter for the wet snow is mainly from surface and volume scattering only, whereas ground-surface scatter dominates in the dry snow pack.

The study area

The Beas glacier is main source of water for Beas river up to Manali. The snow cover mapping and physical parameter estimation using SAR data was done for Beas basin up to Manali with areas of 350.21 km² (Fig. 1). Climate of the study area is cool and dry and the year unfolds three broad seasons viz. cold season from October to February, hot season from March to June and rainy season from July to September (Thakur, et. al. 2009). Snowfall generally occurs in December and January at elevation above 2500 meters and the most of the region is cut off from the lower region as most of the mountain passes are closed. August is the wettest months throughout the region. The maximum rainfall occurs during July and August and minimum rainfall occurs during October–January. Temperatures range from a mean daily minimum of between -15 degree and 0 degree Celsius in January to maximums of 20 to 30 degree Celsius in June.

Data and software used

The Environment for Visualizing Image (ENVI) with SARSCAPE, Mathematica, MATLAB and C++ and ERDAS Imagine software were used for SAR processing, inversion modeling and image

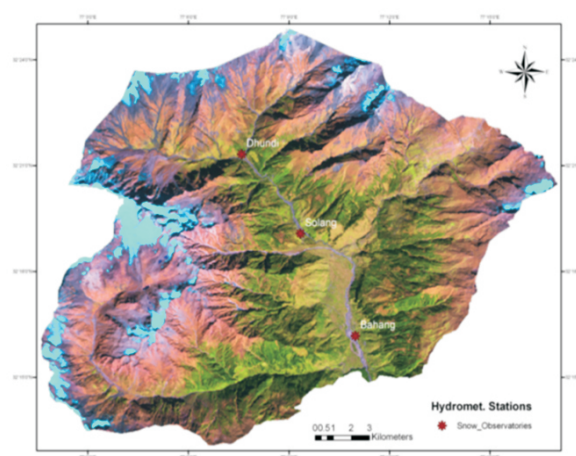


Fig. 1. Landsat colour composite of study area

processing, and Arc Map is used for map products generation. The ground field data of climate and snow parameters were collected during concurrent satellite overpass dates

Methodology

i) SAR Data Pre-processing- was done with SARSCAPE software for converting raw SAR images into geo-coded backscatter images. The dual polarization (HH/VV) image has been read first. Then image were than multi looked to create the power (*.pwr) images. In mountainous areas the topography significantly affects the geometry and radiometry in the SAR image, thus geocoding and calibration using Digital Elevation Models (DEM) are required in order to relate the data to signature data. These radiometric and geometric calibration of multi looked images were done using ASTER Global Digital Elevation Model (GDEM)). The local incidence and layover/shadow maps generated during calibration step are also used in radiometric calibration and masking of layover/shadow areas. All the backscatter images were re-sampled to nominal pixel size, with Universal Transverse Mercator (UTM), zone 43 N, datum World Geodetic System (WGS) 84 system.

During days of con-current satellites overpasses, extensive ground truth was done, to collect the data on snow density, snow wetness, snow depth, snow temperature and snow grain size at various locations in Manali sub-basin. The three permanent snow and hydro-meteorological stations at Bahang, Solang and Dhundi, of Snow and Avalanche Studies Establishment (SASE) Manali, were also used for snow sample data collection. The ground data was used for validation of SAR based inversion models for snow wetness.

ii) Algorithm for Snow Wetness- Snow Wetness (Shi and Dozier,1995) has used the SIR C/X SAR data of Mammoth Mountains, CA, USA for developing a first-order scattering model for snow wetness estimation. This model considered both surface and volume scattering components and it is applicable for incidence

angles from 25-70, surface roughness with Root Mean Square (RMS) height ≤ 7 mm and correlation length ≤ 25 cm. The present work attempts to estimate the snow wetness using dual polarization (HH & VV) data of TerraSAR-X in Manali and surrounding areas using(Shi and Dozier,1995) algorithm, with proper mask for forest, layover/shadow, glacier and snow/non snow pixels. The main inversion model for used for snow wetness is described in detail by(Shi and Dozier,1995). In the wetness model, the total backscatter σ_{pp} at a given polarization is assumed from surface (σ_{spp}) and volume (σ_{vpp}) scattering from near the top of snow pack. The t, s, v in subscript shows total, surface and volume scattering components and, pp in super script shows polarization state.

$$\sigma_t^{pp} \quad \sigma_s^{pp} \quad \sigma_v^{pp} \quad \dots(1)$$

The real part of cross product of VV and HH complex scattering elements, $\text{Re} [\sigma_t^{vv}\sigma_t^{hh*}]$ are also related to surface and volume backscattering coefficient by

$$\sigma_t^{vvhh} \quad \text{Re} \sigma_t^{vv}\sigma_t^{hh*} \quad \sigma_s^{vvhh} \quad \sigma_v^{vvhh} \quad \dots(2)$$

The first order volume scattering from inhomogeneous dielectric half space medium is given by:

$$\sigma_v^{pp} = 3/4 T_{pp}^2 \exp 2s^2 k_1 \cos \theta_i \quad k_2 \cos \theta_i^2 \quad \dots(3)$$

T_{pp} is the power transmission coefficients for a plane interface for vertical and horizontal polarization. s is the standard deviation of the random surface height and ω , is the volume-scattering albedo, which depends on snow density, wetness, particle size variations and shape (Tsang,1992). If snow particles are assumed to be spherical grains, with random orientation, ω becomes independent of polarization (Shi and Dozier,1995). Thus, the ratio for the first-order volume backscattering signals of VV and HH polarization can be represented as function of the local incidence angle and dielectric constant. $DT(\theta_i, \epsilon_s)$, $DTV(\theta_i, \epsilon_s)$, and $DTH(\theta_i, \epsilon_s)$ represents the volume backscattering ratios for VV and HH, $\text{Re}[\sigma_t^{vv}\sigma_t^{hh*}]$ to HH. Therefore equation 3 can further be approximated as below:

$$D_{T \quad i, s} = \frac{VV}{v} \frac{T_{vv}^2}{T_{hh}^2} \quad \text{....(3.1)}$$

$$D_{TH \quad i, s} = \frac{vvh}{v} \frac{\text{Re } T_{vvh}}{T_{hh}^2} \quad \text{....(3.2)}$$

$$D_{TV \quad i, s} = \frac{vvh}{v} \frac{\text{Re } T_{vvh}}{T_{vv}^2} \quad \text{....(3.3)}$$

In this case of surface backscattering, it is a function of the permittivity of wet snow, which mainly depends on snow density, wetness and the roughness of the air-snow interface. The surface backscattering is modeled using first order IEM model for σ_{vv} , σ_{hh} and σ_{vvh} at C-band for range of snow wetness (1% to 15 %), standard deviation of surface height (1-7 mm) surface correlation length (2.3-25 cm) and incidence angles (20° to 70°)(Shi and Dozier,1995). The final simplified surface scattering is given in equation 4.

$$\left| \frac{pp}{s} \right|^2 = \frac{S_R}{a_i b_i S_R} \quad \text{....(4)}$$

α_{vv} and α_{hh} are the same as in small perturbation model. $S_R = (ks)^2 W$ is the surface roughness parameter, where W is the Fourier transform of the power spectrum of the surface correlation function. a and b and coefficients that depends on the incidence angle and are derived from nonlinear regression analysis (Shi and Dozier,1995).. The final snow wetness inversion model is derived by simplifying the above equations(Shi and Dozier,1995)., and where only unknown is dielectric constant of wetsnow:

The coefficients avx , bvx and $avhx$ are derived from statistical analyses and depend only on

$$M_1 [a_{vx} \text{Re}[\alpha_{vv} \alpha_{hh}^*] \times (a_{vx} D_{RS} - D_{TS}) + b_{vx} M_2] \quad (5)$$

$$= M_2 \left[a_{vx} \text{Re}[\alpha_{vv} \alpha_{hh}^*] + \left(\frac{b_{vx} M_2}{(a_{vx} D_{RS} - D_{TS})} \right) - D_{TV} (|\alpha_{vv}|^2) \right]$$

$$M_1 = \sigma_t^{vvh} - D_{TV}(\theta_i, \epsilon_z) \times \sigma_t^{vv} \quad (5.1)$$

$$M_2 = \sigma_t^{vv} + \sigma_t^{hh} - D_{TV} \times \sigma_t^{vvh} \quad (5.2)$$

$$D_{TS} = D_{TV}(\theta_i, \epsilon_z) + \frac{D_{TH}(\theta_i, \epsilon_z)}{(D_{TV}(\theta_i, \epsilon_z) D_{TH}(\theta_i, \epsilon_z))} \quad (5.3)$$

incidence angle. These coefficients are calculated for TerraSAR-x images separately in MATLAB from the relation given in appendix of(Shi and Dozier,1995). work. The algorithm needs no information about the volume scattering albedo or the surface roughness, and with known local incidence angle, it calculates the snow-pack permittivity, which can be directly to snow wetness using following relations. The permittivity of wet snow is modeled as a dry snow value given by(Kendra, et.al. 1994)

$$D_{RS} = \frac{\left| \frac{vv}{v} \frac{T_{vv}^2}{T_{hh}^2} \right|^2}{\text{Re} \frac{vv}{v} \frac{T_{vv}^2}{T_{hh}^2}}$$

The coefficients avx , bvx and $avhx$ are derived from statistical analyses and depend only on incidence angle. These coefficients are calculated for TerraSAR-x images separately in MATLAB from the relation given in appendix of [16] work. The algorithm needs no information about the volume scattering albedo or the surface roughness, and with known local incidence angle, it calculates the snow-pack permittivity, which can be directly to snow wetness using following relations. The permittivity of wet snow is modeled as a dry snow value given by(Kendra, et.al. 1994)

$$\rho_{ds} = 1 - 1.7 \rho_{ds} + 0.7 \rho_{ds}^2 \quad \text{....(6.1)}$$

which depends on density alone plus an incremental increase, which depends on snow wetness alone. This incremental increase in the permittivity is given by (Hallikainen, et. al, 1986).

$$\epsilon_s = 0.02 m_v^{1.015} \frac{0.073 m_v^{1.31}}{1 + \frac{f_s}{f_w}} \quad \text{....(6.2)}$$

Where f_s is the frequency at which the permittivity is measured for X-band, $f_w = 9.07$ GHz is the relaxation frequency of water at 0 °C, and is expressed in percent. If the incremental increase is known, an accurate estimate of m_v may be obtained by inverting equation 6.2(Kendra, et. al. 1998). If density of snow is known, than the base contribution to ϵ_s

represented by the dry snow component ϵ_{ds} can be calculated. Thus the incremental increase is given by:

$$\frac{d}{ds} m_v = \frac{d}{ds} m_v, \quad \frac{d}{ds} \epsilon_{ds} \quad \dots (6.1)$$

Interpretation of SAR image

German TerraSAR-X mission provides high resolution X-band remote sensing SAR images. To fully utilize and understand the image content automated processing is applied. In particular, the interpretation of man-made structures that are typical of built-up or forest areas poses a number of challenges including parameterized image focusing during routine processing, careful despeckling, descriptor and feature extraction, and final classification including specific scattering. SAR includes Imaging radar, an active illumination system, in contrast to passive optical imaging systems that require the Sun's illumination. An antenna, mounted on an aircraft or spacecraft, transmits a radar signal in a side-looking direction towards the earth's surface. The reflected signal, known as the echo, is backscattered from the surface and received a fraction of a second later at the same antenna. Interpreting a radar image is not a straightforward task. It very often requires some familiarity with the ground conditions of the areas imaged. As a useful rule of thumb, the higher the backscattered intensity, the rougher is the surface being imaged. The SAR image objects are identified on the basis of their Tone- defined as the average intensity of the backscattered signal, Shape- defined as spatial form with respect to a relative constant contour or periphery, or more simply the object's outline, Structure- defined as the spatial arrangement of features throughout a region with recurring configuration, and Size- it is may be used as a qualitative recognition element on radar imagery. Also three important terms are associated with SAR image- Shadow- related to the oblique incidence angle of microwave radiation emitted by the radar system, Layover- is a extreme case where responses from, say, a mountain's peak are positioned before surrounding locations, and Foreshortening-

occurs when the radar beam reaches the base of a tall feature tilted towards the radar (e.g. a mountain) before it reaches the top. In SAR image flat surfaces such as paved roads, runways or calm water normally appear as dark areas in a radar image since most of the incident radar pulses are specularly reflected away. Trees and other vegetations are usually moderately rough on the wavelength scale. Hence, they appear as moderately bright features in the image. Very bright targets may appear in the image due to the corner-reflection or double-bounce effect where the radar pulse bounces off the horizontal ground towards the target, and then reflected from one vertical surface of the target back to the sensor. The figure 2, describe each distinguish feature like forest, bridge, snow area with shadow, layover and foreshortening. Image F represents full image of Manali region. Image A shows the bridge, B represents snow area, C represents shadow, D to forest and E to layover respectively.

Results and discussions

The **snow wetness map** is shown in Fig. 3.2 for image of 28 March 2011. The wetness and air temperatures in spring to winter period are propositional to each other. The TerraSAR-X dual pol of 28 March 2011 was used for snow wetness dual polarization mode to estimate σ_{tvvh} as $\text{Re}[VVHH^*]$ and as $\alpha^* \text{SQRT}(\sigma_{thh} \sigma_{tvv})$ respectively. Based on the ground truth in Manali, air temperature, snow wetness and density was above normal in areas near Solang and Manali, giving high wetness in these areas.

The visual interpretation of SAR image helps in estimating the snow cover area for region. The shadow, layover and forest area has been masked out while evaluating the results. Each distinguish feature like forest, bridge, snow area with shadow, layover and foreshortening has been identified successfully in SAR image (Fig. 2). The wetness maps derived from SAR image also matches with the ground data.

The estimated snow wetness matched well with the expected wetness on different aspect areas

of watershed. The south aspect has maximum wet areas and northern aspect has least wet areas. The overall accuracy with respect to ground based wetness at Dhundi and Solang area is ~85%. Since, there are no ground observations in areas above 3000m, so model couldn't be validated in those points. As air temperature of March is more than that of January in this area, the overall wetness in image is found to be more than that of January month.

Conclusion

The inversion model is applied on radar backscattering coefficient (Fig. 3a) for

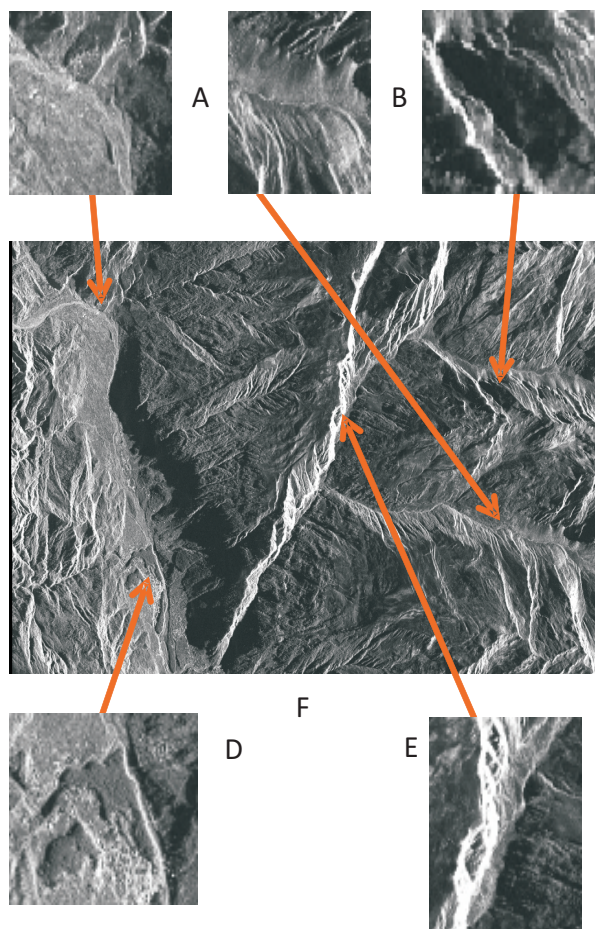


Fig. 2. TerraSAR-X image for Manali region with zoom images of few selected areas

estimation of snow permittivity and snow wetness in Himalayan region. The complex equation has been solved for each incidence angle by developing code(s) in MATLAB, Mathematica and C++. The model has been run

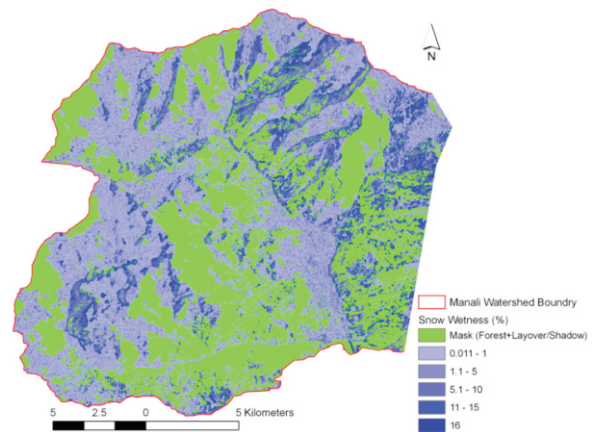


Fig. 3a TSX HH backscatter image (28 Mar 11).

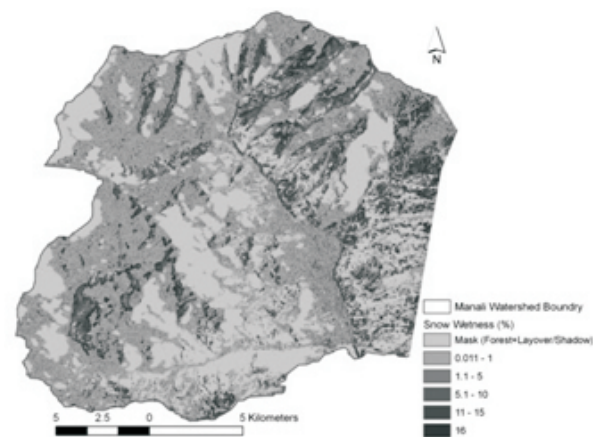


Fig. 3b. Snow wetness of study area, 28 Mar. 11

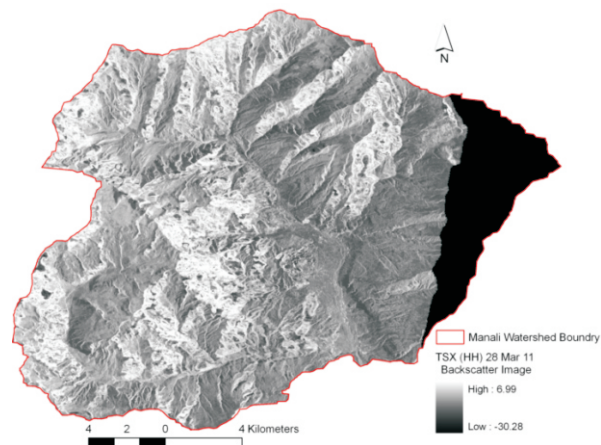


Fig. 3b. Snow wetness of study area, 28 Mar. 11

on incidence angle of range 250-700. The estimated snow permittivity values obtained by using inversion model varies from 1 to 81 and snow wetness from 0 to >15 %. The map's area is divided into different classes, such as no snow,

dry snow and different values of snow wetness in percentage (see in Fig. 3b). The data is validated with ground data which shows an average error of 5%. Overall accuracy in terms of R2 value comes out to be 85 for snow wetness, based on ground truth data for subset area of Manali sub-basin of Beas river up to Manali. The study can be extended for snowmelt runoff modelling and snow avalanche risk assessment. For accurate mapping of snow cover and wetness, the effect of vegetation cover on snow may be included.

Acknowledgment

The authors acknowledge with thanks the encouragement and valuable suggestions received from the Directors IIRS, Dehradun and SASE, Chandigarh and the help they received from the field staff and scientists at SASE field stations in Manali for data collections. Project is funded by the ISRO under TDP and RISAT-UP project on snow and glaciers studies with optical and microwave remote sensing; and data by DLR under TerraSAR-X science service project (0445).

References

1. Baghadi, N. (1997), Capability of multitemporal ERS-1 SAR Data for Wet-snow mapping. **Remote Sensing of Environment**, 60, 174-186.
2. Bartsch, A., *et. al.* (2007), Monitoring of spring snowmelt with Envisat ASAR WS in the Eastern Alps by combination of ascending and descending orbits. In: **Proc. Envisat Symposium**, Montreux, Switzerland, ESA SP-636.
3. Dhanju, M. S. (1983), Studies of Himalayan snow cover area from satellites. Hydrological Applications of Remote Sensing and Remote Data Transmission, **Proceedings of the Hamburg Symposium, IAHS** (145), 401-409.
4. Dozier, J. and Painter H.T. (2004), Multispectral and hyperspectral remote sensing of alpine snow properties, **Annu. Rev. Earth Planet. Sci.**, 32, 465-94.
5. Goodison, B.E., *et. al.* (1980), Application of synthetic aperture radar data to snow cover monitoring. In: **Sixth Canadian Symposium on Remote Sensing**, at Halifax, Nova Scotia.
6. Gupta, R. P., *et. al.* (2005), Mapping dry/wet snow cover in the Indian Himalayas using IRS multi spectral imagery. **Remote Sensing of Environment**, 97, 458-469.
7. Hallikainen, M. *et. al.* (1986), "Dielectric properties of snow in the 3 to 37 GHz range," **IEEE Trans. Antennas Propagat.**, AP-34, pp.1329-1339.
8. Kendra, J. R. *et. al.* (1998), Radar Measurements of Snow: Experiment and Analysis, **IEEE Transactions on Geoscience and Remote Sensing**, 36(3), 864-879.
9. Kendra, J. R., Ulaby, F. T., and Sarabandi, K., 1994. Snow probe for in situ determination of wetness and density, **IEEE Trans. Geosci. Remote Sensing**, 32, 1152-1159.
10. Koskinen J, *et. al.* (2010), Monitoring of Snow Cover Properties During the Spring Melting Period in Forested Areas. **IEEE Transactions on Geosciences and Remote Sensing**, 48(1), 50-58.
11. Luoju, K. P. (2009), Enhanced sar-based snow-covered area estimation method for boreal forest zone. **IEEE Transactions on Geoscience and Remote Sensing**, 47(3), 403-407.
12. Nagler, T., Rott, H. (2004). Snow Classification Algorithm for Envisat ASAR. In: **Proc. of the 2004 Envisat & ERS Symposium**, Salzburg, Austria, ESA SP-572.
13. Rango, A. and Salomonson, V.V., 1975. Employment of satellite snow cover observations for improving seasonal runoff estimates. In **Operational Applications of Satellite Snow Cover Observations**. NASA-SP-391, 157-174.
14. Rees, W.G. (2006) **Remote Sensing of Snow and Ice**. Taylor and Francis/CRC Press Inc.

15. Rott, H., and Mätzler, C. (1987). Possibilities and limitations of synthetic aperture radar for snow and glacier surveying. **Annals of Glaciology**, 9:195–199.
16. Shi, J. and Dozier, J. (1995). Inferring snow wetness using C-band data from SIR-C's polarimetric synthetic aperture radar. **IEEE Transactions on Geoscience and Remote Sensing**, 33, 905–914.
17. Shi, J. Dozier, J. and Rott, H. (1994), Snow mapping in alpine regions with synthetic aperture radar. **IEEE Transactions on Geoscience and Remote Sensing**, 32, 152–158.
18. Singh, G., Venkataraman, G. (2010), Snow permittivity retrieval inversion algorithm for estimating snow wetness. **Geocarto International**, 25(3), 187-212.
19. Tsang L. (1992), Dense media radiative transfer theory for dense discrete random media with particles of multiple sizes and permittivities. **Prog. Electromag. Res. Symp.**, 6, 181-225.
20. Thakur, P. K., *et. al.* (2009), Snow cover mapping using multi-sensor SAR data for parts of western Himalayas. In: **Int Symp on Snow and Avalanches (ISSA)**, at SASE, Manali, India.

(**S.P. Aggarwal** and **Praveen K Thakur** is working with Water Resources Division, IIRS, Dehradun,

E-mail: praveen@iirs.gov.in, spa@iirs.gov.in,

Snehmani is working as Dy. Director, SASE, Him Parisar, Chandigarh.

E-mail: snehmani@sase.drdo.in

P. K. Garg, and **R. D. Garg** are working with Department of Civil Engineering, Indian Institute of Technology (IIT), Roorkee.

E-mail: gargpfce@iitr.ernet.in and garg_fce@iitr.ernet.in)

Glacier Monitoring and Debris Cover Mapping Using Remote Sensing and GIS Techniques with Reference to Gangotri Glacier

Snehmani, Satwant Kaur, A Ganju, M R Bhutiya, A K Nigam

Abstracts

Accepting the challenge of monitoring debris-covered glaciers and their features with coarse-resolution satellite imageries providing similar spectral signature of surrounding moraines, the present paper attempted to monitor Gangotri Glacier and its snout's fluctuation during 1935- 2006 using GIS and remote sensing technology. For the purpose, ortho-rectified, cloud-free remotely sensed images acquired from different sensors at different periods have been used. It has been found that the glacier has reduced in size by 1.5 km in a period of 71 years. Notably, the pace of decline accelerated over the period: 5.0 meters during 1935-1962 to 27 meters during 1991-2001 annually. The altitude of the snout has shifted to about 140 m upwards during 1935-2006.

The paper applied automated mapping method. A mask for clean-ice and debris-covered glacier ice has been computed using band ratioing (3/5) method by generating the binary imageries using a suitable threshold and converted in vector polygon map. The final outline of debris-covered glacier ice is generated using GIS techniques. The validation of the results has been carried out with Landsat thermal data. The thermal mask, generated from the single sixth thermal band of Landsat image using a suitable threshold, has shown the potentials of mapping debris-covered glacier ice using thermal and band ratio imageries.

Key words: Glacier mapping, snout monitoring, climate change analysis, digital image processing

Introduction

Glaciers are sensitive to climate, hence indicators of climate (Oerlemans, 1994); studied to monitor environmental and climate changes. In the case of high mountain regions, remote sensing techniques are often considered the only way to analyze and monitor glaciers (Bishop et al., 2001; Bolch and Kamp, 2006). The terminus of Gangotri Glacier has been retreating since 1780, and several studies shed light on glacier fluctuations (see Naithani et al. 2001); Ahmad and Hasnain 2004; Bahuguna et al. 2007; Kumar et al. 2008; and Bhambri and Chaujar 2009). It has been observed that debris-covered ice has increased due to glacier retreat over the time in Himalayas (e.g. Bolch et al. 2008), Alps (Bolch and Kamp 2006) and Caucasus, Russia (Stokes et al. 2007). The debris-covered (also called "debris-mantled" or "moraine-covered") glaciers have been recognized as an efficient

sediment transport agent in cold mountain environment (Kirkbride 1995). The sediment transported by the glacier on its surface, within glacier ice, and below the glacier ice is known as supraglacial, englacial and subglacial, respectively (Small, 1987). One way to distinguish between a debris-covered glacier and surrounding bedrock is the use of surface temperatures as the supraglacial debris is often cooler due to the underlying ice. Use of thermal signature from Landsat imagery for glacier mapping (see Ranzi et al., 2004). A few studies have used for Himalayan debris-covered glaciers. The present paper attempts to estimate snout's fluctuation of debris-covered Gangotri Glacier during 1935-2006 using topographical maps and multi-temporal and multi-spectral satellite data. The automated mapping method has been pressed into service using Landsat ETM+ data.

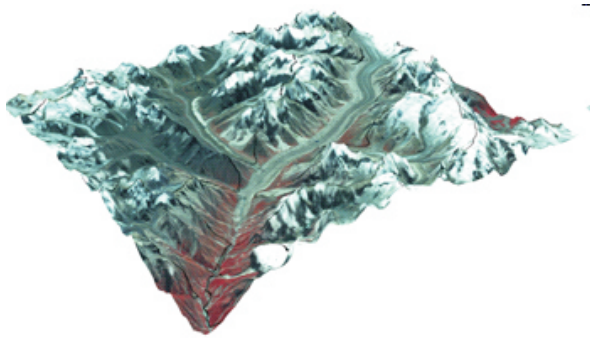


Fig. 1 Landsat 4-3-2 band image (2 Sep'2001) draped on the SOI DEM

Study area

Gangotri Glacier in Garhwal Himalayas, having length of 30.4 km and 130 km² area and selected for the present study, covers the uppermost

section of the Bhagirathi valley. It originates from the Chaukhamba group of peaks (~7058m) and flows in northwesterly direction up to Gaumukh (Fig. 1). Fieldwork suggests that Gangotri and Raktavan Glaciers have a large cave at their snout. The Glacier system is a cluster of several large and small glaciers, including Swachhand, Maiandi, Kirti and Ghanohim). Raktavan Glacier is an inactive tributary glacier, detached from the main glacier and directly contributes water to the Bhagirathi River. Visual interpretation of the various satellite images indicates that the surface of Gangotri glacier is covered by thick debris from its terminus to about 19 km upstream where Swachhand Glacier, a tributary glacier, joins Gangotri Glacier.

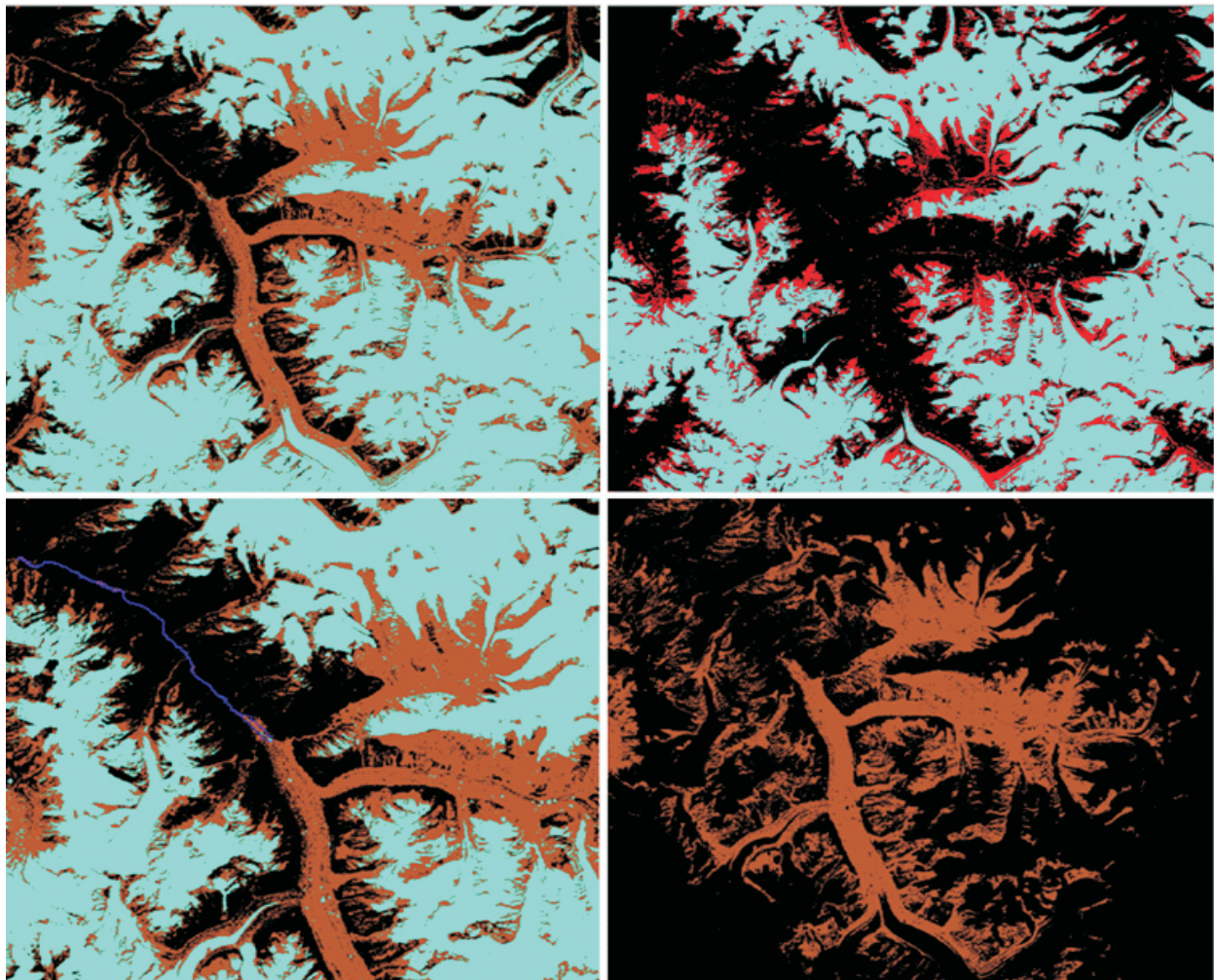


Fig. 2: Gangotri and its tributary glaciers. (A) TM 3/5 ratio image differentiating snow (Cyan); (B) TM 4/5 ratio image; (C) vector layer of the River (Blue) overlaid on the TM 3/5 image; (D) extracted Debris cover (brown) from snow & water body

Methodology

The present study uses multi-temporal and multi-spectral satellite imageries, such as Landsat MSS, TM, ETM+ and Cartosat-1 for glacier mapping (Table 1). Landsat MSS, TM and ETM+ scene downloaded from USGS website (<http://edcsns17.cr.usgs.gov/NewEarthExplorer/>), Cartosat 1 imagery was obtained from National Remote Sensing Centre (NRSC), Hyderabad.

Mapping of debris-covered glaciers

Glacier mapping from multispectral images: Ratio images were calculated based on band

TM3/TM5 for glacier mapping. Binary imageries were generated using threshold value between 1 and 2 for the debris-covered glacier ice and more than the two for the clean glacier ice (Fig. 2). Both binary imageries were converted in vector polygon maps to observe that water bodies and shadow areas were misclassified as the debris-covered glacier area. All these misclassification were eliminated using GIS editing tools. The course of Bhagirathi river has been delineated

Table 1
Snout monitoring since 1935

Year	Length of the Glacier (m)
1935	31907.2
1962	31776.3
1972	31424.1
1976	31043.8
1990	30852.8
1999	30612.5
2001	30558.3
2006	30475.9

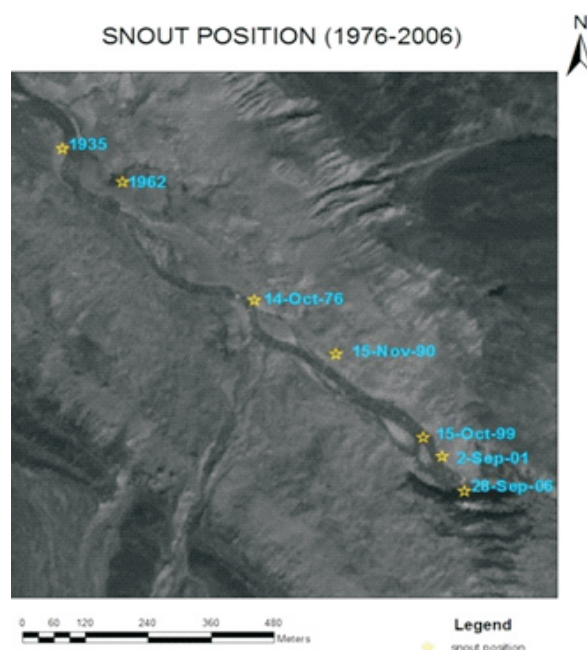


Fig 3: Shift in the Snout position of Gangotri glacier since 1935

Table 2
Length of Gangotri Glacier

Year	Satellite/ Sensor/ Map	Spatial Resolution (m)/Scale	Snout position				
			Latitude	Longitude	Altitude from SOI Toposheet (m)	Altitude from ASTER DEM (m)	Retreat (m) & Retreat Rate (m/y)
1935	SOI Toposheet	1:50,000	30° 55' 58.89" N	79° 04' 17.99" E	3965	3902	--/--
1962	SOI Toposheet	1:50,000	30° 55' 58.42"N	79° 04' 22.05" E	3994	3912	131.19/4.85
14 Oct 1976	Landsat/MSS	Resampled to 60	30° 55' 48.86"N	79° 04' 31.68" E	4050	3925	351.88/25.13
15 Nov 1990	Landsat/TM	30	30° 55' 45.35"N	79° 04' 37.61" E	4067	3935	191.02/13.64
15 Oct 1999	Landsat / ETM+	30	30° 55' 39.80"N	79° 04' 43.99" E	4090	3968	240.24/26.69
2 Sep 2001	Landsat / ETM+	30	30° 55' 38.53"N	79° 04' 45.40" E	4096	3977	54.26/27.13
28 Sep 2006	Cartosat 1	2.5	30° 55' 36.21"N	79° 04' 47.02" E	4105	4015	82.31/16.46

with the help of region growing properties, the automated way to convert the particular raster pixels to vector, and the vector polyline of the river was created. Landsat ETM+ thermal band has been used for the evaluation of the glacier delineation.

Results

Gangotri glacier retreated about 1.5 km during 1935-2006. The rate of retreat has not been same throughout the period. The retreat rate accelerated in the late 90's (Table 1). The results of debris-covered glacier mapping reveal that band ratio thresholding is potential in debris-covered glacier ice mapping. Misclassification of water bodies and shadow areas, however, place constraints.

Validation of the results

The results of glacier mapping by band ratio were correlated with the temperature image generated from the Landsat ETM+ thermal band. The DN was converted into radiance and the spectral radiance to temperature using following equations. Results derived from temperature map show 5 to 13°C group covered the debris-covered glacier ice (Fig 4).

DN to Spectral Radiance Conversion

$$\text{Spectral Radiance} = 1.238 + (15.6 - 1.238) * \text{BAND} \frac{IV}{255}$$

Spectral Radiance to Temperature conversion

$$\text{Temperature} = 1260.56 / \log (607.76 / \text{SR Image} + 1)$$

Kelvin to Celsius conversion

$$\text{Temp in Kelvin} = \text{Temperature image} - 273$$

Conclusions

The results show that the Gangotri glacier has been retreating during the study period (1935-2001), but at a varying rate. The rate of retreat has been 5 m/y during 1935-1962, accelerated to 27 m/y during 1991-2001, and recorded decline thereafter. The altitude of the snout was shifted to about 140 m upwards during 1935-2006. The high resolution CARTOSAT 1 image greatly helped in interpretation of polygenetic

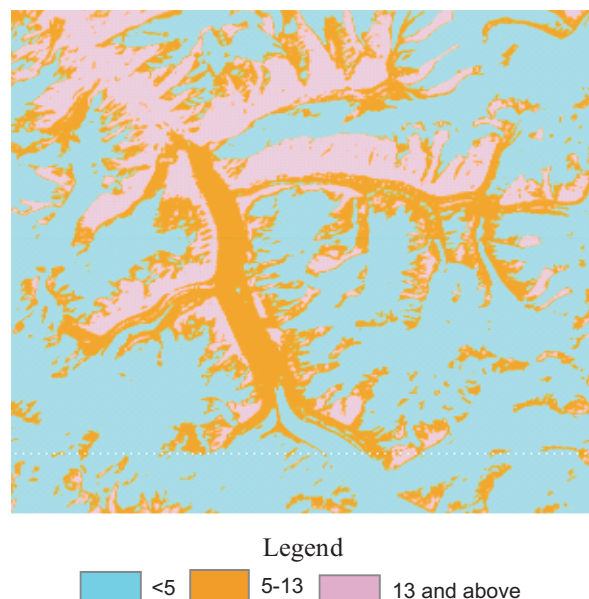


Fig4: Temperature Map generated from LANDSAT-6 Band

complex mountainous landscape. The water bodies have appeared as hindrance for the automated mapping of debris-covered glaciers of the case of the Garhwal Himalayas. The shadow areas strongly affect the single thermal band thresholding, hamper the automatic mapping of debris-covered areas. Thresholding procedure is scene-dependant and subjective in nature, depending on the interpreter.

Acknowledgements

Authors are thankful to DST for funding under project No ESS/91/03/2006, dated Nov 14, 2007 and to Dr. Rakesh Bhambri for his suggestions to improve the paper.

References

- Ahmad, S. and Hasnain, S. I. (2004), 'Analysis of satellite imageries for characterization of glacio-morphological features of the Gangotri Glacier, Ganga headwater, Garhwal Himalayas', D. Srivastava, K.R. Gupta. & . S. Mukerji (Ed.), **Geological Survey of India**, 80, pp.61-67.
- Bahuguna, I.M. (2008), 'Himalayan Glaciers', **ISG Newsletter**, 14, pp.36-43.
- Bahuguna, I.M., et al. (2007), 'Himalayan glacier retreat using IRS 1C PAN stereo data',

International Journal of Remote Sensing, 28, pp.437-442.

Bahuguna, I.M., et al. (2004), 'Fusion of panchromatic and multi-spectral Indian Remote Sensing satellite images for identification of Gangotri Glacier snout', D. Srivastava, K.R. Gupta. & . S. Mukerji (Ed.), **Geological Survey of India**, 80, pp.61-67.

Bhambri, R. and Bolch, T. (2009), 'Glacier Mapping: A Review with special Reference to the Indian Himalayas', **Progress in Physical Geography**, 33, pp.672-704.

Chambri, R. and Chaujar, R.K. (2009), 'Recession of Gangotri glacier (1962-2006) measured through Remote Sensing Data', **Proceedings of National Seminar on Management Strategies for the Indian Himalaya: Development and Conservation**, pp.254-264.

Bishop, M. P. et al. (2001), 'Terrain analysis and data modeling for alpine glacier mapping', **Polar Geography**, 25, pp.182- 201.

Bolch, T. and Kamp, U. (2006), 'Glacier mapping in high mountains using DEMs, Landsat and ASTER data', Grazer Schriften der Geographie und Raumforschung: **Proceedings of the Eighth International Symposium on High Mountain Remote Sensing Cartography**, La Paz, Bolivia, pp 37- 48.

Bolch, T., et al. (2008a), 'Planimetric and volumetric glacier changes in Khumbu Himalayas since 1962 using Corona, Landsat TM and ASTER data', **Journal of Glaciology**, pp.592-600.

Kirkbride, M.P. (1995), 'Processes of transportation In Modern glacial environments: processes, dynamics and sediments', J. Menzies ed., **Glacial Environments**. (1), pp.261-292. Butterworth- Heinemann, Oxford.

Kulkarni, A. V. and Suja, A.M. (2003), 'Estimation of recent glacial variations in Baspa Basin using remote sensing techniques', **Journal of Indian Society of Remote Sensing**, (31), pp.81-90.

Kulkarni, A. et al.(2007), 'Glacial retreat in Himalayas using Indian Remote Sensing satellite data', **Current Science**, (92), pp.69-74.

Kulkarni, A. et al.(2005), 'Alarming retreat of Parbati glacier, Beas basin, Himachal Pradesh', **Current Science**, 88, pp.1844-1849.

Naithani, A.K. et al. (2001), 'Geomorphological evidences of retreat of the Gangotri glacier and its characteristics', **Current Science**, (80), pp.87-94.

Oerlemans, J. (1994), 'Quantifying global warming from the retreat of glaciers', **Science**, (264), pp.243 - 245.

Ranzi, R., et al. (2004), 'Use of Multispectral ASTER images for mapping debris-covered glaciers within the GLIMS Project', **IEEE International Geoscience and Remote Sensing Symposium**, pp.1144-1147.

Shukla, A. et al.(2009), 'Estimation of debris cover and its temporal variation using optical satellite sensor data: a case study in Chenab basin, Himalaya', **Journal of Glaciology**, (55), pp.444-452.

Small, R.J.(1987), 'Englacial and supraglacial sediment transport and deposition', In Gurnell AM, Clark MJ ed. **Glacio-fluvial Sediment Transfer; An Alpine Perspective**, Chichester: John Wiley & Sons, pp.111-145.

Stokes, C.R., et al.(2007), 'Recent glacier retreat in the Caucasus Mountains, Russia, and associated increase in supraglacial debris cover and supra/proglacial lake development', **Annals of Glaciology**, (46), pp.195-203.

(Snehmani, Satwant Kaur, A. Ganju, M. R. Bhutiyani, are working with SASE, Him Parisar, Chandigarh (UT), and A. K. Nigam is working with BIET, Jhansi (UP),
Email: snehmani@sase.drdo.in)

Modelling Glacier Sensitivity of Gangotri Glacier, Indian Himalayas

Snehmani, Mahima Chatranta, A Ganju, M R Bhutiyani, A.K Nigam

Abstracts

Glaciers are excellent indicators of climate change where climate stations are rare or non-existent. However no authenticated quantitative relationships exist among different causative parameters like solar radiation, air temperature, precipitation, wind, cloudiness and the glacier fluctuations for Indian Himalayas. Glacier sensitivity is the key parameter that links change in climate to the glacier volume. The variation in precipitation and temperature brings imbalances in mass balance and ultimately to glacier volume change. The glacier snout position, thus responds directly to the temperature and precipitation fluctuations. The effects of the precipitation fluctuations tend to get averaged out as their influence slowly propagates from the accumulation zone to the snout region (Oerlemans, 2005). Based on these physical assumptions, in the present study, the mathematical model by Oerlemans (2005) is applied to analyze the length changes of Gangotri Glacier in response to the climatic fluctuations, which relates the recession of the glacier with respect the local climate (i.e. temperature and precipitation).

The temperature and precipitation data were used from SASE's Field Observatory located at Bhojbasa at an altitude of 3792m to study the relationship between glacier response and climate fluctuations. The length records of Gangotri Glacier derived from the Oerleman's model accord well with the length measurements of glacier from multi-sensor and multi-temporal (Landsat-MSS/TM/ETM+, Cartosat-1) satellite imageries. Thus Oerleman's model has worked quite well in the available temperature and precipitation data for Gangotri Glacier and show potential to use this model on other Himalayan glaciers.

Key Words: Glacier sensitivity, Oerleman's model, AWS data, time-series multi-sensor satellite imagery

Introduction

Glaciers are dynamic and fragile ice bodies on the landscape and are products of the climate and climatic changes. They change their dimensions (i.e. length, area and volume) in response to climatic variables in the surrounding environment. However the response of a glacier to a climatic change involves a complex chain of processes (Nye 1960, Meier 1984). Changes in atmospheric conditions (e.g. solar radiation, air temperature, precipitation, wind and cloud cover) influence the mass balance and energy balance of the glacier (see Kuhn 1981, Oerlemans 2001). Glaciers reflect this climate variability and the characteristic response time (i.e., inertia, or 'memory') of a glacier ranges from years to centuries (e.g., Johannesson, 1989; Harrison et al., 2001; Pelto and Hedlund, 2001; Oerlemans,

2001), and any given glacier will reflect an integrated climate history on those timescales. For example, Oerlemans (2005) used the length records of 169 glaciers located around the world to construct a quantitative record of 20th century warming, and found that the glacier record agreed remarkably well with the instrumental record.

In the present study we apply Oerleman's coarse grained model (OCGM) for Gangotri Glacier in the Garhwal Himalayas. The model uses two climatic parameters - temperature and precipitation as an input to calculate the length change and rate of recession for any glacier. The model relates the recession of the glacier to its local climate (temperature and precipitation). The temperature and precipitation data for Gangotri Glacier is available for the past eleven years (2000 - 2011). We have used these climate

data sets to validate the strength of OCGM model in Himalayan terrain. To best of our knowledge this is first attempt to measure the length change and rate of Gangotri Glacier recession from OCGM. The study area and data sources

Gangotri Glacier is one of the largest Garhwal Himalayan glaciers, which is about 30 km long with its width varying from 0.5 to 2.5 km. It is a valley-type compound basins glacier, located in the Uttarkashi district of the state of Uttarakhand in India (figure 1). This glacier is bound between 30°43'22"-30°55'49"" (lat.) and 79°04'41"-79°16'34" (long.), extending in height from 4120 to 7000 m.a.s.l. It is a cluster of many glaciers comprising the main Gangotri Glacier as the trunk part of the system. This glacier originates from the Chaukhamba group of peaks (7000 m.a.s.l) and flows in the northwesterly direction Forming the source of Bhagirathi River at Gaumukh (also known as the mouth of a cow in Hindi literature; snout of Gangotri Glacier). Bhagirathi River after its confluence with the river Alaknanda at Devprayag is known as river Ganga. This glacier is one of the most sacred shrines in India, having immense religious significance. Hence, the retreat of the glacier in the recent past has generated much concern.

The temperature and precipitation data for Gangotri Glacier is obtained from SASE's Field

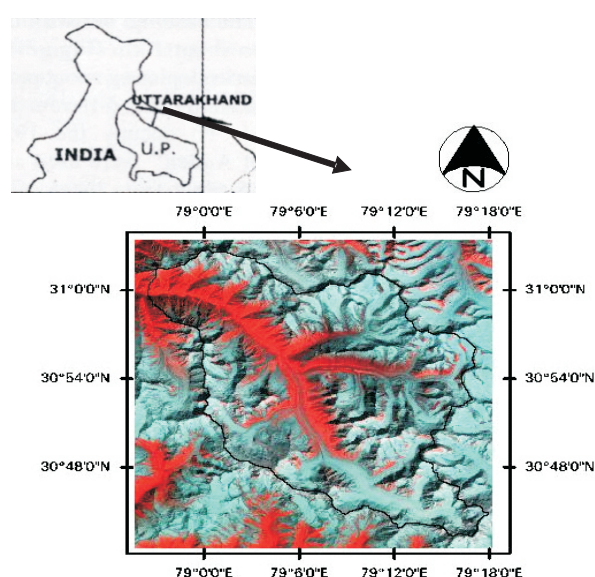


Fig. 1: "Gangotri Glacier" in satellite imagery

Table 1: Average Annual Temperature of Gangotri Glacier obtained from the manual Observatory at Bhojbasa.

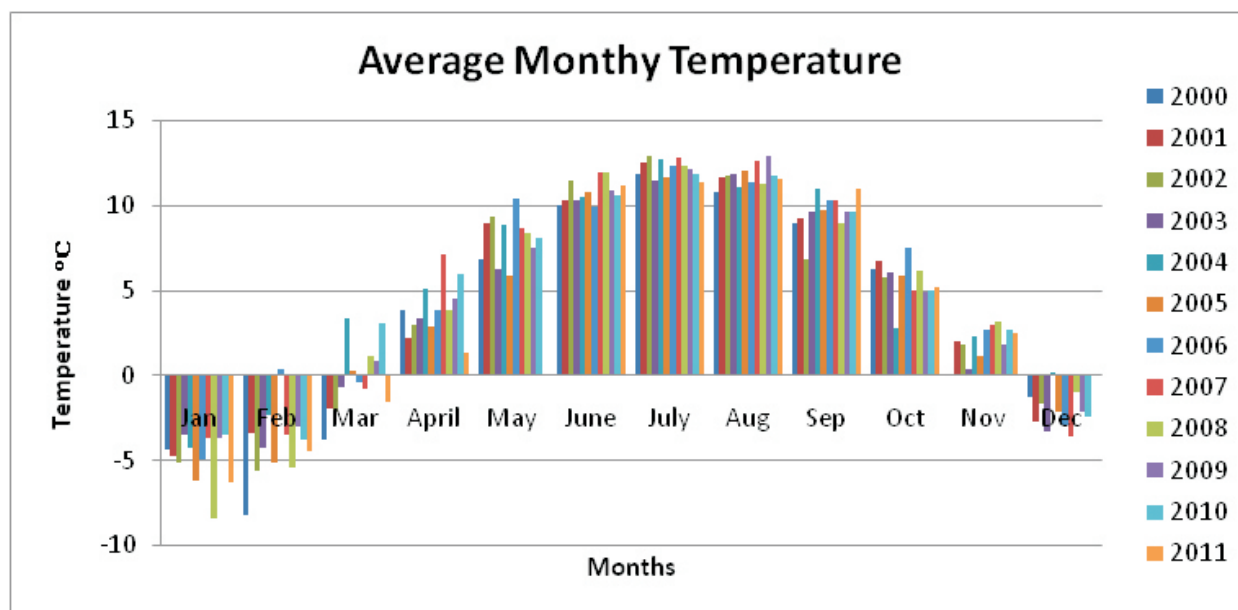
Year	Mean Temperature (°C)
2000	3.41
2001	4.25
2002	4.02
2003	3.96
2004	5.12
2005	3.91
2006	5.04
2007	5.00
2008	4.37
2009	4.71
2010	5.00

Observatory located at Bhojbasa at an altitude of 3792 m.a.s.l. This observatory is located below at a distance of 4 km from the present snout (Goumukh) of Gangotri Glacier. Thus can be used as a representative site for the collection of atmospheric data which assume to affect the variability in Gangotri Glacier. All meteorological data were collected as per World Meteorological Organization standards. The daily maximum and minimum temperatures were averaged out to calculate average temperature of a particular day. Similarly average monthly temperatures were calculated from the mean of daily temperature. The mean monthly temperatures from Bhojbasa observatory for different years (i.e. 2000-2011) are shown in Fig. 2. In addition Landsat images were downloaded from USGS website (<http://edcsns17.cr.usgs.gov/NewEarthExplorer/>) and the Cartosat 1 image was obtained from National Remote Sensing Centre (NRSC).

Background and Methodology

The Oerleman's coarse grained model (OCGM) Model

The Oerleman's coarse grained model (OCGM) states that the rate of change of the length of a glacier at any time is determined by its geometry (shape) and climate. The shape of a glacier is described by the static bedrock, valley topography and the dynamically changing ice surface. The climate determines how much ice is



accumulated or ablated at any point over the glacier (i.e. specific mass balance).

The OCGM model is based on the few assumptions:-

1) Corresponding to a climatic condition and glacier geometry, there is a unique equilibrium length of the glacier which it will attain if the climatic conditions are unchanged for a long enough period.

(a) To first approximation, the climatic conditions that determine the equilibrium length are the annual average precipitation and the annual average temperature.

(b) The most important factor of the glacier geometry that determines the equilibrium length is its slope.

Years	Length (km)	Rate of Recession (m)
2001	30.42	39
2002	30.26	21.8
2003	30.10	20.43
2004	29.94	31.55
2005	29.79	7.34
2006	29.63	20.12
2007	29.47	16.9
2008	29.32	9.02
2009	29.16	10.96
2010	29.42	12.18

2) The change in equilibrium length per unit change in climatic conditions is called the glacier's climate sensitivity. If the climatic conditions change the glacier responds by attaining its new equilibrium length. The time scale over which it attains its new equilibrium length is called its response time.

3) The variation in precipitation mainly influences the accumulation zone and variations in temperature mainly influence the ablation zone. The front position thus responds directly to the temperature fluctuations. The effects of the precipitation fluctuations tend to get averaged out as their influence slowly propagates from the accumulation zone to the snout region.

Based on these physical assumptions, the mathematical model generated by Oerlemans to describe climate sensitivity and glacier response time was used for present study. Choose some reference time t_0 . Let the temperature at $t = t_0$ be $T(t_0)$ and the equilibrium length of the glacier corresponding to this temperature be L . Further let the actual length of the glacier at time t be $L + l(t)$. If the temperature at time t is given by $T(t)$, denote the variation of the temperature by

c is climate sensitivity () the response time, and p is the average precipitation in meters/years, s the slope in and L the length in meters. The value of 230 has been the result of calibration with the set of numerical models that take

glacial geometry into account. The climate sensitivity (c) and the response time (τ) parameters are depend on the glacier geometry and local precipitation (at the snout). The parameters of Gangotri glacier are as follows.

$\Delta T(t) = T(t) - T(t_0)$. The equation for the time variation of the length is,

$$\tau = \frac{13.60}{0.006 \times 0.5} \frac{1}{\sqrt{1 - 205}L}$$

Table 2: Derived parameters for Gangotri Glacier

Length	30.2 km
Slope	0.083
Precipitation	1.5 m/y
Climate sensitivity	7000 m/k
Response time	190 years

$$l(t) = e^{-t/\tau} (l_0 e^{t_0/\tau} - \frac{c}{\tau} \int_{t_0}^t dt' e^{t'/\tau} \Delta T(t'))$$

Length of the glacier was obtained from Cartosat 1 image of Sep 2006 at 2.5m resolution and slope is obtained by AWiFS image of Gangotri Glacier blended on ASTER Digital Elevation Model in ERDAS IMAGINE 9.2. Slope is taken as a ratio of vertical distance to horizontal distance (tan). Climate sensitivity and response time are obtained by putting the values into above equation. Once the values of climate sensitivity and response time generated, the length (t) and rate of recession v(t) can be easily calculated using the formula given below.

Once the length is obtained from the above formula, the derived length can be used to calculate

$\Delta l = l(t) - l(t_0)$ and the rate of recession at time Where v (t) is the rate of recession at time t.

$$v(t) = \frac{1}{\tau(1 - e^{-(t-t_0)/\tau})} (\Delta l e^{-\frac{t-t_0}{\tau}} + \frac{c}{\tau} \int_{t_0}^t dt' e^{(t'-t)/\tau} \Delta T(t'))$$

Table 3: Length and Rate of recession obtained from OCGM

Results and Discussion

The derived length from the model clearly shows that Gangotri glacier has retreated from 30.42 km to 29.42 km during the last ten years i.e. from 2001 to 2010. However for the year 2010 models shows advancement in the glacier length rather

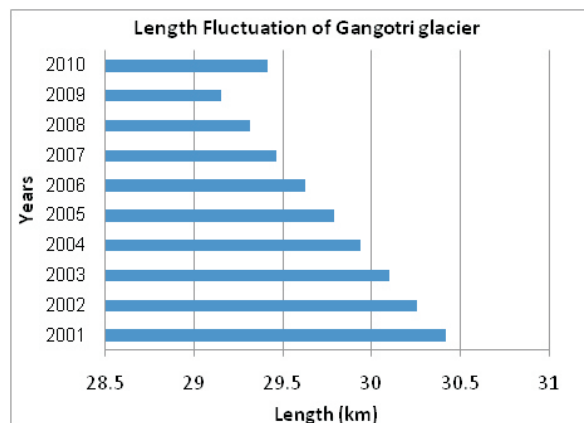


Fig. 3: Length of the glacier in different years (2000-2010)

than its retreat, which further needs to be verified from field data. Rate of recession for the year 2001 is about 39 m which in the year 2010 has decreased to 12.18 m. This is also reported by prior field based studies (Raina 2009). The average retreat from 2001 to 2010 comes out to be about 18m per year from OCGM model. In order to validate the length and rate of recession results obtained from OCGM model, are compared with the multi -temporal and multi sensor satellite data (Table 4).

Table 4: Comparison of length of the Gangotri Glacier obtained from OCGM with Satellite images

Comparison of results obtained from OCGM with satellite images			
Date of Pass	Satellite/ Sensor	Length Obtained from Satellite imageries	Length Obtained from OCGM
2 Sep 2001	Landsat/ETM+	30.55m	30.42m
29 Sep 2006	Cartosat 1	30.47m	29.63m

For the year 2001 model generates the length of 30.42 and the (Landsat- ETM+) image of 2nd Sep 2001 provides the length of about 30.5 similarly for the year 2006 model provides the length of about 29.63 and the Cartosat 1 imagery of 28th Sep 2006 provides the length of about 30.5. Thus the length obtained from the model accord well with the multi-sensor

satellite imageries (Table 4). This comparison clearly shows that the results obtained from the model are quite reliable.

Conclusions

Oerleman's model has worked quite well with the available temperature and precipitation data of Gangotri glacier. It captures the dynamics of the length fluctuations of Gangotri Glacier reasonably well and can be applied for other glaciers in the Indian Himalayas.

Acknowledgements:

Authors are thankful to DST for financial support under project No ESS /91/03/2006 to carry out present research work and to Dr J Oerleman, Rakesh Bhambri and Bhanu Pratap for their valuable suggestions to improve the manuscript.

References

Harrison W.D., D.H. Elsberg, K.A. Echelmeyer and R.M. Krimmel (2001): On the characterization of glacier response by a single time-scale. *Journal of Glaciology* 47 (159), 659-664.

Jóhannesson T., C.F. Raymond and E.D. Waddington (1989): Time-scale for adjustment of glaciers to changes in mass balance. *Journal of Glaciology* 35, 355-369.

Kuhn, M. (1981). *Climate and Glaciers*. IAHS Publication no. 131, 3-20

Meier, M. F. (1984). Contribution of small glaciers to global sea level. *Science*, 226(4681), 1418-1421.

Nye, J. F. (1960) *Proc. R. Soc. Lond. A* 256, 559.

Oerlemans J. (2001): *Glaciers and Climate Change*. A.A. Balkema Publishers, 148 pp.

Oerlemans J. (2005): Extracting a climate signal from 169 glacier records. *Science* 308, 675-677; 10.1126/science.

Pelto, M.S. and C. Hedlund (2001): The terminus behaviour and response time of North Cascade glaciers. *Journal of Glaciology* 47, 497-506

Raina, V. K., 2009. *Himalayan Glaciers: A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change*. Discussion Paper, Ministry of Environment and Forests, Government of India, p. 60.

(Snehmani, Mahima Chatranta¹, A. Ganju, M. R. Bhutiyani, are working with SASE, Him Parisar, Chandigarh (UT), and A. K. Nigam is working with BIET, Jhansi (UP)
Email: snehmani@sase.drdo.in)

Estimation of Snow Depth in NW Himalayas Using Field Observations and Digital Elevation Model

H S Jassar, Snehmani, Balwan Singh, S K Dewali, A Ganju

Abstracts

Stability of the snow pack over a mountainous slope is governed by various factors including snow cover, weather conditions and terrain. Snow depth contributing significantly in the occurrence of an avalanche makes it essentially important to model snow depth accurately for assessing the avalanche hazard potential in snow-bound, inaccessible mountainous areas. The sparse network of ground meteorological observation stations, along with the severe weather and terrain conditions in these areas makes it difficult to monitor the varying snow cover during winter.

In the present study, altitude and the snow depth data from the field observatory and Automatic Weather Station (AWS) are integrated in a GIS framework to model mean snow depth successfully with help of the snow depth estimation algorithm of Foppa (2005). The A quasi-physical method was adopted for snow depth measurements, taken at different observation stations, along with Digital Elevation Model (DEM).

Weighted inverse distance, calculated for each pixel from all observation points, was used to prepare snow depth map of complete study area. The snow depth maps were generated from November 2007 to April 2008 and validated using AWS data. To identify the snow and non-snow regions in the study area, time-series MODIS imagery were also analyzed. In addition, accuracy of different methods was used to compare snow depth measurement. Model results correlate well with in situ measured values of the snow depth.

Keywords: *Avalanche, Digital Elevation Model, Quasi physical approach, Inverse Distance Weight Method*

Introduction

Large areas in the Himalayas are covered with seasonal snow during winters to register significant changes in cover during summer. The understanding of the changes in snow depth play important role in hydropower generation, water management, mass balance, strategic planning, avalanche and flood forecasting, and other developmental activities, contributing significantly to the national economy. All this make the accurate estimation of snow depth over the rugged mountainous terrain so as to plan and manage above-mentioned activities (Negi, 2008). Glaciers and snowfields normally exist in remote and inaccessible areas, making regular data collection difficult and hazardous. Notwithstanding, the monitoring of snow in the N-W Himalaya has a long tradition. Snow depth is measured at Automatic weather stations in N-W Himalayas.

Different scholars have used interpolation approaches to accomplish snow depth mapping (see Nando Foppa et al., 2005; Liston et al, 2006). Another group of researchers used the remote sensing based techniques for snow-cover parameters extraction in optical and microwave domains. However snow depth cannot be determined directly using VIR imagery. Polari-metric SAR has also the potential to be used to measure snow depth, using the difference between the VV- and HH-polarized backscattering coefficients (Shi and Dozier 1995). Over the global scale, snow depth patterns on the earth's surface from space are determined by the use of passive microwave remote sensing techniques which makes use of various band frequency combinations to determine the snow depth within certain accuracy limits. Spatial interpolation of snow

depth had been another indirect way of snow depth estimation at different locations. The development of methods to interpolate climatic and snow parameters data from networks of few stations has been the focus of several research projects (Hutchinson and Bischof, 1983; Phillips et al., 1992; Foppa et al, 2005; Price et al., 2000). As per these projects, the interpolation procedures must incorporate the effects of physical processes which determine the climate spatial distribution. Some authors have used simple procedures, which include the latitude and longitude of weather stations (MacIver and Whitewood, 1990).

Because of the strong influence of topography on snow depth amount variations, Liston et al 2006 showed that the inclusion of elevation was critical to generating reliable data for meteorological variables through interpolation.

This study tried to integrate the topographic variables i.e. altitude (by using Digital Elevation Model) and the observations of snow depth amount data from the ground meteorological observatory as well as from Automatic Weather Station (AWS) in GIS environment to provide more accurate and dynamic Snow Depth maps. Snow depth with altitude above m.s.l. had been the main focus.

Study area

The area in and around Manali (HP) and parts of Manali-Leh Highway (Dhundi, Rohtang Pass and

Patsio) has been selected as study area (Fig.1). Falling between latitude $32^{\circ} 15' 33''$ N and longitude between $77^{\circ}-77^{\circ} 45''$ E, the study area falls under the SOI toposheets no. 52H/2, 52H/3, 52H/5 covers the whole study area. Based on the terrain classification for Indian Himalaya, the study area has been divided into two zones, Rohtang pass serving as the divider. These are: (i) Lower Himalayan Zone, and (ii) Middle Himalayan Zone. The former sub-division experiences heavy snowfall, moderately high temperatures, and intense avalanche activity. The slopes have vegetation up to an altitude of 3500m. It experiences a very short winter starting from November till February when the temperatures are in the range of 0°C - 15°C , with maximum precipitation being experienced during this period. The snow cover during this period is mostly dry to moist. The period from March to May experiences high temperatures and rapid ablation. The snow falling during this period rapidly changes from dry to moist and wet. The latter subregion experiences low precipitation and low temperatures. The area has very thin vegetation. The road generally lies on the southern aspect. The area experiences comparatively a long winter from October till March with temperatures as low as -25°C during the peak winter. The ablation period starts from April and extends up to May/June.

Methodology

We have incorporated the variation of precipitation with topographic features. It makes the use of snow depth measurements taken at different observation points along with Digital Elevation Model (DEM) to incorporate terrain features. To generate the snow depth map from point observation, snow depth is calculated at each pixel of the study area with respect to observation point using the elevation variation from DEM. A weighted inverse distance has also been calculated for each pixel from the observation point. Three such observation points (Manali (AWS I), Dhundi (AWS II) and Patsio (AWS III)) were taken in the present study. Final snow depth map was generated by taking weighted sum of the snow

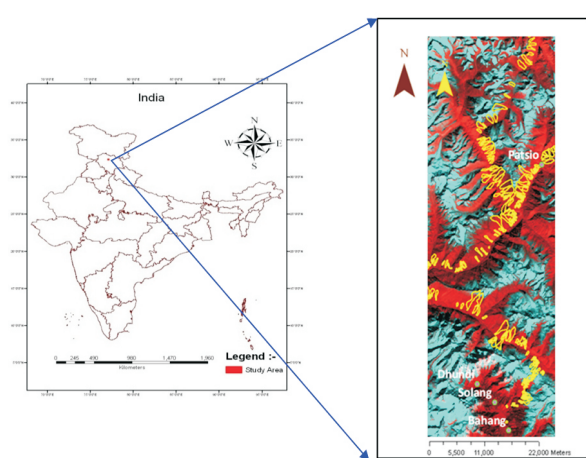


Fig.1 The Study Area shown using AWiFS imagery in FCC.

Fig. 2: Flow Chart of Process followed for generation of Snow Depth Maps

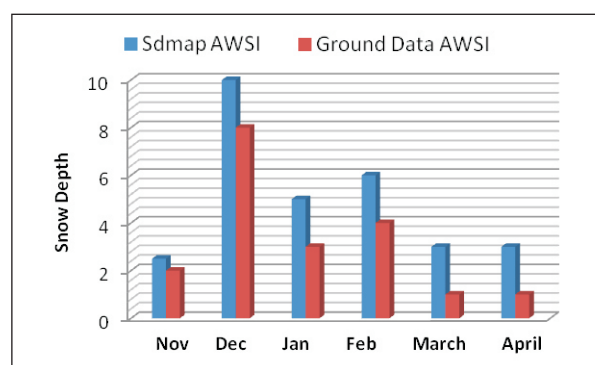
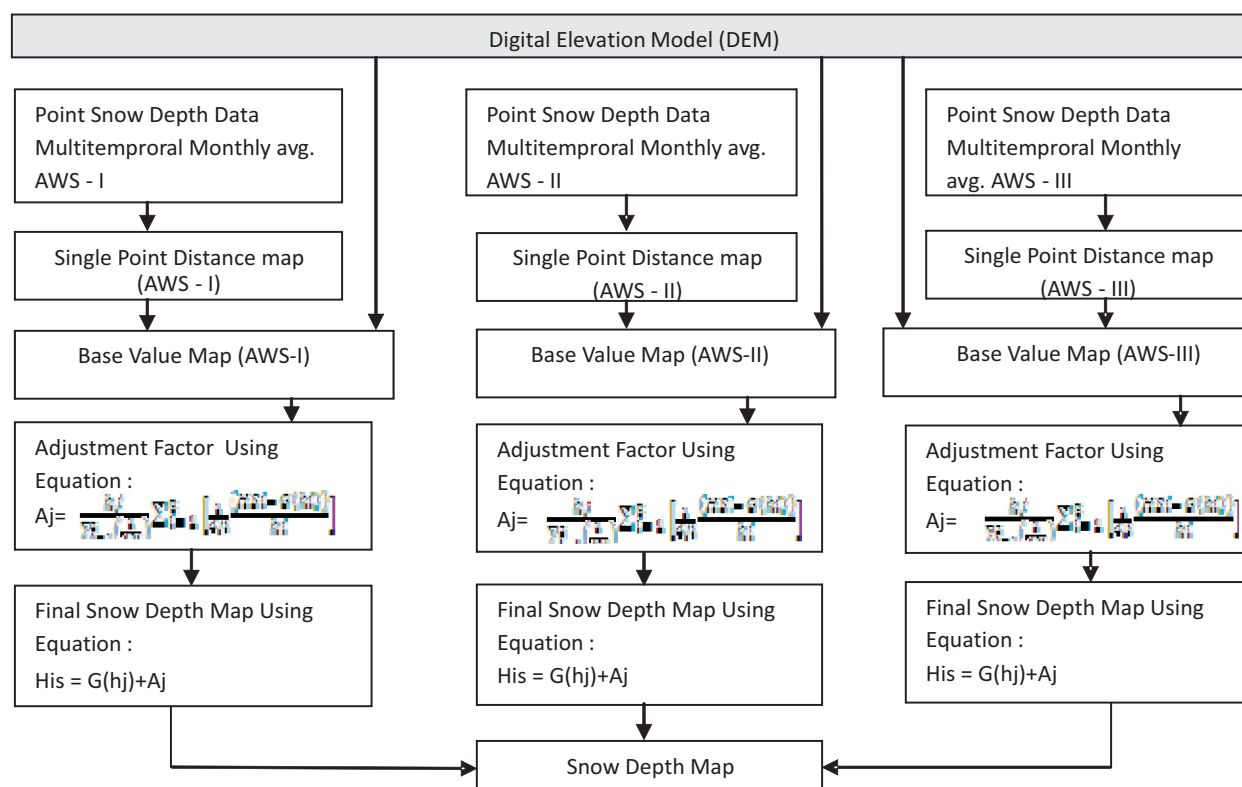


Fig 3a Monthly comparison of observed and measured snow depth values for station AWS I

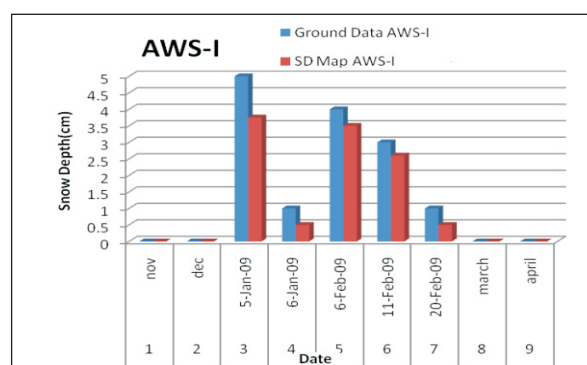


Fig 3c Monthly comparison of observed and measured snow depth values for station AWS III

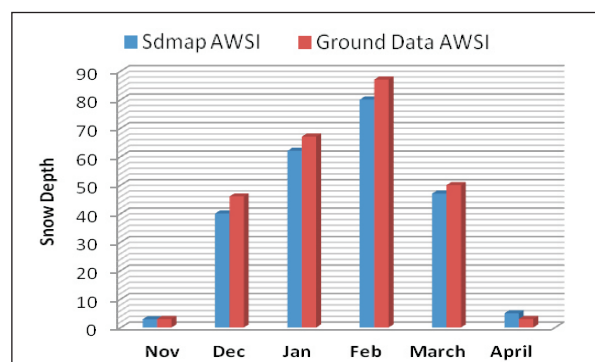


Fig 3b Monthly comparison of observed and measured snow depth values for station AWS II

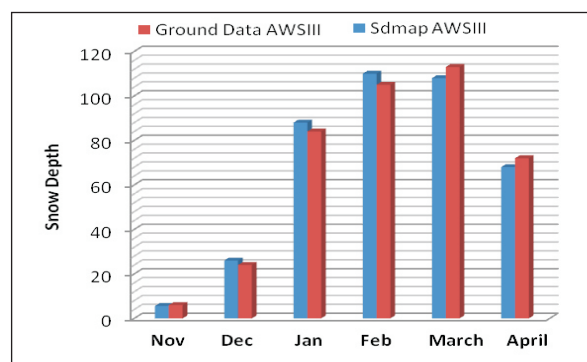


Fig. 4: (a) Monthly comparison of observed and measured snow depth values for station AWS I.

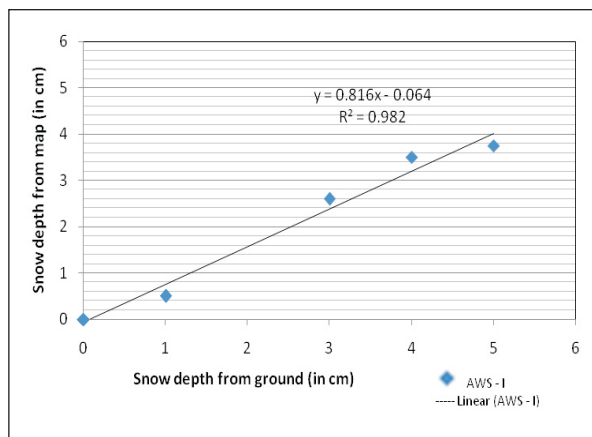


Fig (b) Correlation graph of measured and observed snow Depths for AWSI.

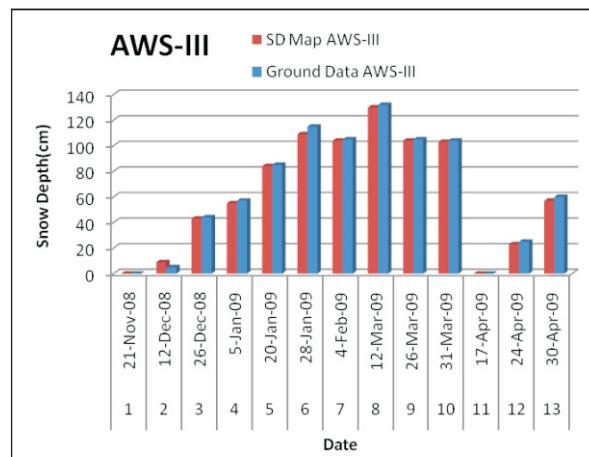


Fig. 7: Generated Snow Depth maps with snow cover area information

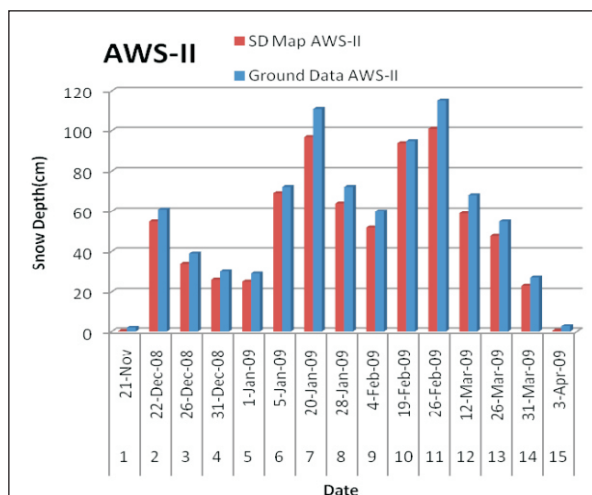


Fig. 6(a) Monthly comparison of observed and measured snow depth values for station AWS II.

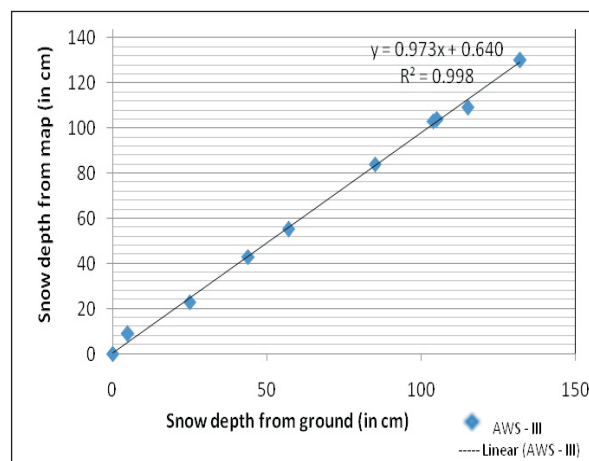


Fig (a) Without MODIS Data (b) With inclusion of MODIS information

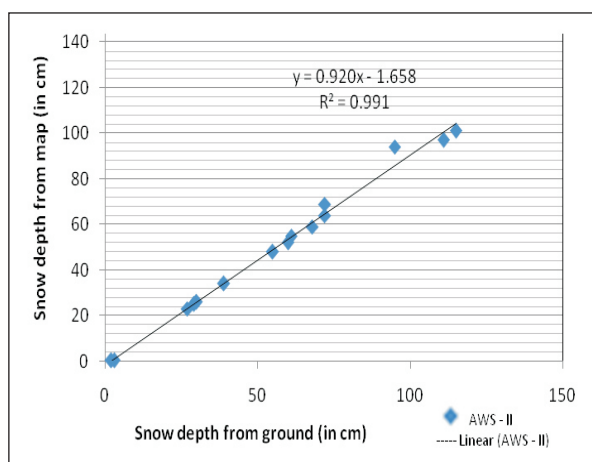
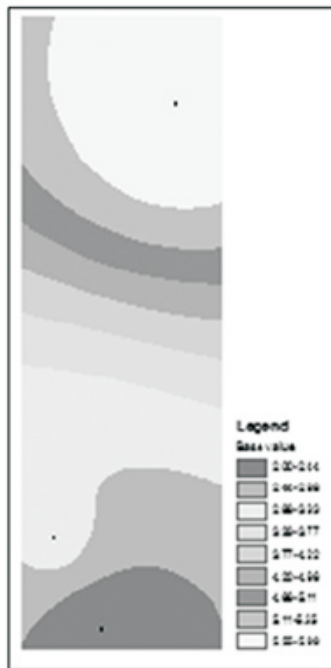


Fig. 6(b) Correlation graph of measured and observed snow Depths for AWS II.

depth maps of all observation points. To identify the snowbound region of the study area, MODIS images of the study period were processed to produce the reflectance maps followed by calculation of NDSI index to map snow and non-snow area. The snow depth maps were generated from Nov 2008 to April 2009. The calculated snow depth maps were validated using data from AWS (Automatic weather station).

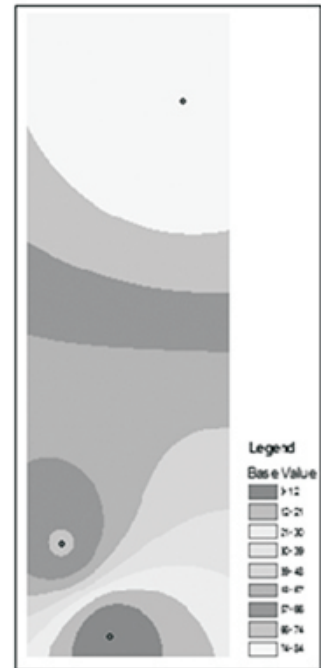
The approach used for snow depth modelling is a quasi physical approach that utilizes the known physical relationship between snow depth at a particular point and the topography.



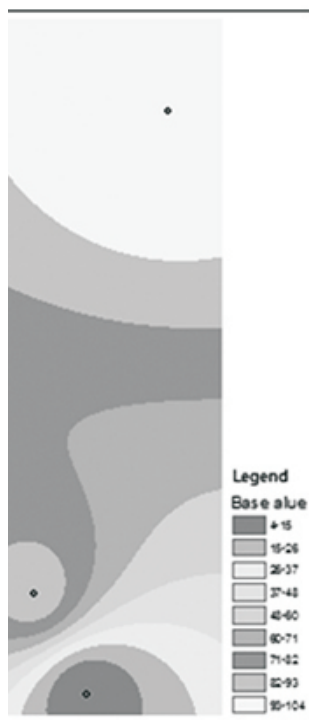
Base Value(Nov)



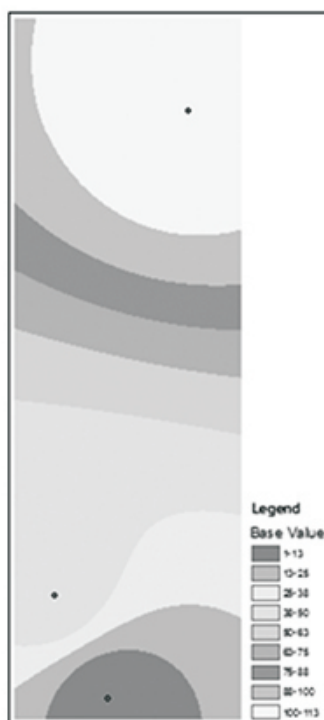
Base Value(Dec)



Base Value (Jan)



Base Value(Feb)



Base Value(March)



Base Value (April)

Fig. 8: Base value Maps for each month (a) Nov. (b) Dec. (c) Jan. (d) Feb. (e) March (F) April

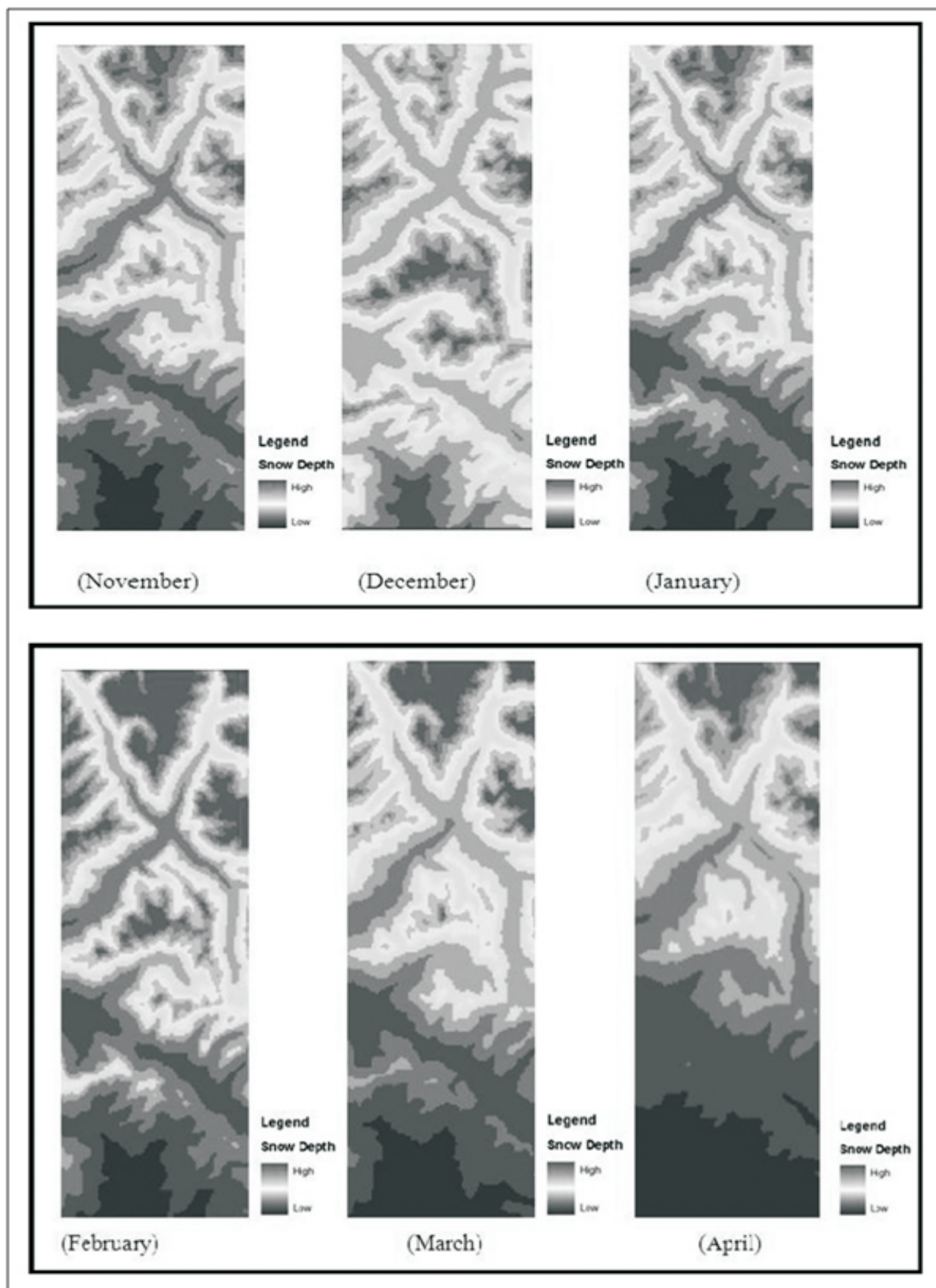


Fig. 9: Generated Snow Depth maps for different months (a) Nov. (b) Dec. (c) Jan. (d) Feb. (e) March (F) April.

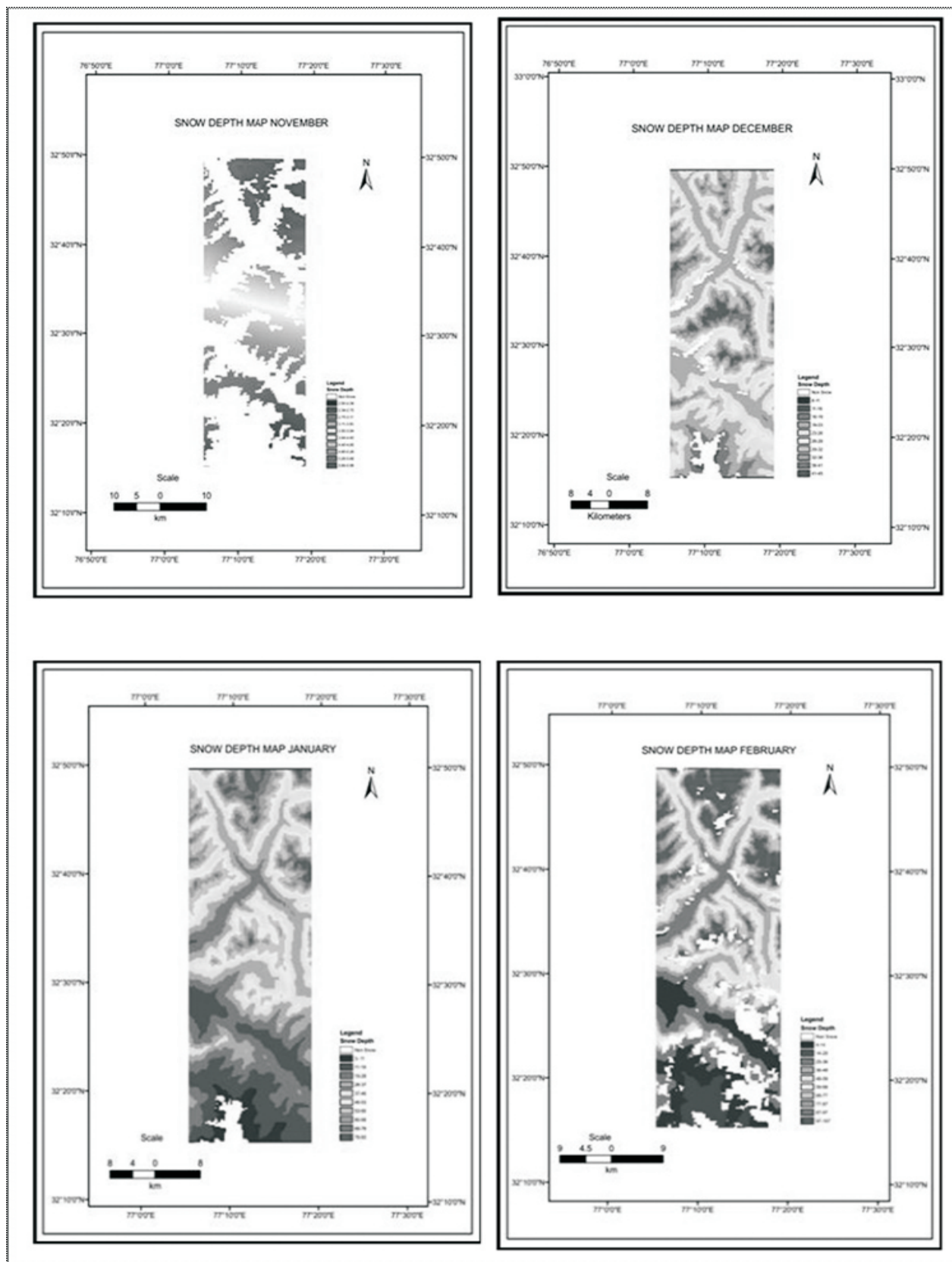


Fig 10 (a) Nov. (b) Dec. (c) Jan. (d) Feb. (e) March (F) April. Generated Snow Depth maps with snow cover area information with inclusion of MODIS information

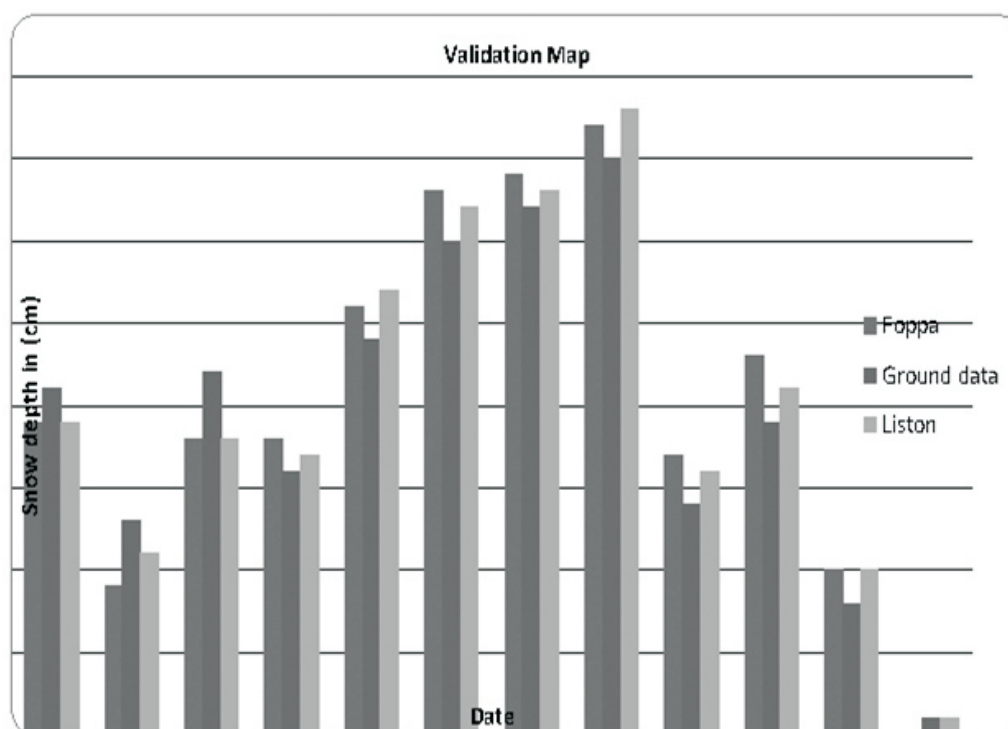
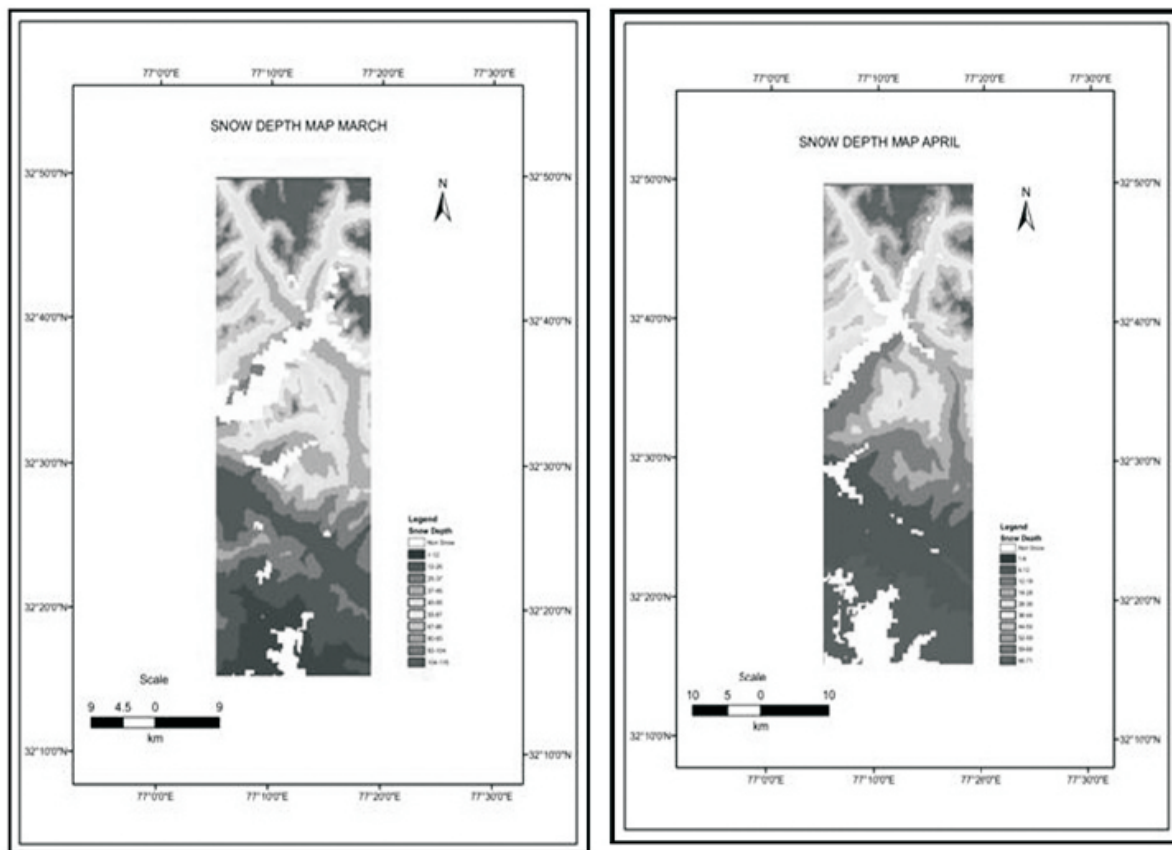


Fig. 9 a: Validation Map for different methods

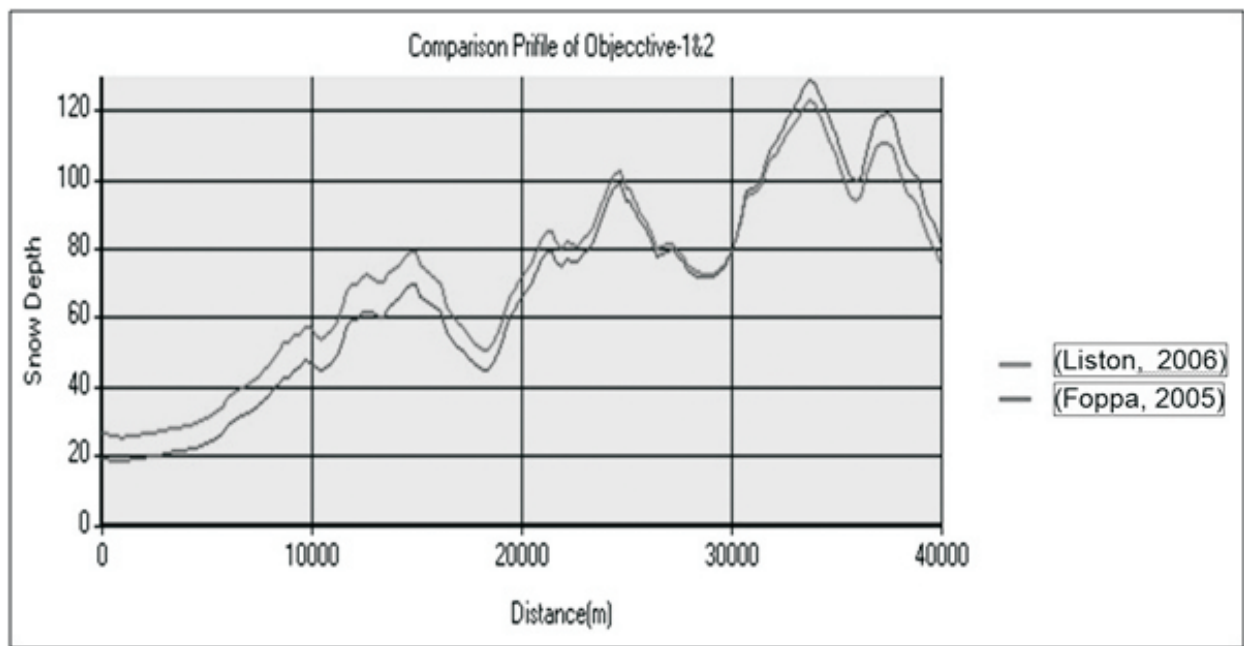


Fig. 9 b Comparison for different methods

ArcGIS software was used for this analysis. The whole scheme for snow depth maps calculation, is discussed in details in the followings.

- Preparation of distance, base value maps, final snow depth maps
- Calculation of adjustment factor for study area.
- Measurement of snow and non snow area using MODIS Data.

In present study, variation of snow depth with altitude above mean sea level (M.S.L.) had been the main focus. The modelling has been done based on the model equation obtained using variation of snow depth with altitude (Point basis) as proposed by Foppa et al, 2005.

$$A_j = \frac{h_j}{\sum_{i=1}^3 \left(\frac{1}{d_{ji}} \right)} \sum_{i=1}^3 \left[\frac{1}{d_{ji}} \left(\frac{HS_i - G(h_i)}{h_i} \right) \right] \dots \dots \text{eq. 1}$$

Where: H_j : altitude of the grid cell j in m a. s. l. D_{ji} : distance between grid cell j and observation station i in km. HS_i : measured snow depth at observation station i in cm. $G(h_i)$: base value of modelled snow depth at the observation station in cm. H_i : altitude of the observation station in m a. s. l., j : grid cell j , to be varied at a 1 km grid over

the whole area. i : observation station i , $i=3$ and minimum distance to the grid cell j .

$$HS = G(h_j) + A_j \dots \dots \dots \text{eq. II}$$

Where: HS : snow depth in cm., G : base value in cm., A : compensation value in cm., h : altitude of the grid cell in m a. s. l., j : grid cell to be calculated.

Results

Considering standing snow amount data from three ground observation stations, the standing snow patterns over these stations have been shown for the period of November to April. The

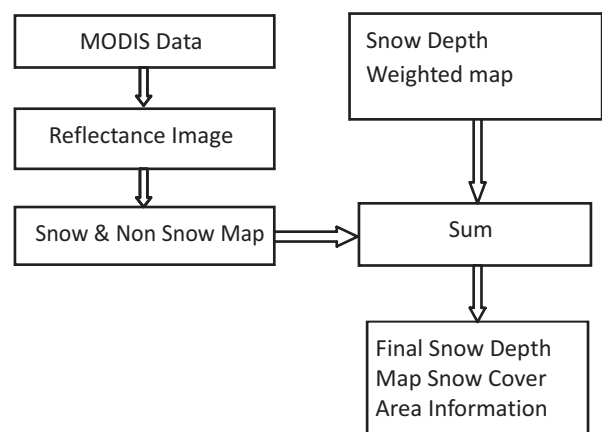


Fig-2 Flow Chart for snow & non Snow map

pattern shows that there is good correlation between the variations with the altitude and depending on the month of the year. The daily average snow depth maps generated of the study area from November 2008 to April 2009. A careful observation of the average snow depth map shows increasing snow depth pattern from Nov 08 to Jan 09, nearly constant snow depth amounts from January till mid February and decreasing trend in the late winter. The trend in variation suggested the idea for snow depth modelling using GIS environment. The hybrid approach based snow depth Adjustment factor estimated for each month has been represented in the form of graph for different months. This particular factor is found based on various combinations of different stations located at different altitudes and then average values have been taken for each month. The more difference in the altitude between the two observatories reference locations greater will be the range of accurate prediction by the model.

The snow depth maps have been extracted based on the snow cover area information generated using MODIS sensor satellite data. The areas, not covered by snow, get removed by inclusion of this information. This approach has been very useful as it helped to improve the accuracy of final snow depth maps. For validation of snow depth maps was done with using from the automatic weather station (AWS). These values, compared with the measured snow depth values, show the comparisons of derived snow depth amount value with AWS stations. A very good correlation of the predicted snow depth amount was found with the AWS sites data. One probable reason for the slight difference between the measured and ground AWS values may be due to the local terrain effects. The coefficient of correlation for AWS I, AWS II and AWS III has been found to be 0.998, 0.982 and 0.991 respectively. The trend observed through graphical form shows good accuracy of our model. The inclusion of more parameters like slope, aspect and solar illumination corrections will further help to achieve more accurate results. This type of

information can prove to be very helpful for avalanche forecasters and other snow depth based applications.

Concluding remarks

The results obtained from the approach used in this study are highly encouraging. The inclusion of data for a larger period and more number of stations will further improve the results obtained. The integration of multi-spectral information for snow covered area help in to improve the accuracy of the result by removal of the non snow area. Also this approach can be integrated with other methods to retrieving snow depth information. For example in passive microwave domain, the AMSR-E sensor gives average value of snow depth over a larger area. It provides information at spatial resolution of kilometres (i.e. very coarse) and gives good results for dry snow only. In comparison to this the proposed GIS model outputs snow depth maps at 40m resolution, this model was focused on small topographical variations which could help deriving better results.

Decreasing snow depth patterns in the late winter were also analyzed and correlated with the ablation of snow cover. During the late winter months melting starts and the inclusion of melt factor based on slope, aspect and solar illumination conditions can provide better results.

Acknowledgement

Authors acknowledge with thanks the help provided by the scientists and other staff members at SASE, Chandigarh in providing the field data.

References

- Cline, D.W. *et. al.* (1998), 'Estimating the spatial distribution of snow in mountain basins using remote sensing and energy balance modelling', **Water Resources Research**, 34 (5), pp.1275–1285.
- Daly C. *et. al.* (1994), 'A statistical-topographic model for mapping climatological precipitation over mountainous terrain', **Journal of Applied**

Meteorology, 33, pp.140–158.

Foppa N., *et. al.* (2005), 'Snow depth mapping in the Alps: Merging of in situ and remotely-sensed data', **EARSeL eProceedings**, 4.

Negi, H. S. *et. al.*, (2008), 'Estimation of snow depth and detection of buried objects using airborne Ground Penetrating Radar in Indian Himalaya', **Current Science**, 94, No.7 pp. 865-870.

Hutchinson, M.F. and Bischof, R.J. 1983, 'A new method for estimating the spatial distribution of mean seasonal and annual rainfall applied to the Hunter Valley, New South Wales', **Australian Metrological Magazine**, 31, pp.179-184.

Liston Glen E. and Kelly Elder (2006), 'A Meteorological Distribution System for High-Resolution Terrestrial Modeling', **Journal of Hydrometeorology**, 7, pp. 217-234.

MacIver D. C. and R. D. Whitewood (1992), 'Forest climates of Ontario, Part I, Bioclimate profiles 1968– 1988', **Environment Canada, Atmospheric Environment Service**, Ontario Ministry of Natural Resources, Toronto.

Phillips D. L., *et. al.* (1992), 'A comparison of geo-statistical procedures for spatial analysis of precipitation in mountainous terrain', **Agriculture and Forest Meteorology**. 58, pp.119-141.

Price D. T., *et. al.* (2000), 'A comparison of two statistical methods for spatial interpolation of Canadian monthly climate data', **Agriculture and Forest Meteorology**, 101, pp.81-94

Shi, J., and J. Dozier (1997), Mapping seasonal snow with SIR-C/X-SAR in mountainous areas, **Remote Sensing of Environment**, 59, 294-307

(**Snehmani, H S Jassar, A. Ganju, S K Dewali**, are working with SASE, Him Parisar, Chandigarh (UT), and **Balwan Singh** is M. Tech. student at Department of Geography, Bharathidasan University, Trichy

Email: Harpreet_gis@yahoo.com)

Application of Open Source GIS in Coastal Disaster Management with reference to Porbandar District, Gujarat

Manjush Koshy, Siddharth Vora, Nitish Thakkar, P. M. Sreekant, J. Shaji

ABSTRACT

Data capture using satellite remote sensing tools has made the biggest strides in the last few years. Very high resolution (VHR) optical satellites with a pixel size of 1 meter or less has improved the efficiency and accuracy of geo-information applications in disaster management. The Indonesian Tsunami of December 26, 2004 brought up importance of advanced crisis informatics capabilities for natural hazards management. This paper highlights the multilevel application of disaster informatics in local geographic scales using Open Source Geographic Information System (OSGIS). Local Spatial Knowledge (LSK) is one of the major prerequisites in effective disaster management. GIS based hazard risk analysis and information disclosure provide highly effective tools to support risk reduction. Gujarat has the longest coastline of about 1600-km constituting approximately 25% of the country's coastline, cyclone and storm surge are some of the common disasters wreaking havoc on Gujarat coasts and due to a fault-line under the Arabian Sea, probability of a tsunami cannot be ruled out. The coastal area of Porbandar was selected to analyze the vulnerability of the coastal settlements in the Municipality. Appropriate tracking of evacuation routes and modes of evacuation are developed in a matrix of geospatial components. Vulnerability of lowland areas and inland water bodies that are connected to sea through the coastal fresh water tidal creeks are mapped. Supported by Open source GIS software's, thematic layers are integrated, queried and geographically analyzed to derive supportive information on hazard proneness of the coastal settlements in the area. Interpreted data is used to produce maps for assessing vulnerability of areas, rescue routes and shelters. The objective of this paper is to demonstrate the use of open source geo-spatial tools and data sets that provide a cost-effective way to support disaster risk assessment in smaller and medium sized urban areas.

Introduction

Hoetmer defines emergency management as the discipline and profession of applying science, technology, planning and management to deal with extreme events that can injure or kill large numbers of people do extensive damage to property and disrupt community life (Drabek and Hoetmer 1991). Natural disasters have their greatest impact at local level, especially on the lives of common people. In developing countries, disaster management is limited to post-disaster recovery, rehabilitation and reconstruction. Developed countries concentrate towards disaster planning and preparedness measures which considerably reduce the overburden on post disaster activities, and also saves valuable lives. Impact of disasters on the society can be reduced by preparing communities to be more

disaster resilient. The shift from relief and recovery management approach to risk and vulnerability management approach should be achieved for effective disaster management. The Advent of high resolution satellite imaging technologies has improved the efficiency and accuracy of geo-information applications in disaster management. Very high resolution (VHR) optical satellites with a pixel size of 1 meter or less has improved the efficiency and accuracy of geo-information applications in disaster management. While dealing with extreme events, many of the critical problems that arise are inherently spatial in nature. The value of GIS in emergency management arises directly from the benefits of integrating a technology designed to support spatial decision making into a field with a strong need to address

numerous critical spatial decisions. GIS is a valid tool in Disaster Management activities like Preparedness, Mitigation, Recovery, and Disaster Response (Fig. 1.). In the chaos that usually follows a natural disaster, taking the time to create maps may seem low down on the priority list when a rapid response is key to helping to save lives. But mapping for disasters is relevant when important questions like "where are the affected populations, where can they be evacuated to, where is it safe etc. could be answered by implementing pre disaster planning methodologies for better disaster resilience. Using geospatially linked information it is possible to pinpoint hazard trends and the consequences of potential emergencies or disasters. When hazards are viewed with other map data, such as buildings, residential areas, rivers and waterways, streets, pipelines, power lines, storage facilities, forests, etc., disaster management officials can formulate vulnerability indices. More importantly, human life and other values (property, habitat, wildlife, etc.) at risk from emergencies can be quickly identified and targeted for protective action. After potentially vulnerable locations are identified, risk is assessed and mitigation needs can be addressed. This process involves analysing the developments in the immediate aftermath of a disaster, evaluating the damage and determining what facilities are required to be reinforced for construction or relocation purposes. By utilizing a geographically referenced information system, agencies involved in response can share information through databases on computer-generated maps in one location. Most disasters do not allow time to gather these resources. Geospatial tools thus provide a mechanism to centralize and visually display critical information during an emergency. This would facilitate scientists and disaster managers in creating models that would simulate trends observed in the past, present and also assist with projections for the future.

Crisis Informatics or disaster informatics is an emerging field showcasing the application of

information communication technology (ICT) in Disaster Management. Crisis informatics concerns with the extended social arena of disaster response which includes preparation, warning, response and recovery. Utilizing modern techniques of geo-informatics such as, Remote Sensing, GIS and GPS actions can be solicited in more systematic and precise way to respond to disasters, mitigate their effect and to make a better preparedness plans.

Proprietary GIS software is costly for local level disaster preparedness plans. Free and Open Source Geographic Information System (FOSGIS) encompasses its open source; agile, free sharing property into GIS software thus making it more popular as a decision support tool for cost effective community level disaster preparedness and response plans. Quantum GIS (QGIS) is free user-friendly open source desktop-GIS software that supports Linux, Windows and Mac operating systems. QGIS is released under the General Public License (GPL) and is available for Linux, and Windows operating systems. QGIS can freely be downloaded, installed and configured by any person having basic computer knowledge. FOSGIS promotes the use of geo-information technology in disaster management at the local level with minimal financial investment. The local authorities can reap this fruitful technology with minimum infrastructure like a computer, internet and printer, provided the local authorities should be trained in using this technology. This will enable in building a relevant and up to date disaster informatics dataset at the grass root level that will enhance the effectiveness of district, state and national disaster informatics data repository.

As most of the populated areas in the world are situated near coasts around the world, vulnerability of such coastal settlements to disasters like cyclones, storm surge and tsunami is a matter of great concern. Gujarat has the longest coastline of about 1600-km constituting approximately 25% of the country's coastline, cyclone and storm surge are some of the common disasters wreaking havoc on Gujarat

coasts and due to a fault-line under the Arabian Sea, probability of a tsunami cannot be ruled out. This paper is an attempt to demonstrate the application of open source geospatial tools and technologies in disaster management and the potential of Google Earth as a free online remote sensing data set for disaster management purpose is emphasized.

The study area

To demonstrate the application of Open Source geospatial tools and technologies in disaster management Porbandar Municipality was selected the study area is situated in the coastal belt of Gujarat in Porbandar district. Porbandar municipality has vast networks of water bodies, lagoons and tertiary geological plains situated in the Kathiawar peninsula. Porbandar is the birthplace of Father of the Nation Mahatma Gandhi and is a very important place of historic significance. Porbandar municipality has an area of 17.056 sq.km. The municipality has a coastline of 3.10 Kms. The study area lies between 21037'30" and 21039'50" north latitude, 69035'16" and 69040'38" east longitudes. It is bounded on the north by Khapat panchayat, on the east by Chhaya Municipality, on the west by Zaver and Bokhira panchayats and on the south west by Arabian Sea. The municipality has a population of 133,051 persons (Census 2001). For conducting vulnerability study of the settlements in the coastal Municipality with very high population

density, a small area of Porbandar Municipal town with comparatively high risk with its proximity to seafront and continuous inland water body network was selected on the basis of risk proximity of the settlements.

Methodology

Porbandar Municipality has a high density of population, important utilities and public installations along the coastal stretch warrants mitigative measures against natural calamities like tsunami cyclones and storm surge. With the help of high-resolution satellite images of 1m spatial resolution available in Google Earth, high quality geospatial inventorying and mapping of disaster vulnerability of the coastal settlements is attempted. Google Earth images were used to extract different thematic layers like location of individual households, roads, creeks and inland water bodies etc. Online digitization was done to extract different layers using Google Earth in KML/KMZ format (Fig. 2.). Other data collected from the local bodies like municipal maps were used to generate the study area boundary. According to feature geometry, different KML files are converted to ESRI Shape file in QGIS platform. Depiction of geographical trend and spatial pattern of natural disasters like storm surge, cyclone and tsunami is modulated in a geographically referenced frame work. Vulnerability mapping and risk assessment of the area includes human settlements risk mapping in terms of its nature of coastal locations. Locations for safe rehabilitation of the evacuated people are spatially represented. Vulnerability of lowlands and inland water bodies that are connected by creeks that are tidally active proximal to the coast line are mapped. Thematic mapping of the area from satellite data is done with perspective of disaster preparedness and response planning. The area has had some bad experience with cyclones which has already revealed its grip on the coastal dwellings of the municipality. The main concern in developing a disaster preparedness and response mapping system includes the identification of each and every settlement at

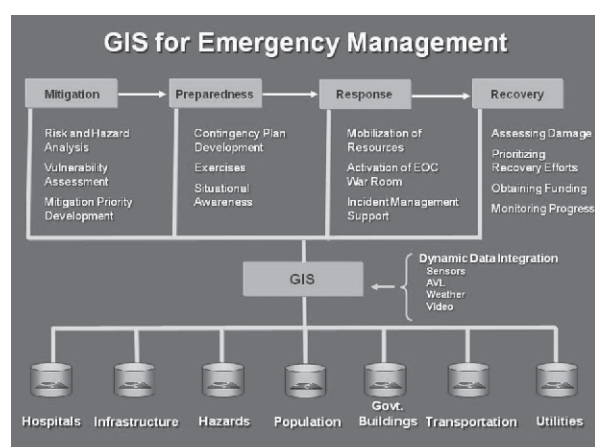


Fig. 1 GIS in disaster management (Source: ESRI white paper, October, 2008)

risk and assigning them varying vulnerability weightages depending on their proximity to the coast line, proximity to a creek/inland water body, proximity to road connectivity and proximity to evacuation shelters. Thematic layers and spatial datasets are integrated and geographically analyzed to derive meaningful data on vulnerability of the coastal settlements. The secondary hazard area like creeks and connected water bodies near coast line are also mapped. Using this digital database, Coastal Regulation Zone (CRZ) is demarcated; the 200m and 500m regulation lines were drawn in QGIS uniformly along the coast from the High Tide Line (HTL). The Coastal Regulation Zone (CRZ) was delineated by creating a buffer of 200m from the High Tide Line (HTL) which is the No Development Zone (NDZ) and another buffer of 500m was created from the HTL as per the government of India CRZ standards (Fig. 3). The settlements in CRZ zones were identified using buffer analysis in QGIS. The risk zone mapping includes identification of the settlements with high hazard vulnerability near coast line and Coastal Regulation Zones (CRZ) that has little or no road connectivity and are far away from the evacuation shelter. The second part includes appropriate tracking of evacuation routes and modes of evacuation in terms of the geographical context, air lift and supply capabilities by means of helicopters need to be used in areas that are not directly accessible after the catastrophe, two prime air service facilities were identified one is the Porbandar airport and another one is a helipad located in Bokhira Panchayat ground were identified with reference to the coast and town of Porbandar which can be used in rapid response activities operating from remote. The next is mapping locations where evacuated people can be safely kept, which include open spaces, schools or colleges, public and community assets with sufficient capacity, situating at a safer distance from vulnerable coastline. The Maharani Shree Baluba Kanya Vidhyalaya, Arya Kanya Gurukul School and ST. Marys School were identified.

The final analysis includes generating the settlement vulnerability map for the settlements in the area. Techniques to measure vulnerability have varied according to the discipline assessing the vulnerability and “what” is “vulnerable to what”. Depending on the perspective of the analysis, there can be social vulnerability (Carmen et al. 2003), which addresses the capacity of human populations to respond to an event. A coastal disaster vulnerability mapping of settlements for tsunami hazard is attempted against risk of the area. Different vulnerability ranks were assigned to the settlements depending on criteria like, road connectivity of the settlements, coastal proximity of the settlements, proximity to inland water bodies and proximity of evacuation shelter of the settlements. Different index values were set to sum up the vulnerability index of the area

All the data was projected into UTM 42N, WGS84, the study area was then divided into grids of 30m x 30m interval and the settlement layer having risk ranking was intersected with the 30m grids and centroids were generated for each grids in QGIS. This point layer having different vulnerability weightages was used for further analysis based on the Inverse Distance Weighted interpolation technique in QGIS a 3D raster model is developed to generate a settlement vulnerability map (Fig. 4). It can be done by the assumption that grids containing features which are not settlements or any other human or living establishments can be omitted as zero vulnerable and the 30 m grids containing adjacent or contiguous settlement patterns can be further included in a comparatively larger vulnerability rank. The priority will be given more to the settlements which are within 200m from the shoreline and other criterion which increases the vulnerability value is the proximity to creeks and low lying areas. The settlements which intersect the roads and in the West side will be given priority more than those which intersect grids in the East. The concentration of raster colors representing high vulnerability can be mapped as the areas which need preference

in the time of information, orientation and rescue. The strategy implemented to address coastal disasters vulnerability of the settlements in the region aim to attend to emergencies rather than plan for prevention. This study will help non geospatial groups in multi dimensional visualization of vulnerability while participating and responding in a disaster scenario.

Results and discussion

In many countries like India, risk analysis is limited to hazard mapping, showing areas where different levels of hazard can be expected and the past occurrences. The available risk information is usually at too limited in spatial and temporal resolution to provide useful information on increasingly complex and dynamic risk patterns. Even where risk analysis takes into account vulnerability, this is normally restricted to the physical aspects. In most countries it is extremely rare to find risk analysis to take account of the social, economic, institutional and cultural aspects of vulnerability (Srivastava et al. 2004). During the preparedness and response phases, GIS can accurately support better response planning in areas such as determining evacuation routes or locating vulnerable infrastructure and vital lifelines, etc. It also supports logistical planning to be able to provide relief supplies by displaying previously available information on roads, bridges, airports, railway and port conditions and limitations. Apart from this, activities such as evacuee camp planning can also be done using GIS. It can also provide answers to some of the questions important to disaster management, such as the exact location of the fire stations if a five-minute response time is expected or the number and locations of paramedic units required in a specific emergency. Based on the information provided by GIS, it is also possible to estimate what quantity of food supplies, bed space, clothes and medicine will be required at each shelter based on the number of expected evacuees.

Paper highlights the potential use of OSGIS in disaster management. Quantum GIS and Google Earth, jointly can be used effectively in disaster

management activities. OSGIS is a cost effective method for local level community preparedness and public participatory geographic information sharing, it can be used for organizing mock drills and community preparedness plans. GIS can be implemented at the local level through qualified local body officials by the use of OSGIS. Local body representatives could be trained in use of QGIS software. The local knowledge on disasters is highly important; OSGIS helps in taking technology to the common people. More efforts should be made towards capacity building of local people by use of available resources. It will help in developing their own knowledge base, and to develop methodologies like public participatory GIS, that promotes activities for reducing risks in a sustainable way thereby increases disaster resilience of the community by making people think spatially there by helping them better understand the area they live in and the risk they are exposed to. Spatially referenced accurate information allows the command and response units to work more efficiently and coordinate regional disaster response more effectively with the spatial location known and with a proper plan figured out, people will still have a chance to stand to the disaster.

Conclusions

This study gives an idea, how effectively Open Source Geographic Information System (OSGIS) and Google Earth can be used in disaster management the high resolution imagery available in Google Earth is imperative as a means of enhancing local level and large scale mapping efforts in disaster management. The present study delineates the purpose of an assessment of the area during a coastal disaster like storm surges, cyclone or tsunami, with special preference given to early evacuation planning and community preparedness and an information system developed in QGIS platform. The main aim of this study is to achieve the task-specific delivery of geographic information to those in actually facing or responding to a disaster. The quality and timeliness of response services during a disaster can be improved using

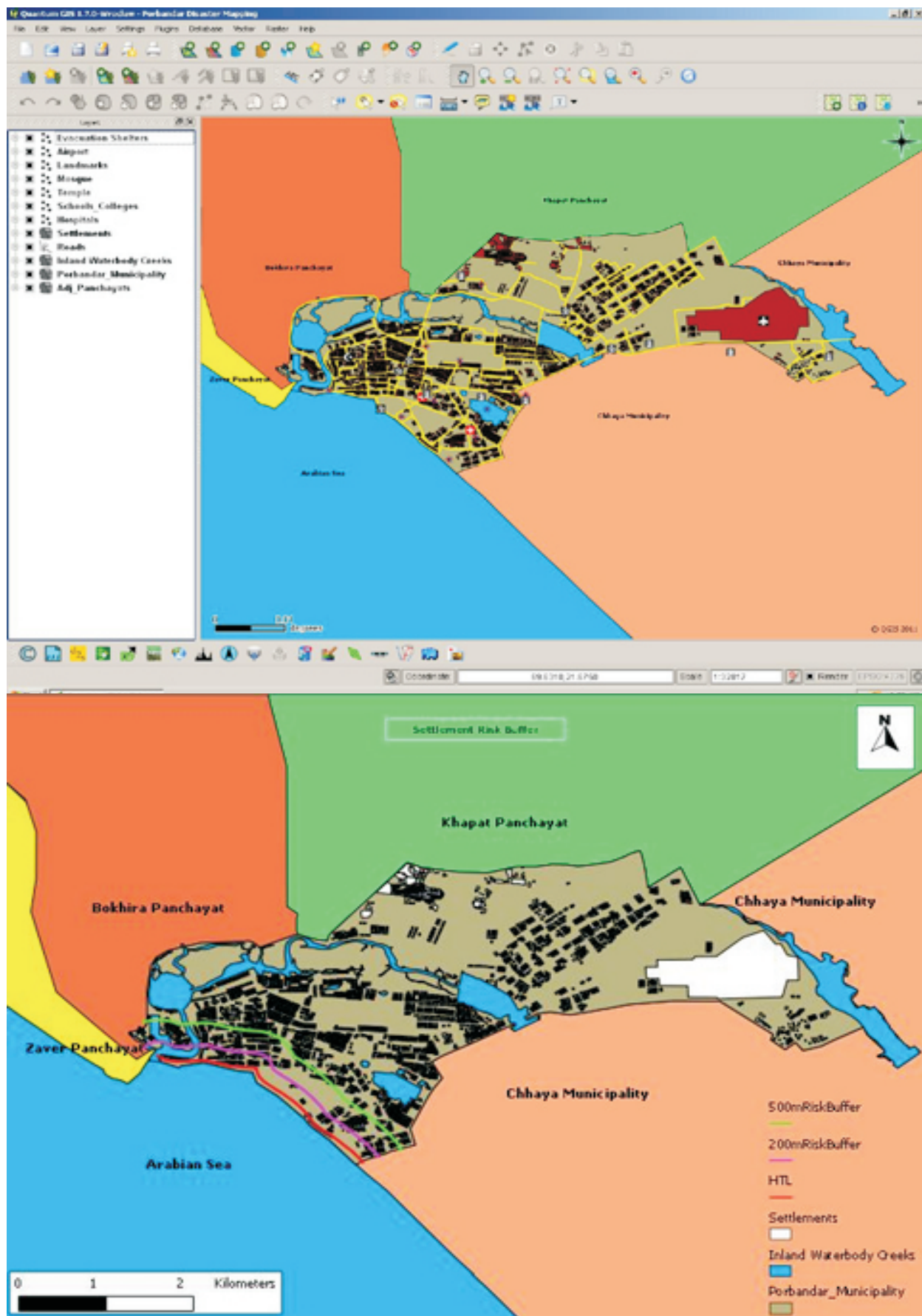


Fig. 2

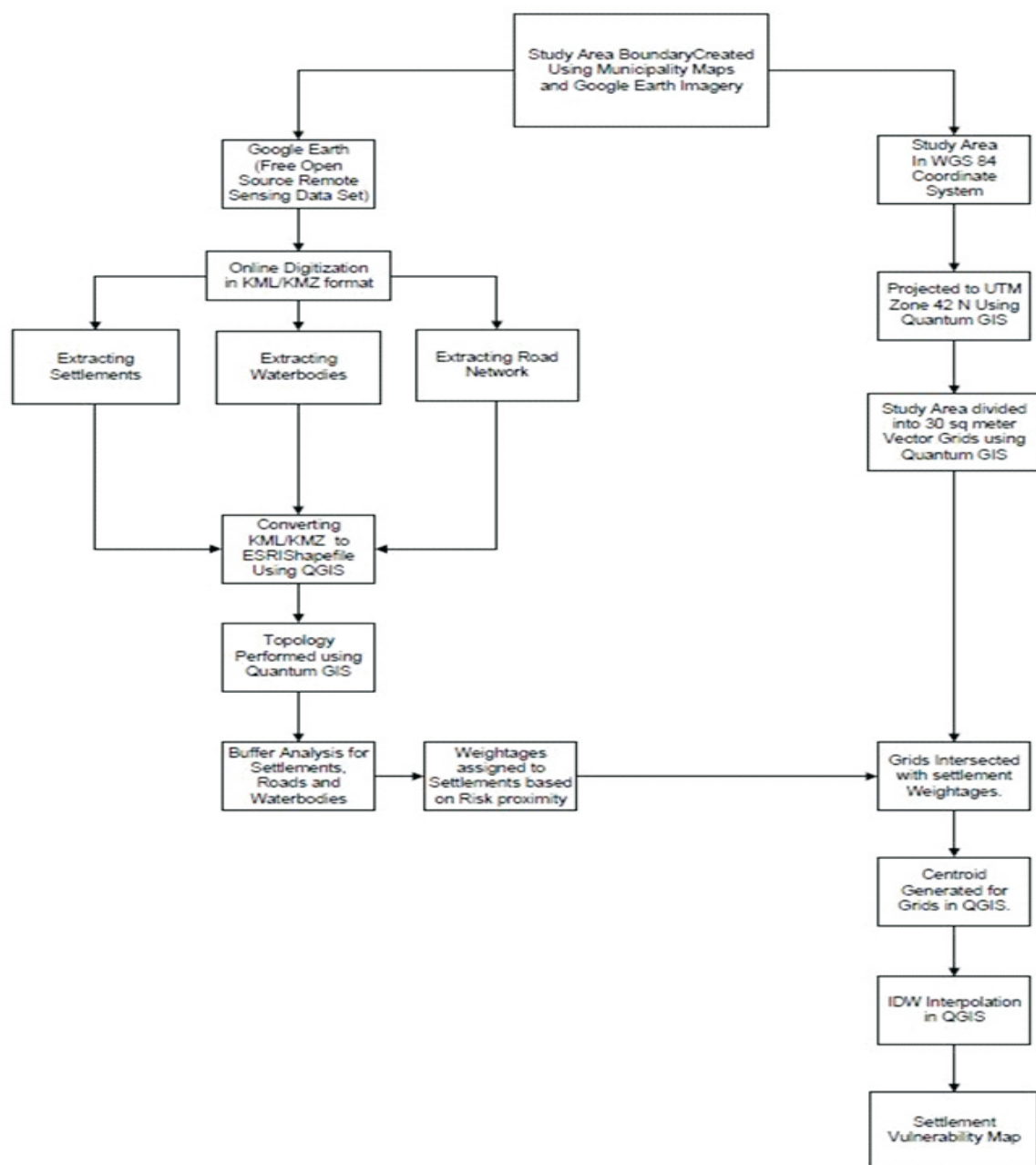


Fig. 3 Settlement risk buffer

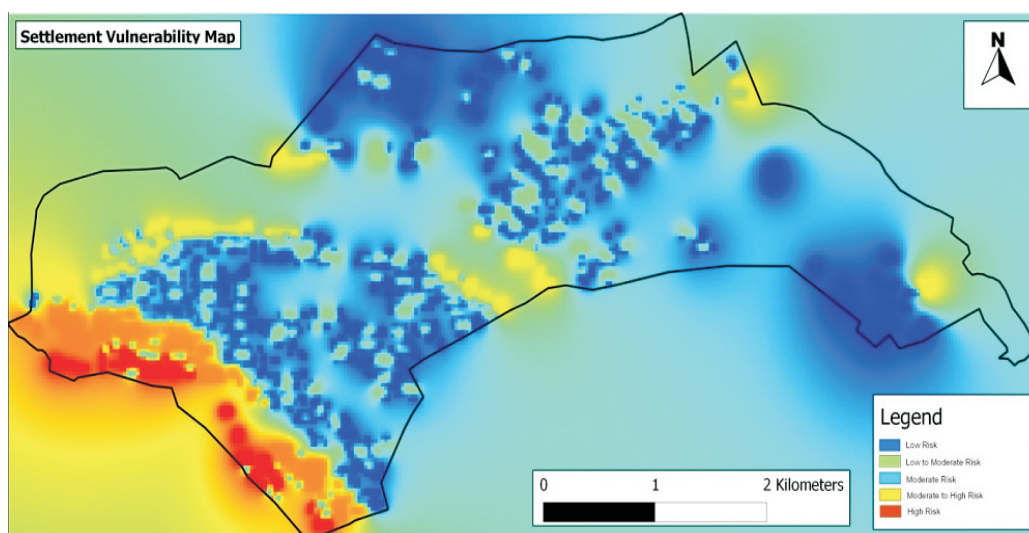


Fig. 4 Settlement vulnerability map

this system. Crisis mapping has evolved over the past few years with the aim of making the process more collaborative and more immediate. It provides vital information to disaster managers for strategic planning. Use of OSGIS is a cost effective method for local level community preparedness and public participatory geographic information sharing, it can be used for preparing maps for organizing mock drills and community preparedness plans, GIS makes people think and act spatially. Accurate information allows the command and response units to work more efficiently and coordinate regional disaster response more effectively with the spatial location known and with a proper plan. Disaster management plans are to be integrated within the mainstream planning and development activities of local authorities and GIS needs to be deliberately

infused into these activities for a better disaster resilient society. The local authorities can develop a crisis informatics unit by implementing this methodology and can make this system available to other.

References

Carmen Lacambra S. (2003), **The Need for an Ecosystem- Inclusive Vulnerability Index for Coastal Areas in Colombia.**

Drabek, T. E. and G. J. Hoetmer, (1991), **Emergency Management Principles and Practice For Local Government.**

Management an ESRI White Paper, October 2008.

Srivastava, S. K. et. al. (2004), community centric approach of geo-informatics for disaster risk reduction, **GIS Development.**

(**Manjush Koshy, Siddharth Vora, Nitish Thakkar, P. M. Sreekant** are associated with Crisis Informatics Division, Centre for Advanced Remote Sensing and Environmental Studies (CARE), Trivandrum and **J. Shaji** with Department of Geography, University College, Trivandrum, Kerala, India.

Email:manjushkoshy@yahoo.com)

A GIS-based Avalanche Hazard Mapping for Manali Region, Himachal Pradesh

Snehmani, Satish Kumar, A. Ganju, M. R. Bhutiyani

Abstract

Accurate mapping of avalanche hazard is of primary importance especially in the case of transport routes, tourist spots, and settlements in the mountainous region. However, only a few models do exist for Avalanche Hazard mapping in the Himalayas. The present study proposes a new method to generate avalanche hazard maps and also to estimate avalanche run-out distances. A high resolution Digital Elevation Model (DEM) was generated with the help of Cartosat-1 panchromatic stereo imageries to extract various terrain parameters. Analytic Hierarchy Process (AHP) method was adopted to prepare avalanche hazard map. Avalanche run-out distance, flow height, velocity, momentum, and impact pressure were calculated in RAMMS (Rapid Mass Movements) software.

Sensitivity analysis with AHP was carried out in GIS environment. Sensitivity analysis indicates that the evaluation map derived from base could be used for avalanche hazard mapping. Moreover, the results show a good association with the registered/recognized avalanche sites in field. Two new potential avalanche sites, identified, were located near Manali north portal.

Introduction

Avalanches are triggered mainly because of terrain factors, snow pack properties and meteorological parameters. The Himalayan region has varying terrain and snow properties and receive heavy snow fall, leading to severe avalanche activities. Presently avalanche forecasting, structural control and artificial triggering of avalanches are being used to reduce the avalanche dangers. Avalanches are more frequent during January to March, the period the Himalayan ranges experiencing heavy snowfall. Thus the avalanche activity affects the army posts, road network, villages etc. The Himalayas are classified in three zones: the Lower, the Middle and the Upper. A large part of the Himalayan ranges are covered throughout the year with snow, and have varying seasonal characteristics in winter and summer.

Study area and Dataset

The study area covers parts of road axis along Manali-Leh highway. This area is covered under part of Survey of India mapsheets 52 H/2 and 52

H/3. For the purpose of avalanche terrain classification, the study area can be divided into two zones: (i) Lower Himalayan zone, and (ii) Middle Himalayan zone, Rohtang pass serving the divider. The former zone experiences the heavy snowfall, moderately high temperatures and intense avalanche activities. It experiences short winter from November to February when the temperatures are in the range of 0-15 degree Celsius and maximum precipitation being experienced, snow cover is dry to moist. The time from March to May experiences high temperatures and rapid ablation. The snow cover during this time rapidly changes from dry to moist and wet. It lies on windward side of Pir Panjal range, slopes having vegetation up to an altitude of 2800 m. The latter region experiences low temperatures and low precipitation owing to leeward side of slope. There is very thin vegetation and roads generally on southern aspect. This area experiences comparatively longer winters from October to March with temperature as low as -25°C during peak winter. The ablation period starts from April up to June.

This area experiences relatively lower avalanche activity. In this study, we consider terrain parameters such as slope, aspect, curvature, and elevation. Analytic Hierarchy Process (AHP) along with GIS is used for identification and demarcation of avalanche prone areas. Numerical simulation model (RAMMS) is used for calculation of run-out distances, flow height, velocity, momentum, and impact pressure. Field

observation data are used for accuracy assessment and validation of results.

Cartosat and LISS data are acquired from NRSC. IRS 1-D LISS III multispectral imagery, dated 02-February-2008 and 17-April-2008 at the resolution of 23.5 m were used for characterization of ground cover. Two SOI Mapsheets were used to generate contours, Drainage, Settlement, Tracks and Forest cover.

Methodology

The Analytic Hierarchy Process (APH) was adopted for mapping of avalanche prone areas (Saaty, T.L., 1977). This is multi criteria decision analysis method and a numerical simulation model (RAMMS).

Survey of India topo-sheet on 1:50, 000 scale was used to generate the drainage, settlements, tracks and forest cover. To carry out terrain analysis, the high resolution Digital Elevation Model (10 m) was generated from Cartosat-1 Pan Ortho Stereo imagery, dated 29th September, 2006 was employed. Slope, Aspect, Curvature and Elevation maps were generated using Digital Elevation Model.

Analytic Hierarchy Process (AHP)

In the present study, Analytic Hierarchy Process (Saaty, T.L., 1977) was used to calculate the weighting factors with the help of preference matrix, where all the identified relevant criteria were compared against each other with

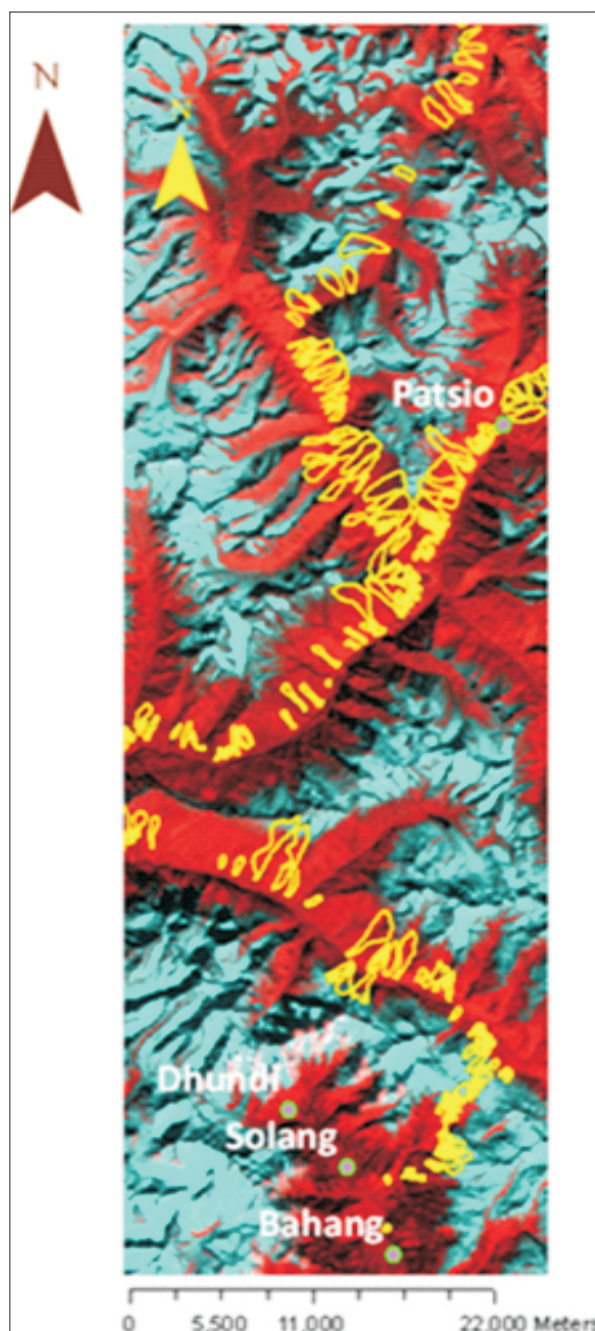


Fig 2: Analytic Hierarchy Process

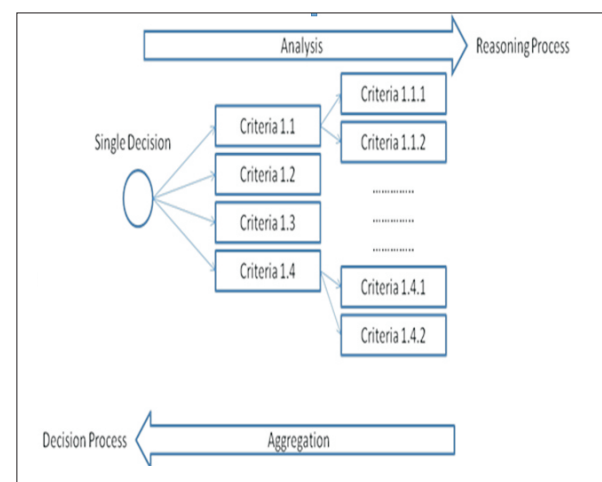


Fig 2: Analytic Hierarchy Process

reproducible preference factors.

Analytic Heirarchy Process (AHP) is the aggregation of criterion approach. This method facilitite to make a decision in logical manner. The decomposition of the problem, comaparitive process and heirarchic aggregation of the priorities (See Fig. 2). At each level of the heirachy, a preference matrix is built up through comparison to access the decision maker preferences between the criteria of considered level. The parameter used in this method to check consistency ratio. Consistency ratio is the measure of how much variation is allowed and it must be less than 10%. (Satty, T.L., Vargas,) suggested a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance (preference/dominance). Following table gives the scale of comparison.

Table 1: Scale of Comparison in AHP
Intensity of importance

1	Equal importance
3	Moderate importance
5	Strong importance
7	Very Strong importance
9	Extreme importance
2,4,6,8	Intermediate values
Reciprocals	Values for inverse comparison

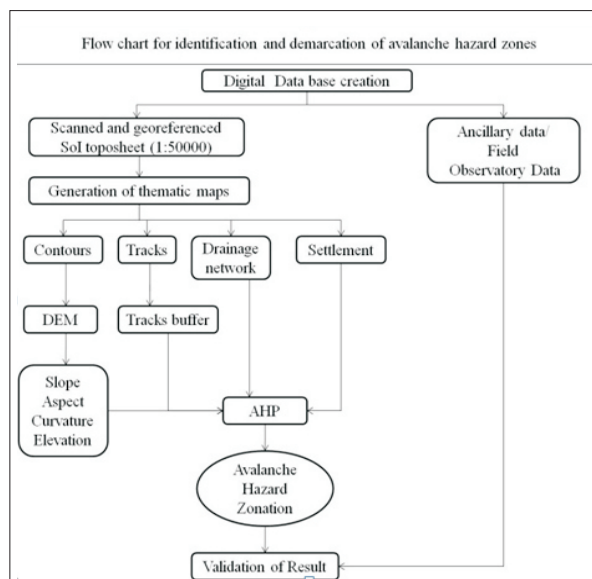
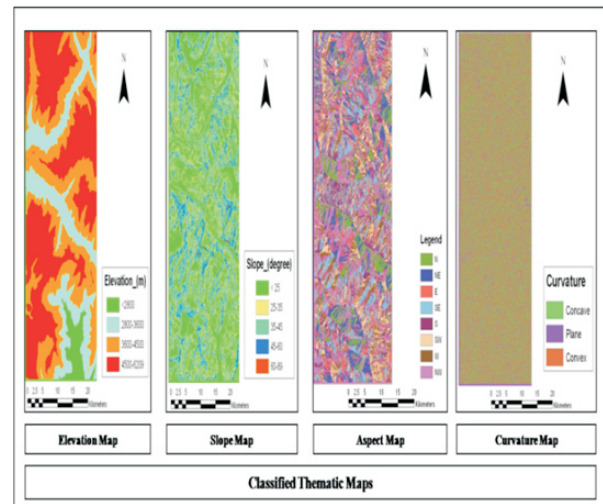


Fig. 3 Flow chart of Avalanche Hazard Mapping



*Fig. 4 Thematic maps]
(Elevation, Slope, Aspect & Curvature)*

The thematic maps e.g. slope, curvature, aspect, and elevation were generated based on DEM.

Weight assigning procedures

Weights and ratings can be determined based on the subjective expert's opinions as well as based on the objective analysis. In present study factors and their categories were assigned numerical values based on the field experience, knowledge of the experts, study area and the regression analysis of past avalanche occurrences with terrain causative factors.

Among all the factors, the slope is taken as the most important one. A range of slope between 300 and 450 was considered the most critical for avalanche formation. The slope below the 300 generally does not promote downhill movement of snow packs, and the slope above 600 is too steep to collect any significant snowfall accumulation.

Table 2: Weightage for the slope in AHP

Slope (in degrees)	Weightage
< 25	1
25-35	7
35-45	9
45-60	5
60-89	1

Source: After McCulung, D.M. and P.A. Schaerer

(The curvature/terrain shape influences the shape of accumulated snow, where the snow pack weakness would occur. On a convex slope, weight of the snow, on steeper part of the curve, sets up stress in snow pack in rounded upslope part of the curve (Maggioni, M.&Gruber,2003) see Table 3 for curvature weights.

Table 3: Weights for the Curvature in AHP

Curvature Type	Weightage
1.	Concave1
2.	Plane3
3.	Convex9

The tree line starts from 2800 m, and there are, thus, rare chances of avalanches (see Table 4 for weights)

Table 4: Weight for Elevations in AHP

Altitude (In meters)	Weightage
< 2800	1
2800-3600	7
3600-4500	9
> 4500	2

Different aspects receive different intensities and incident angle of sunlight. These variations result in inconsistent energy exchange between the pack and the atmosphere, as well as within the snow pack itself. Differing aspects also create different snow cover environments leading to stress discontinuity in snow pack, which generally causes avalanches (Shary, P.A. et. al., 2002). The weightage given is as follows:

Table 5: Weightage for aspect in AHP

Direction (in degree)	Assigned Weight
0-45	1
45-90	9
90-135	5
135-180	7
180-225	3
225-270	7
270-315	9
315-360	1

Table 6: A Cross Tabulation Matrix

	Slope	Curvature	Aspect	Elevation
Slope	1	3	5	7
Curvature	0.33	1	4	5
Aspect	0.20	0.25	1	3
Elevation	0.14	0.20	0.33	1

The assigned preference values were synthesized to determine ranking of the relevant factors in terms of numerical values which were equivalent to weight of the factor. The square matrix of order four gives four eigen values with each four eigen vectors. It is regarded sufficient to calculate only the eigen vector resulting from the largest eigen values since this eigen vector contains enough information to provide by its eigen vector components (Saaty, T.L., 1977).

The thematic maps such as slope, aspect, curvature, and elevation were mathematically added to generate Avalanche Hazard Index map in Geographic Information System. The Avalanche Hazard Index is defined as,

$$AHI = S + A + C + E$$

Where, AHI is the Avalanche Hazard Index and S, A, C, and E are the weighted thematic maps of Slope, Aspect, Curvature, and Elevation respectively.

Identification and demarcation of release points and avalanche sites

The release points were marked on basis of the AHP results. Comparing the result using 3D visualization in ArcScene. The avalanche

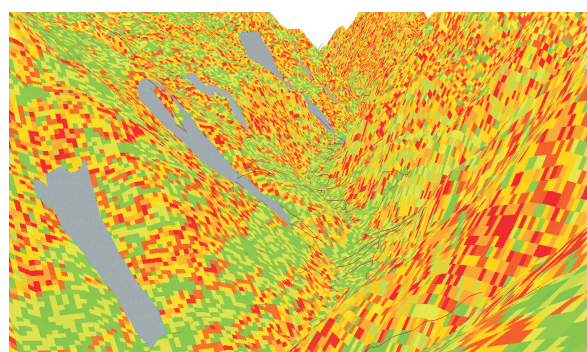


Fig 5: 3D Perspective View of Avalanche Sites

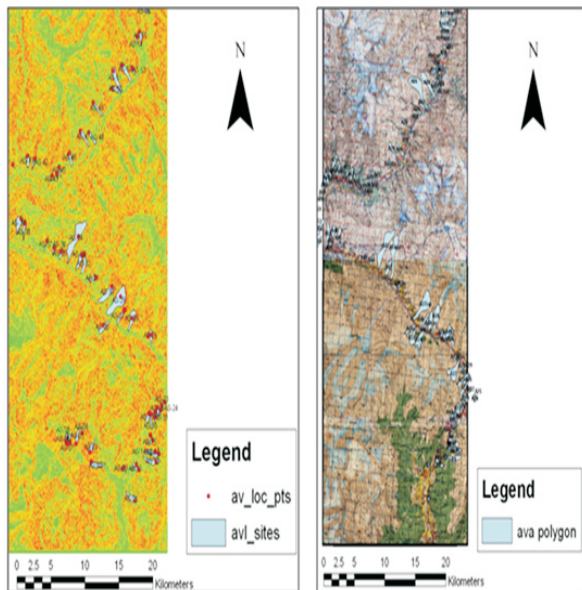


Fig 6: Avalanche Hazard Fig 7: Registered Avalanche

polygons were drawn depending on the terrain in (3D) perspective view. This procedure was provided a better visualization of the avalanche sites.

Estimation of avalanche run-out distance

The avalanche release area is an important parameter to be estimated for avalanche hazard mapping procedure. The release area is often difficult to determine due to terrain inaccessibility and bad weather conditions in upper areas of an avalanche track. RAMMS was developed by "Avalanche, Debris Flow and Rock fall" research unit of the WSL Institute for Snow and Avalanche Research, SLF. RAMMS (Rapid Mass Movements) is a numerical simulation model to calculate motion of geophysical mass movements (snow avalanches, rockslides, debris, shallow landslides) from initiation to run-out in three-dimensional terrain. This numerical simulation model solves the equations which governs the avalanche flow in first and second order numerical solution schemes (ramms.slf.ch, 2010).

Avalanche is treated as an unsteady flow on two-dimensional mountain surface using Voellmy-fluid flow law. The run-out distance, flow height,

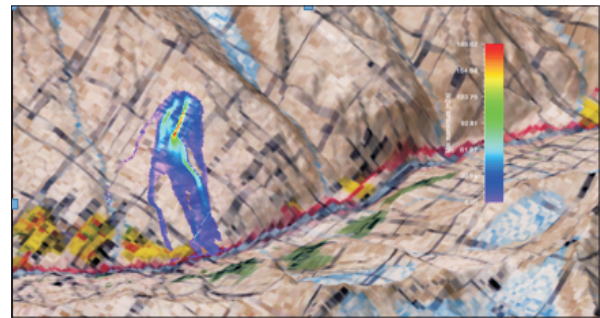


Fig. 9: Momentum Distribution of an Avalanche Site

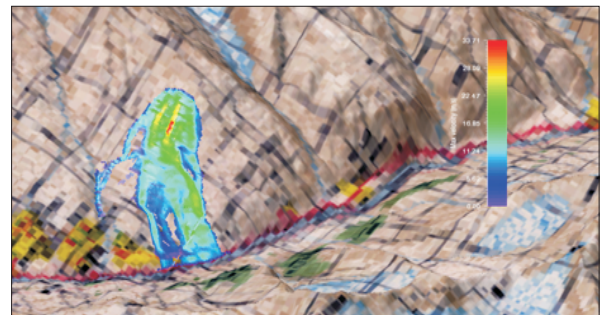


Fig. 10: Velocity Distribution of an Avalanche Site

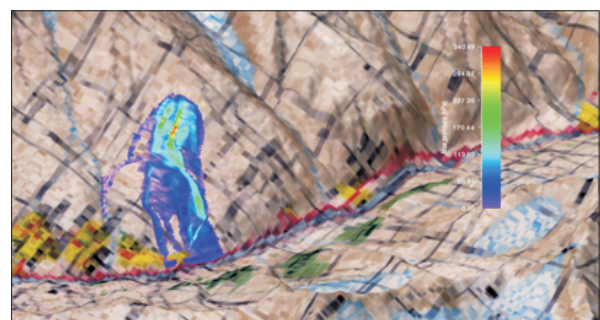


Fig. 11: Pressure Distribution for an Avalanche Site

velocity and impact pressure of the avalanche is calculated using RAMMS. This study was done by mathematical model in RAMMS using friction values for the calculation. An accurate prediction of avalanche runout distances, flow velocities and impact pressures in natural three-dimensional terrain is the driving motivation behind the development of improved snow avalanche dynamics models.

This model provided baseline information of Avalanche flow height, Velocity throughout the flow, Impact, pressure, momentum and avalanche run out distance. It was also used for creating the animation of the avalanche run-out.

Five avalanche sites were considered for comparing the results. Simulation was carried out for the friction and snow parameters for the date 02-02-2008. The snow height referred to as release height is taken from average values of three days 01-02-2008, 02-02-2008, and 03-02-2008. Friction and the snow parameters were provided by the observatory at Dhundi. Following friction parameters were taken.

Coulomb friction coefficient (μ) = 0.20, Turbulent friction (ξ) = 800 kg/S², Fracture depth (release height) = 1.9637 m, Density of snow = 300 kg/m³, End Time = 500 sec, Dump step = 10, Momentum threshold = 8%, Return period = 10 years, Avalanche type = large, Numerical scheme = second order.

AHP is the multi criteria weight sensitivity was applied for avalanche hazard mapping. A feasible range of the weights deviation was required to be specified. Four criteria were used including slope, aspect, curvature, and elevation. All these criteria were compared against each other in a pair-wise comparison matrix which was a measure to express the relative performance among the factors. The values of comparison were determined according to the scale in table 1. This analysis was applied to examine the weight sensitivity in criterion

factors. The results indicate that the derived evaluation map could be used for mapping of avalanche prone areas. Sensitivity analysis should be conceived in the evaluation of AHP that examine the extent of output variation when parameters including weights or criteria were systematically varied over a range of interest. This analysis shows that how change in criteria weights affects the outcomes spatially and quantitatively. The results of numerical simulation model depend upon the input parameters. The sensitivity of the avalanche run-out distance is calculated between the slopes of 300-450 in the starting zone of MSP-7 avalanche site. If the friction value is close to the critical slope, the run-out is very sensitive. If the run-out slope is increased from 80-100 the calculated run-out is 480 m longer. Hence input parameters are strongly sensitive in the influence of avalanche run-out distance.

The influence of momentum, velocity, and pressure were shown in figures 13, 14, and 15. The velocity of avalanche run-out was strongly sensitive in the elevation of 3000 m-3200 m which was recorded from 20 m/s to 30 m/s.

Pressure of avalanche run-out was higher sensitive between elevations of 3100 m to 3300 m which was 200 KPa to 350 KPa. With the result of sensitivity analysis the MSP7 and MNP4 are more sensitive avalanche hazard sites.

Results and Discussion

The avalanche run-out study for five avalanche sites near the proposed Dhundi- Telling tunnel has been calculated. So as per the calculations, control measures and safety assessment can be easily carried out. Calculations for the site MSP 7 is given as: Real calculation time for MSP-7 avalanche site was 5.38 minutes. Simulation resolution was 22.0 m. Number of quad-cells were 427581. Numbers of nodes were 428892. Release volume was 338424.76 m³.

AHP was used over the other methods such as multi-criteria and statistical methods because of its robustness. Here the sub-criterion can also be

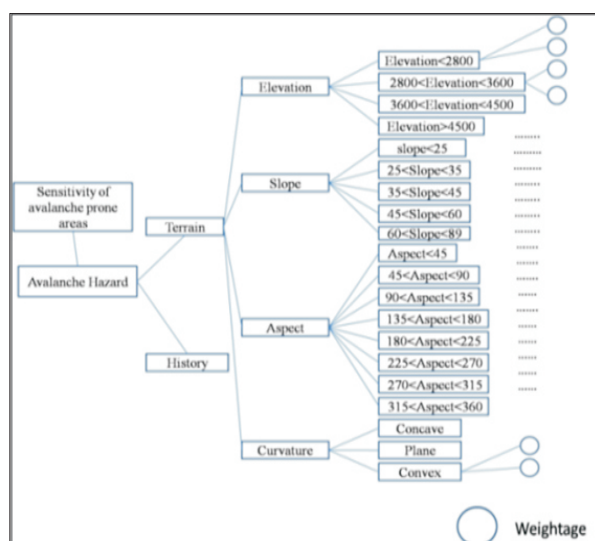


Fig. 12: Flow chart of sensitivity analysis in avalanche hazard mapping

taken in for calculation. For making decision over many criterion and sub-criteria of AHP becomes handy to assign the desired weightings to all. Thus advantage of this method, we can compare all the factors and sub-factors with each other. In AHP, the consistency ratio is numerical index to check the consistency of the comparison matrix.

The AHP results generated were analyzed with reference to the registered avalanche sites. The registered avalanche sites were prepared from direct field survey and research work done at SASE. The results show good correlation with the registered avalanche sites. This study is very useful for avalanche hazard zonation, safety assessment and planning for infrastructure in difficult mountainous regions. Two new potential avalanche sites have also been identified which are located near Manali north portal. A mathematical process of AHP has been used to find out the avalanche sites considering terrain factors. The other two factors such as meteorological parameters and the snow pack properties were not considered. As Himalayas show complex variation in the meteorological conditions in mere aerial distance of 100 km and thus the snow pack properties also change over that particular range. The registered avalanche sites were marked on basis of occurrence of avalanche in the study area. Hence the difference in the proposed and registered sites occurs. In AHP the results completely depend on the preference matrix generated by comparing the factors with each other. And expertise in assigning the proper weightage in AHP would come only with experience. To generate more accurate results time to time ground survey is very essential. Also the values obtained from the satellite data are the values at that particular instant when the satellite passes over the study area.

Overall maximum velocity was 36.5549 m/s maximum, flow height was 17.9976 m, and maximum pressure was 400.877 kPa. This study

is very useful for avalanche hazard zonation, safety assessment and planning for infrastructure in difficult mountainous regions.

Conclusions

The avalanche hazard mapping by using AHP and numerical simulation model can be used in avalanche hazard management. The RAMMS model is made especially for the Switzerland, not well suited to Himalayas. However, with some modification this model can be implemented to the Himalayas as well.

As the avalanche database will grow, future goals will become more ambitious. For maintaining the current database, more spatial information may be added. This study deals with the terrain factors causing avalanche and other factors for future scope are: Snow pack properties and meteorological conditions can be incorporated. Taking more ground observation values from observatories avalanche simulation and run-out study can be done to know the impact for snow cover type. In future, multisensory and more time series satellite data can provide more realistic output incorporated with RAMMS to get avalanche run-out distance, impact pressure, velocity of flow, and momentum of sliding snow mass.

Acknowledgement

The authors thank Vishal Chitroda, Mahesh Jagdale from SIG, Pune. Also, they are thankful to the scientists and staff members of SASE for their support and help.

References

- Barbolini, M., et. al.(2004) 'Effects of Release Conditions Uncertainty on Avalanche Hazard Mapping'. Natural Hazards, 25, 225-244.
- McCulung, D.M. and P.A. Schaerer (2006), The avalanche Handbook, The montaneous books, Seattle USA.
- Maggioni, M. and Gruber, U., (2003) 'The influence of topographic parameters on

avalanche release dimension and frequency” Cold Regions Sciences and Technology, 37,407-419.

Saaty, T.L., (1977), "A scaling method for priorities in hierarchical structures", J. Mathm. Psychol, 15, 234-281.

Saaty, T.L., Vargas, L.G., (2008), "Prediction, projection and forecasting", Kluwer academic publishers, Dordrecht.

Sharma S. S. and Ganju A., (2000), "Complexity of avalanche forecasting in western Himalayas: an

overview", Cold Region Science and Technology, 31,95-102.

Shary, P.A. et. al., (2002) "Fundamental quantitative methods of land surface analysis", Geoderma, 107, 1-32.

Snehmani, Siv Kumar and C. Kumari (2005) "The Avalanche hazard Analysis along Dhundi-Darcha-Patsio Road Axis using Geoinformatics techniques" Conference Paper in Indian Society of Remote Sensing, Deharadun, India, 1-16, 2005.

(Snehmani, Satish Kumar, A. Ganju, and M. R. Bhutiyani are working at Snow & Avalanche Study Establishment, Chandigarh, India, (SASE-RDC), Him Parisar, Sector-37 A, Chandigarh-160036 (UT), India,

E. mail: snehmani@gmail.com)

Landscape Visualisation for Participatory Approach to Village Master Plans: A Case Study of Alsisar Village in Rajasthan

Milap Punia, Arnab Kundu

Abstract

The study applies geo-spatial technologies in the field of micro-level decentralized planning in Rajasthan. For the purpose, the study uses landscape visualization prototype for landscape planning for highlighting public facilities and building of importance at village level for conservation and planning. It examines the challenges and requirements of 3D visualization approach and its potential for application in decision making process of Gram Sabha. The main emphasis is on 3 D representation and providing interaction functionalities to the user to understand and comprehend features effectively in 3 D, representing changing socio-economic and ecological trends and process at various scales. Until now, geographers and environmental planners have been relying on abstract, two-dimensional representations, where as representation of public facilities in 3 D can convey spatial information effectively to all stakeholders to adopt or take decision in participatory manner towards good governance to achieve goals of decentralisation. Landscape planning would therefore benefit from technological improvements to 3D visualization tools.

Developments in the field of computer graphics have dramatically extended possibilities for representing landscapes and environmental information. Geographic Visualization refers here to a set of tools and techniques supporting geospatial data analysis through the use of interactive visualization along with proper graphic representation. In a broad sense, use of computer-supported, interactive, visual representations of (geospatial) data with human understanding and decision-making processes. It emphasizes knowledge construction over knowledge storage or information transmission by integrating local landscape values into design process. For this study, Alsisar village in Jhunjhanu district of Rajasthan is being attempted for rural landscape and 3d modeling. Datasets used are for land-use ecosystem at village level are IRS-P6, LISS-IV images and free Google Earth images for extracting different features like, roads, settlements and drainage etc. This study also attempts high resolution satellite data, stereo data, free data available and models cutting across various platforms like GIS environment, Graphic interfaces for analysis, dissemination and visualization.

Keywords: Landscape, visualisation, 3D modeling, decentralization, Village plans, rural planning.

Introduction

Landscape is being perceived by scholars in various ways, namely objective sense, perceptual subjective, functional and as a dynamic object, undergoing change with time. The process of landscape changes (ecological and social subsystems of the landscape) and the forces driving these processes, as well as their consequences, were studied in their historical context at several spatial hierarchical levels (country, region and survey areas in different types of landscape). Ervin, 2001 stated six

landscape elements for which interaction (machine or real) can be designed for modeling. They are landforms, vegetation, water, structures, animals including human and atmosphere. Richard Hobbs (1997) also speaks of the landscape as the best scale for measuring local effects of global changes, one must add that for an actual landscape and for management and planning policy, it is often essential to conceptually organize landscape components-internally heterogeneous, functionally variable and spatially fluctuating- into regions or localities. Considering the close linkages

between natural and social phenomena, impacts in landscape can only be evaluated on a clearly delimited spatial-temporal level, i.e. based upon a conceptual and data framework.

Ervin's elements can be extracted from earth observation sensors and can be further modeled in GIS environment and finally the results can be disseminated through WebGIS functionalities. Elements can be 2 D, 2 ½ D and 3 D, which needs to translate into a model for various applications. The model describes the process of forming the shape of an object. The two most common sources of 3D models are those originated on the computer by an artist or engineer using some kind of 3D modeling tool and those scanned into a computer from real-world objects. Models can also be produced procedurally or via physical simulation. 3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling) or scanned. 3D models are widely used anywhere in 3D graphics. Actually, their use predates the widespread use of 3D graphics on personal computers. The need for 3D information is rapidly increasing. Currently, many human activities make steps toward the third dimension, i.e. urban planning, land use, environmental monitoring, telecommunications, public rescue operations, landscape planning, transportation monitoring, real-estate market, hydrographical activities, utility management, military applications. Basically, the area of interest grows significantly when 3D functionality is offered on the market. Moreover, the role of geo-information in all kinds of business processes is getting quite transparent. The research in 3D GIS is intensive and covers all aspects of acquisition, storage and analysis of real world phenomena. Among all, 3D analysis and other related issues (topological models, frameworks for representing spatial relationships, 3D visualization) are mostly in the focus of investigations. Ervin and Hasbrouck

(1999) present a concise history of visualization techniques for landscape planning. Over the past 15 years there has been an increase in research projects seeking to develop or apply technological tools for 3D landscape modeling; Danahy, 1989; Danahy and Hoinkes, 1995; Herwig and Paar, 2002; Snyder, 2003). Cambray (1993) proposes CAD models for 3D objects combined with DTM as a way to create 3D GIS that is a combination of Constructive Solid Geometry (CSG) and B-rep. Pigot (1995) developed a 3D topological model based on 0,1,2, 3 cell, which maintains an explicit description of relationships between cells. Work by Pilouk (1996) focused on the use of TIN data structure and relational database for 2D and 2.5D spatial data. He proposed an integrated data model for 3D GIS (i.e. TIN and 3D FDS), which produced a practical approach to the problem. Moreover, the author developed the Tetrahedron Network (TEN) data structure that is based on simplexes. The structure assures a strict consistency check, built on the generalized Euler's Equality.

Landscape Planning has (Bishop, 1994) covered a new approaches to GIS-based landscape visualization. It addressed landscape assessment, GIS-modelling, visual representation, and perceptual issues in digital landscape representation. These included questions of realism and perception of simulated landscapes as well as representational validity and criteria. There are a number of neglected or unresolved research areas requiring further exploration. These include issues of real world dynamics, human perception of landscapes, simulated sensory environments, new and emerging technologies, as well as landscape visualization for improved communication, public engagement, and decision-making (e.g. Lange and Hehl-Lange, 2005).

Major advances took place in the ways how we represent and assess the landscape, and likewise how we use simulation and virtual representation in environmental decision-making (e.g., seminal work by Zube et al., 1987).

Although the visual is by far the dominant human sense, focusing only on the visual aspect of landscape design provides us with only a partial “view”, literally, of our environment. Further developments in landscape visualization may spur greater informed public participation as supported by visualization technology for communication between policy makers and non-experts (e.g. mobile phone augmented reality allowing the streaming of data of planning proposals while one is on-site), improved integration of landscape quality in decision-making, and a pro-active approach to shaping our future environments. This would require further investigation into the use of 3D visualizations and the relevant phases of planning and design, the primary audience, and the level of engagement. Landscape characteristics are the real evidence of the activities and activities of the people who occupied, developed, used and shaped the land to serve human needs, they may reflect the beliefs, attitudes, traditions, and values of these people. There are several processes to understand much better of rural landscape, viz. Land Uses and Activities, Patterns of Spatial Organization, Response to the Natural Environment, Cultural Traditions. The major components are Circulation Networks, Boundary Demarcations and Vegetation Related to Land Use, Buildings, Structures, and Objects, Clusters, Archeological Sites, Small-scale elements. Appleton and Lovett (2003) also show that how GIS-based visualization helps to take a decision for rural landscape or environment planning. Landscape based modeling is necessary for the rural landscape planning, conservation of water bodies, compared to its application in project assessment, such as EIA (environmental impact assessment) or for simulating landscape change. Landscape planners and researchers have adopted technologies that were developed for other areas (Steinitz, 1992). Zube, et. al., (1987) review various simulation techniques, and conclude that the future of 3D landscape visualizations lies with computer graphics. 3D visualization

can offer information that cannot be provided only by land use maps. Therefore 3D visualizations can be helpful in stakeholder discussions on environmental and ecological effects of land use changes. A number of scholars have discussed the potential contribution of maps to a comparable policy domain, that of participatory spatial planning (PSP), for example Ball (2002), Tress and Tress (2003) and Hoogerwerf (2005).

Data models are necessary in order to process and manipulate real world objects with computer. The data models are abstractions of real world objects or phenomena. Abstractions are used in order to drafts or manipulate the complex and extensive reality. Each attempt to represent reality is already an abstraction. The only complete representation of a real world object is the object itself. Models are strictures, which combined abstractions and operands' into a unit useful for analysis and manipulation. Using models the behavior, appearance and various functions of an object or buildings can be easily represented or manipulated. In principle, 3d model can subdivide into three independent classes, the wire frame model, the surface model and the solid volume model

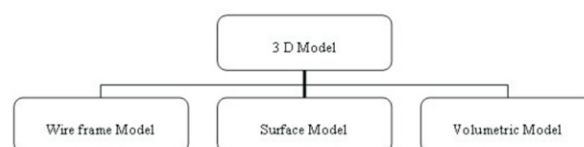


Fig: 1 Types of 3D model (adopted from Kasser, M. and Egels, Y., 2002)

Among the most commonly used volume models are the boundary representation and the constructive solid geometry (CSG).



Fig: 2 Data Frame model, 3D model and real view of model

Boundary representations describe a three dimensional objects are elements (faces, edges and vertices). A boundary representation holds implicit a hierarchy in its data structure. An object is defined by its faces, the faces by its edges, the edges by its vertices and the vertices by 3 coordinates. A BRep model is organized in topologic part and geometric part. Whereas topologic part describes the neighborhood relations between vertices, edges, and faces. The geometric part holds the geometric information about the topologic elements (e.g. the three coordinates of the vertices).

Constructive solid geometry describes the object instead of its bounding faces and edges by a set of defined volumetric primitives and basic operations of these primitives. The basic idea is that complex objects are represented a ordered, addition, subtraction and intersections of simple objects. The primitives, who are used to the sequential built up in model, are directly visible in the data structured. Hence, basic volumes like cuboids, cones, globes, cylinders etc. are contained in the data structured as primitive and directly accessible.

Broad objective and Study Area

This study is theoretical for comprehending concept of geovisualisation and technical in sense to conceptualise various methods to represent geographic space in absolute and realistic way. To answer some questions may be in later part of this study about like, what more 3 D can contribute to understand geographic space? How good geographic features can be represented in 3 D? Interpretation and observation of processes through which a socio-economic, ecological and natural landscape has gone through. For this research initiative, an attempt will be made to strengthen participatory approach to planning processes especially in rural from PRIs perspective of decentralised planning as well as urban landscape. Village can be considered as large biomes or ecosystems given resource components, linkages and interdependence. Village ecosystems are more often subject to changes and variability with respect to

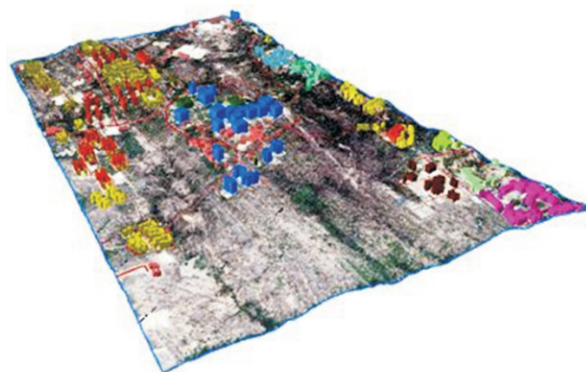


Fig: 3 Integration of continuous and discrete landscape features

composition, functioning and production. The components of village ecosystem include resources such as land, soil, water, vegetation, fauna and livestock, and activities such as agriculture, animal husbandry and fisheries. Thus, large villages (small agrarian towns) like Alsisar, Fatehpur and Mandawa in Jhunjhunu district of Rajasthan is undertaken. For prototype developing and testing it is attempted on Alsisar and JNU campus. Total population of Alsisar village was around 4699 in 2001 and it was 2199 in 1961 as per census.

Methodology

Topographical features are used for basic information and these features are updated, integrated with the help of high resolution remote sensing datasets, viz. roads, building foot prints, drainage, wells, trees and other features. Some features are extracted from Google Earth images in kml format and are reshaped in GIS environment. Realistic 3 D structures are made in sketch up environment for further integration in GIS for application based on utility. For doing this real structure, texture and dimensions are required. They were collected from field using DGPS, laser distance meter and terrestrial camera. So, its an integrated approach using landscape elements in GIS -> 3 D Model-> WebGIS functionality along with interactions at users level to comprehend landscape. Use this method 3d view of the JNU campus has been shown (Fig: 3).

Result and discussion

Land use at finer scale such as the village

ecosystem is significant as such systems are highly dependent on the land resources. Agriculture is directly driven by availability of arable land and water resources. Thus rural communities and their livelihoods are directly dependent on the land resources, and land use change has far reaching consequences in a village ecosystem with implications for major services. Land use/ cover classes are extracted from LISS-IV of IRS-P6 remote sensing data of 04 November 2008 using supervised classification method. Main classes in the region are agriculture (mainly after monsoon rains only), settlements, wasteland (sand dunal area), forest, plantation, water bodies and current fallow.

The Article 243-G of the Constitution of India provides that the States/ UTs may bestow Panchayats with such powers and functions to enable them to prepare plans for economic development and social justice and to implement them. Every village panchayat is empowered to make its own plan and can forward their master plans through gram sabha

to district planning committee to approve it for financial sanctions or requirements. From village plan perspective, buildings of public infrastructure are identified, namely schools, medical facilities, panchayat bhavan, patwar bhavan, post office, rural banks, day care, electricity grids, pumping stations, religious places, cremation grounds, places of historical importance, libraries and structures for water conservation and storage. Other units which are of interest are forest land, common property resources and grasslands.

While planning for village master plan, some land allocation should be thought of for commercial purposes, road construction, sewage, houses for poor or landless, community centres and structures for water conservation and management. Some margin area for future requirements needs to be left out around roads as per importance and transport demands. For this a buffer of 100 feet from national and state highways, 50 and 60 feet for district or rural

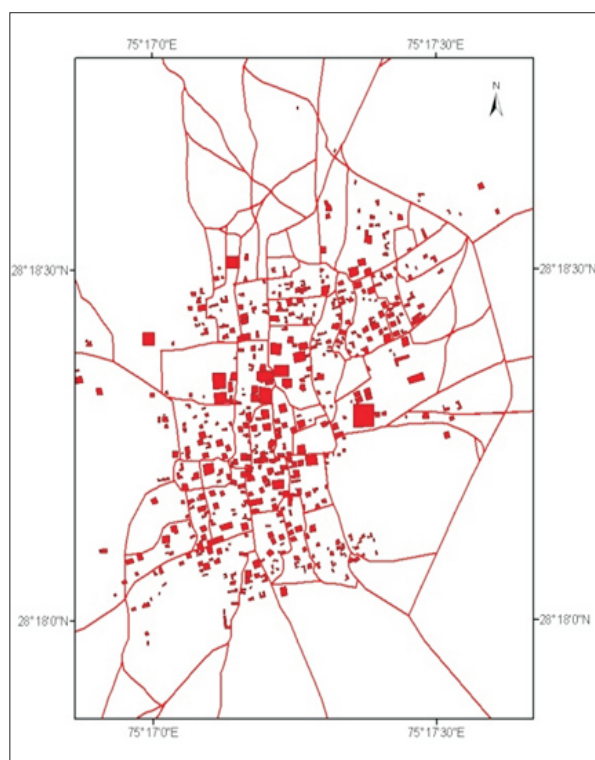


Fig: 4 Alisar Buildings and Road Networks (2D view)

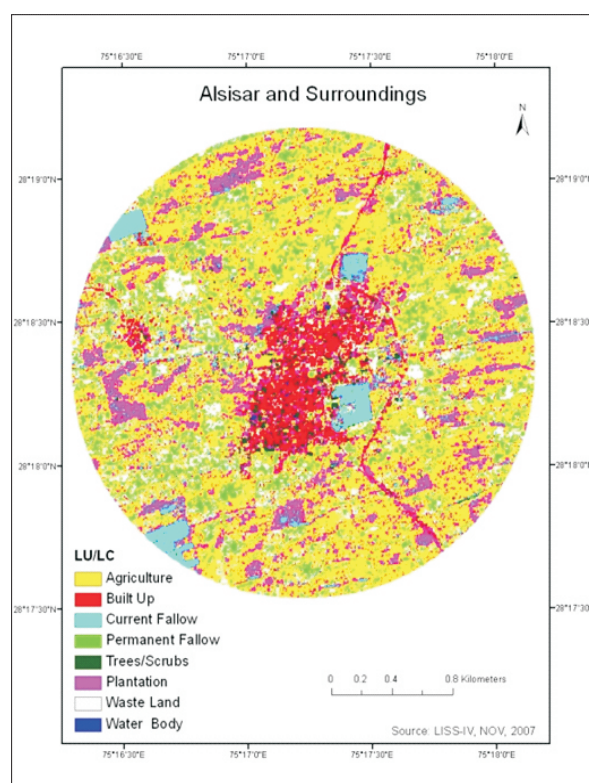


Fig: 5 Supervised Classifications with 5 kms Buffer from village centre

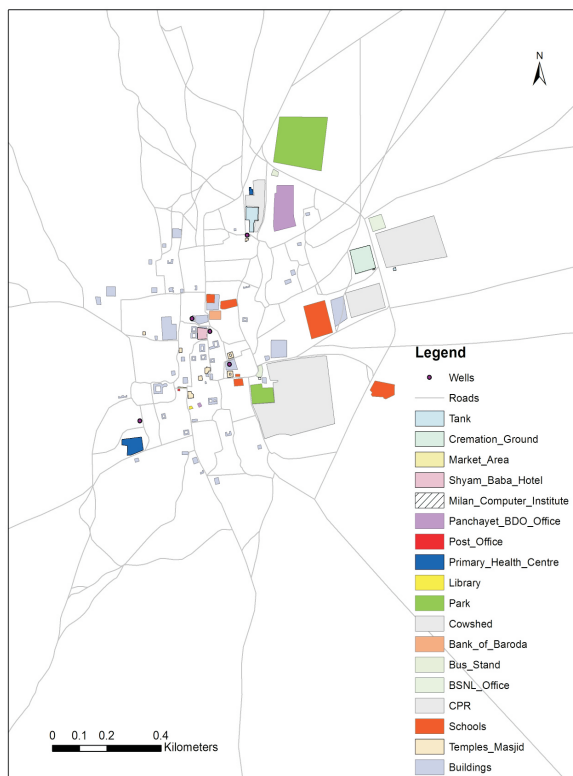


Fig. 6 Village Master Plan

roads from its centre line.

Building heights and façade texture is captured in field through distance laser meter and camera for generating realistic model as shown in Fig. 2. Linear features like road network, metalled and kachha roads are accurately extracted. Building as well as area features like farm and playground are also extracted from GE with in required accuracy to represent on 1: 4000 scale. It has been updated and validated by Leica DGPS acquired roads and area features.

Village has gone through spread in number of settlements, mainly consists of old havelis, traditional wells for water conservation and utilization, ponds, temples and other habitation. Thus, this technique can help to manage resources locally and for designing village master plans under PRI. During field work, it was felt that even selected representatives of PRI were quite supportive of this discussion about making master plans and representing available infrastructure in 3 D and representing changing landscape at various scales. The surrounding area has been shown in 3d view for visualization.

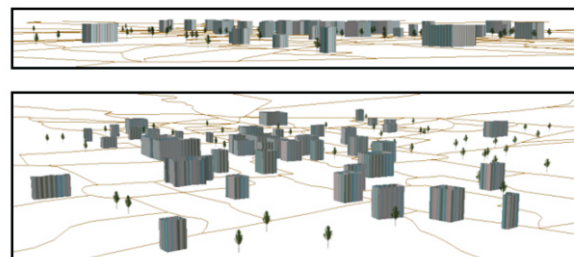


Fig. 7 3D view of study area in OGC- 3 D- LOD-1 format.

The building footprint is of sufficient accuracy to further model it and represent it in 2 ½ and 3 D. Since in this study, the focus is on representing buildings along with elements like terrain/landform which can be used for resource planning at that level. Representation of public facilities in 3 D can convey spatial information effectively to all stakeholders to adopt or take decision in participatory manner towards good governance to achieve goals of decentralisation.

Conclusions

It is observed that initially proposed prototype is beneficial for representing a region as a landscape and further generating model in 3 D for old havelis and traditional wells as area features. This project is still attempting to extract 3 D features and landscape elements from stereo products like cartosat-1 and from cartosat-2. It still needs to exploit the dissemination and geovisualisation potentialities of available free web functionalities. Finally various stages and processes will be translated into web academic content in theory and real Indian case studies on geovisualisation for e-learning course.

References

- Ball, J., 2002, "Towards a methodology for mapping 'regions for sustainability' using PPGIS", *Progress in Planning*, (58), p.81-140.
- Bishop, I.D., (1994). Introduction: special issue landscape planning: expanding the tool kit. *Landscape Urban Plan.* 30, 1–2.
- Cambray, de B., (1993). Three-dimensional (3D) modelling in a geographical database. *Proceedings of AutoCarto 11, Minneapolis, USA*, pp.338-347.

Danahy, J. W. (1989). Irises in a landscape: an experiment in dynamic interaction and teaching design studio, In M. McCullough, W. J. Mitchell, & P. Purcell (Eds.), *Proceedings of the CAAD Futures_89*. The electronic design studio: Architectural knowledge and media in the computer era (pp. 363–376). Cambridge, MA: MIT Press.

Danahy, J. W., & Hoinkes, R. (1995). Polytrim: collaborative setting for environmental design. In M. Tan & R. The (Eds.), *Proceedings of the CAAD Futures_95*, CASA. The global design studio (pp. 647–658), National University of Singapore.

Ervin, S. M., & Hasbrouck, H., (1999). 30 years of computing in landscape architecture. *Landscape Architecture* (November), 54–56.

Ervin, S. M., (2001). Digital Landscape Modeling and visualization: a research agenda, *Landscape and Urban Planning*, 54: 49–62.

Hehl-Lange, S., (2001). Structural elements of the visual landscape and their ecological functions. *Landscape Urban Plan.* 54, 105–113.

Herwig, A., & Paar, P. (2002). Game engines: tools for landscape visualization and planning? In E. Buhmann, U. Nothelfer, & M. Pietsch (Eds.), *Proceedings at Anhalt University of Applied Sciences. Trends in GIS and virtualization in environmental planning and design* (pp. 162–171). Heidelberg: Wichmann.

Hobbs, R. J., (1997). Future landscape and the future of landscape ecology, *Landscape and*

Urban Planning, 37(1): 1–9.

Hoogerwerf, T., and R. van Lammeren, (2005), "The suitability of visualizations with a different degree of realism for participatory spatial planning". WU-CGIWeb- article, 2005a.h.

Kasser, M. and Egels, Y., (2002), *Digital Photogrammetry*, Taylor and Francis, ISBN: 0-748-40944-0.

Lange, E., Hehl-Lange, S., (2005). Combining a participatory planning approach with a virtual landscape model for the siting of wind turbines. *J. Environ. Planning Manage.* 48 (6), 833–852.

Pigot, S., (1995). A topological model for a 3-dimensional Spatial Information System, PhD thesis, University of Tasmania, Australia.

Pilouk, M., (1996). Integrated modelling for 3D GIS. PhD thesis, ITC, The Netherlands, 200pp.

Snyder, K. (2003). Tools for community design and decision-making. In S. Geertman & J. Stilwell (Eds.), *Planning support systems in practice* (pp. 99–120). Berlin: Springer.

Steinitz, C. (1992). Some words of caution. *Landscape and Urban Planning*, 21, 273–274

Tress, B. and G. Tress, (2003), "Scenario visualisation for participatory landscape planning-a study from Denmark", *Landscape and Urban Planning*, 64(3), p.161–178.

Zube, E. H., Simcox, D. E., & Law, C. S. (1987). Perceptual landscape simulations: history and prospect. *Landscape Journal*, 6(1), 62–80.

(Milap Punia is Associate Professor and **Arnab Kundu** is Research Scholar a tCentre for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University, New Delhi-110067, India.

E-mail: milap.punia@gmail.com | arnknd@live.in)

Mapping of Debris-Covered Gangotri Glacier in Garhwal Himalayas Using Remote Sensing

Rakesh Bhambri, Ravinder Kumar, S.K.Kulshrestha

Abstract

Mapping of debris-covered glaciers using remote sensing techniques is recognized as one of the challenges for generating glacier inventories and automated glacier change analysis. The use of visible (VIS) and near infrared (NIR) bands does not constantly provide sufficient information to detect the debris-covered ice with remote sensing data due to similar spectral signal of the surrounding debris. This paper demonstrates the use of automated mapping method for the debris-covered glaciers with a case study of the Garhwal Himalayas based on an ASTER DEM and thermal data. Morphometric parameters such as slope, plan curvature and profile curvature were computed by the ASTER DEM and organized in similar surface groups using cluster analysis. A thermal mask was generated from a single band of an ASTER thermal imagery; while the clean-ice glaciers were mapped using a band ratio based on ASTER bands 3 and 4. Vector maps were generated from the output of the cluster analysis, the thermal mask and band ratio mask for the preparation of final outlines of debris-covered glaciers using GIS overlay operations. The automated mapped debris-covered glacier outline of Gangotri Glacier derived from 2006 ASTER data varied by about 5 per cent from the manually outlined debris-covered glacier area of the Cartosat-1 high-resolution image in the same year. It has been found that post-depositional sedimentation by debris flow/mass movement was a constraint in the full automated mapping of debris-covered glaciers in the polygenetic environment of the Himalayas. In addition, the resolution of ASTER stereo data and thermal band limits automated mapping of small debris-covered glacier with adjacent end moraine. In future, when high resolution DEMs will be available, the accuracy will be sufficient for a fully automated glacier monitoring, including the smaller ones. However, the results obtained from the Gangotri Glacier confirm a strong potentiality of the present approach in future.

Introduction

Glaciers are composed of snow, ice, water and rock/debris materials, moving slowly down the gradient. The Himalayan glaciers are often covered with snow, glacier ice and varying amount of debris (scree) consisting of dust, silt, sand, gravel, cobble and boulders (Shroder *et al.*, 2000). The assessment of debris-covered glacier ice is significant for glacier mass balance and glacier dynamics. It is, therefore, essential to monitor debris-covered glaciers at regular intervals. Field based monitoring of glaciers is time-consuming and poses the potential risk of long stays in remote and extensively rugged areas of extreme weather conditions. Recent developments in RS and GIS technology offers a vast potential to map and monitor large glaciers (Bhambri and Bolch 2009; Bolch *et al.* 2010, Bhambri *et al.* 2011).

Clean glacier ice can be mapped through image processing techniques on multispectral data such as simple band mathematics and classification (Bhambri and Bolch 2009). However, these image-processing techniques appeared ineffective to map debris-covered glaciers due to the similar spectral signature of surrounding rocky moraines and glacier fore-fields (Bishop *et al.* 2001, Raup *et al.* 2007). Thus studies have used additional parameters derived from remote sensing data, including, (i) morphometric parameters (e.g. slope, plan and profile curvature (Bishop *et al.* 2001, Bolch and Kamp 2006); (ii) multi criteria technique including multispectral image classification (glacier ice, vegetation), neighborhood analysis (connection to glacier ice), change detection (Paul *et al.* 2004), and morphometric parameters with optical and thermal datasets

(Bolch et al 2007) and optical–thermal remote sensing data with inputs from geomorphometric parameters (Shukla *et al.* 2010); (iii) difference in thermal properties of glacier ice, snow and debris-covered ice using thermal satellite images (Taschner and Ranzi 2002, Ranzi et al 2004, Mihalcea et al 2006, 2007). However, most of these methods are region-specific, and thus fail to capture differences in regional/local landscape conditions such as (a) different size, shape and height of debris-covered glacier snouts, (b) vegetation cover, (c) surface ponds, (d) characteristics of debris-cover (medial moraine vs. thick debris cover on whole tongue), and (e) the amount of debris cover on ablation zone.

The present study has been conducted with the following two objectives in mind:

- i) to discuss the challenges related with debris-covered glacier mapping based on remote sensing data, and
- ii) to demonstrate multiple criteria technique for debris-covered glacier mapping using morphometric parameters such as slope, plan curvature, profile curvature, band ratio technique, thermal band information derived from ASTER data.

The study area

Gangotri Glacier, the largest glacier in Garhwal Himalayas has been selected the study area for present work. The Bhagirathi River is the main source stream of the Ganga River, originating from the snout (Gaumukh; ~3950ma.s.l.) of Gangotri Glacier (Fig. 1).

It originates in the Chaukhamba massif (~6853 to 7138ma.s.l.) and flows northwest towards Gaumukh. The equilibrium-line altitude (ELA) of Gangotri Glacier is ~4875ma.s.l. (Ahmad and Hasnain 2004). The Gangotri Glacier system is a cluster of several large and small glaciers. Swachand, Maindi, and Ghanohim are some of the active tributary glaciers, still connected to the main Gangotri Glacier and contribute to the mass balance of the main glacier. Raktavan Glacier has been detached from the main Gangotri Glacier. Chaturangi Glacier was a part

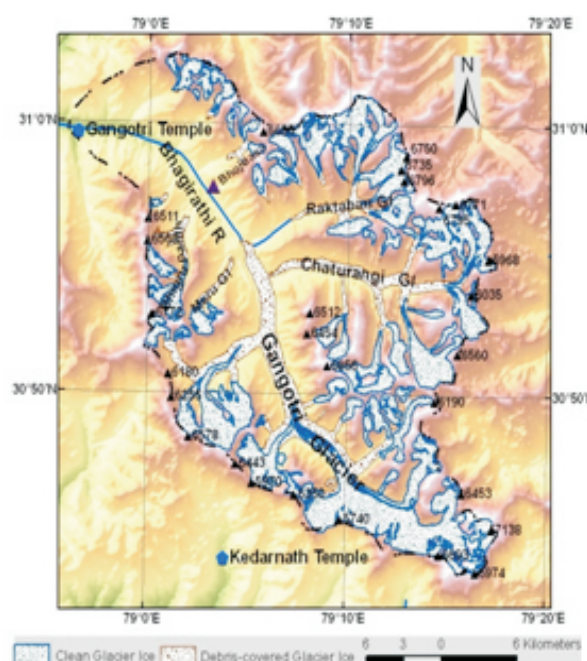


Fig. 1 Gangotri Glacier with its tributary glaciers; Glacier outlines derived from ASTER and Cartosat 1(2006) imageries (source: Bhambri et al 2011).

of the main Gangotri Glacier until 1962, as presented in the Survey of India topographic map. Naithani *et al* (2001) reported that Chaturangi Glacier has retreated 250 m from 1971 to 1999.

Garhwal Himalayan glaciers are fed by summer monsoon and winter snow regimes (Thayyen and Gergan 2010). However, maximum snowfall occurs from December to March, mostly due to western disturbances (Dobhal et al 2008). Field surveys and assessment of satellite images indicate that Gangotri Glacier is covered with debris in the ablation zone (Fig. 2). The debris in upper Bhagirathi basin consists mainly of granite, granitic gneiss and sheared granitic gneiss (Chaujar et al 1993).

Data Sources and methods

i) Satellite data and topographic map- One Level 1A ASTER imagery (October 2006) was acquired with all of its 14 bands from the Land Processes DAAC at EROS Data Center. The high-resolution Indian panchromatic satellite data Cartosat-1 of September, 2006 at 2.5 m resolution was acquired from National Remote

Sensing Centre (NRSC, <http://www.nrsc.gov.in>) for the evaluation of semi-automated outlines of debris-covered glacier area derived from ASTER data. Cartosat-1 data was obtained in 10-bit radiometric resolution which helps in the interpretation of complex polygenetic glacier landscape due to better contrast than other available IRS-IC and ID PAN data. The topographic map 53N/1 (1:50000) is used as a base map, prepared by the Survey of India in the 1960s using aerial photographs with limited fieldwork.

ii) ASTER Digital Elevation Model (DEM)- Terra ASTER is the most economical optical sensor covering a 60 km wide ground track at a 15 m spatial resolution (Toutin 2008) and the primary source of DEM generation under the Global Land Ice Measurements from Space

(GLIMS) Project (Kargel *et al.* 2005, Raup *et al.* 2007). The ASTER DEM for 2006 was generated from stereo 3N and corresponding 3B band based on major steps including: ground control points (GCPs) collection, transformation to epipolar images, parallax-matching, and parallax to DEM using ENVI 4.2 software. Total 11 GCPs were used for 2006 ASTER scene. Moreover 129 tie points (TPs) were used for better image matching for 2006 ASTER scene. Stable streams junctions, road river junctions, and lake-stream junction were used for TPs and GCPs assuming no changes occurred according to time in GCPs locations on the ground. The DEM was generated with a resolution of 30 m as suggested by Kääb (2002), Kamp *et al.* (2005), and Racoviteanu *et al.* (2007) for mountainous regions. The 30 m spatial resolution of ASTER DEMs is also recommended to avoid noise in the

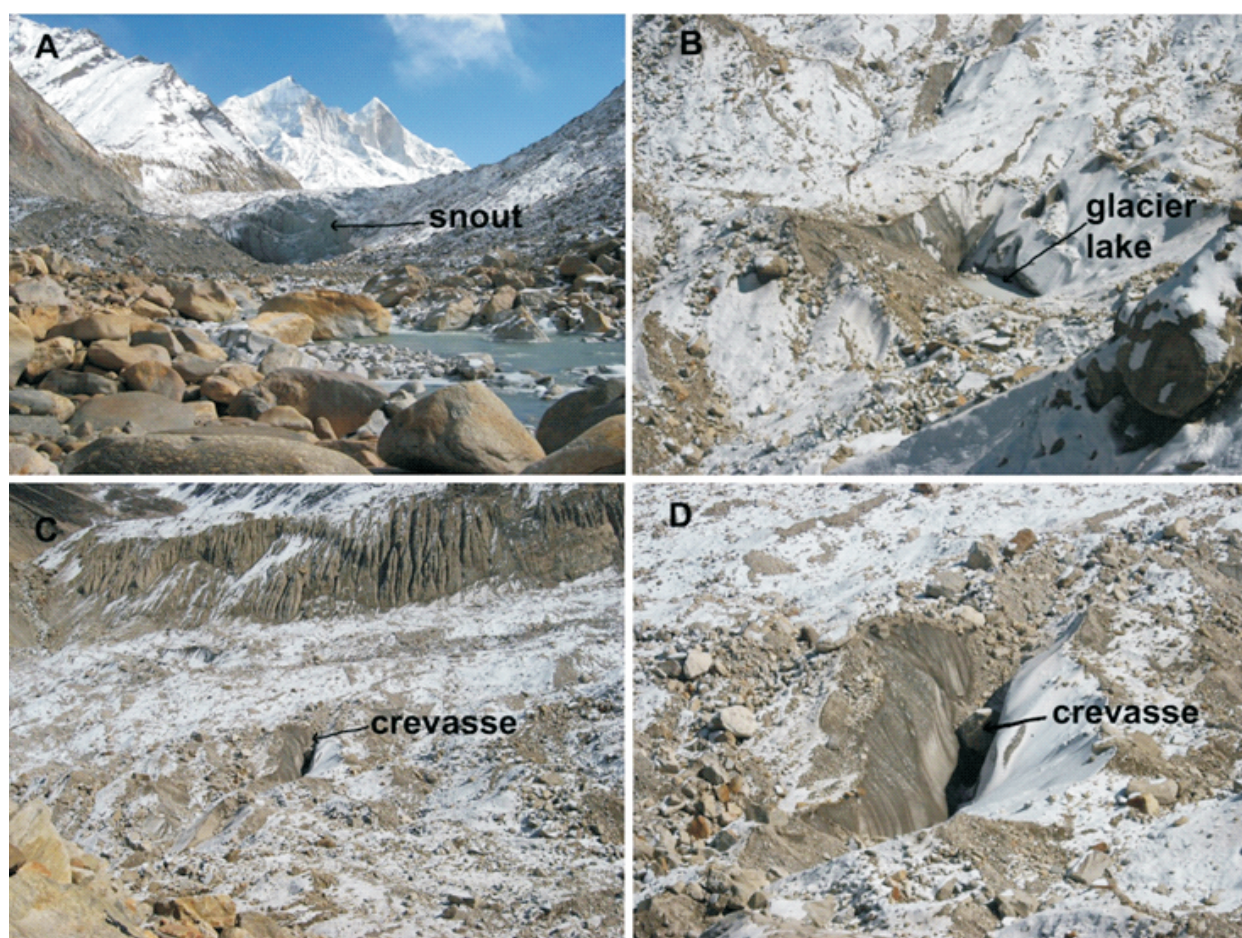


Fig. 2 (a) Snout of Gangotri Glacier, (b) Supra-glacial lake in ablation zone of Gangotri Glacier, (c) Crevasse in ablation zone of Gangotri Glacier, (d) Closer view of crevasse in ablation zone of Gangotri Glacier.

comparison of the 15 m spatial resolution (Toutin 2008). Unnatural peaks in the accumulation zone of Gangotri Glacier were manually removed from the DEM based on clip algorithm using ArcGIS. The resulting holes occurred owing to elimination of unnatural peaks was filled by interpolation method using the SAGA software. Cartosat-1 and ASTER imageries were orthorectified using ASTER DEM.

iii) Automated mapping of debris-covered glaciers- Geomorphometric maps such as slope, plan curvature and profile curvature were computed after the post processing of ASTER DEM using a local morphometric tool of the SAGA software (Conrad et al 2006) using Zevenberg and Thorne (1987) approach. Plan and profile curvature were combined by cluster analysis and placed in ten categories with similar surface characteristics (Fig. 3b) using SAGA. A cluster analysis was conducted again on slope and the previous results of both curvatures and once more rearranged into ten categories

(Fig. 3c). Three out of ten categories were visually selected and reclassified which covered Gangotri Glacier (Fig. 3d). The reclassified output was then converted into a vector polygon map and the Gangotri Glacier was selected manually (Figs.3e and 3f)). However, the result also covered some part of the lateral moraine near the accumulation zone of Ghanohim Glacier. This area was removed using 5.9 to 7.5 pixels as threshold values of single thermal band 12 of ASTER and generated a thermal mask in binary image format. The result derived from the thermal mask was then converted into a vector polygon map and the Gangotri Glacier was selected manually. The thermal mask also misclassified a pro-glacier area near the snout of Gangotri Glacier probably due to its equally cold temperature. Similar results were presented by Shukla et al. (2010) during the mapping of Samudra Tapu Glacier based on ASTER thermal data.

The Band ratio method based on NIR and SWIR bands (e.g. ASTER band 3 and 4) is widely used

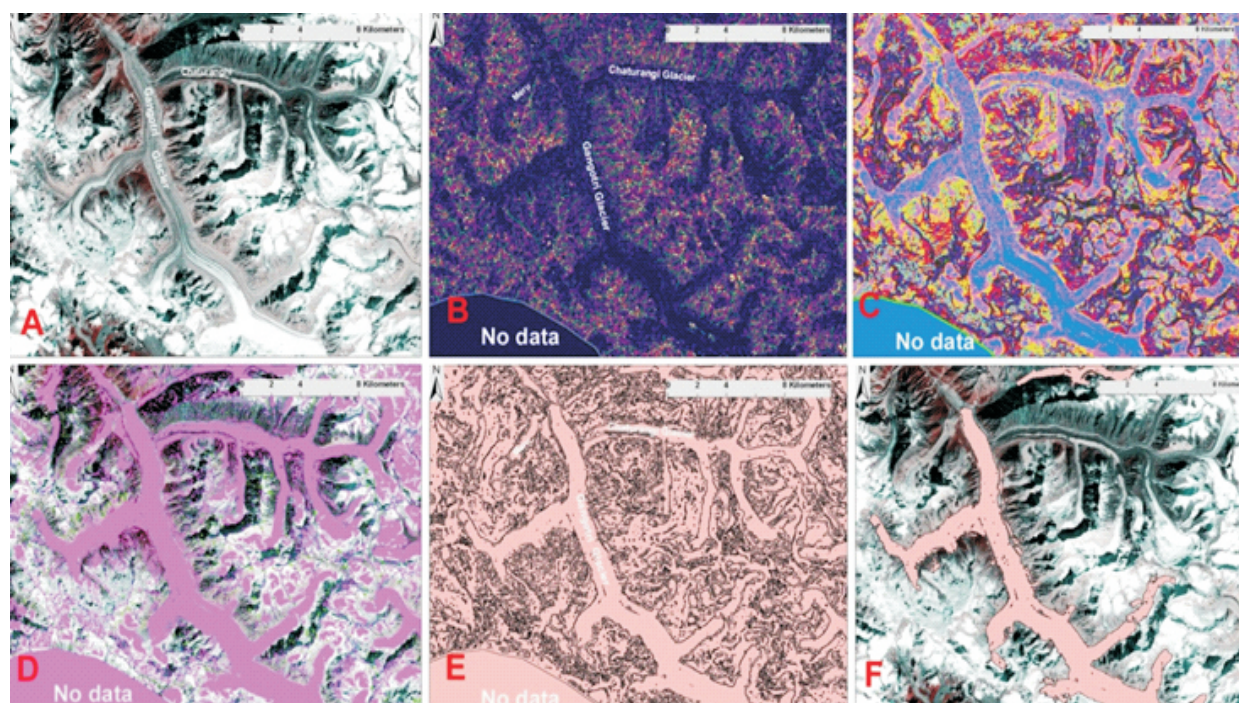


Fig. 3(a) FCC image of ASTER image, (b) Cluster analysis of plan and profile curvature in ten categories, (c) Reclassifying of plan, profile curvature and slope in ten classes, (d) Re-clustering of plan, profile curvature and slope in three categories, (e) Vectorization of three classes, 6(f) Selected Gangotri Glacier vector layer overlaid on ASTER FCC.

for clean-ice glacier mapping (Paul *et al.* 2002; Bolch and Kamp 2006; Bhambri and Bolch 2009). The clean glacier-ice mask was generated in binary image format based on this band ratio using a carefully selected threshold value 1.0 and converted into a vector polygon map. It was found that some dark shadow areas were also misclassified as glacier ice. These misclassified areas were manually improved from the vector polygon (Fig. 4). However, it also covered the surrounding clean glacier ice of Satopanth and Bhagirathi Kharak Glacier. The ice divide was identified via visual inspection of ASTER DEM with hillshade effect and ASTER bands 321 and then manually digitized. This vector layer of the ice divide was used for the segregation of Gangotri Glacier from their surrounding glaciers based on the simple overlay clip algorithm of ArcGIS. The clean ice layer is significant for the correct debris-cover glacier mapping. Each glacier has an accumulation area without debris-cover. Hence, only those classified areas connected to the clean ice layer were selected as a debris-cover glacier by location tool.

It was noticed that misclassified pro-glacier area near the Gangotri snout from thermal threshold can be removed using plan, profile curvature, and slope information. Based on the fact that the end of terminus has a steeper slope than is direct

forefield. The transition is characterised by a bend which can be detected using slope and curvature information (Bolch and Kamp 2006). Therefore, the overlay operation 'intersect' was applied on the vector map layer derived from cluster analysis and the thermal mask vector map layer using ArcGIS for the generation of the final outline of the debris-covered glaciers. The intersect method played a significant role in the elimination of additional area near the snout of Gangotri Glacier derived from thermal threshold, and lateral moraine area near Ghanohim Glacier derived from reclassified cluster output of plan, profile curvatures and slope. However, the transitional zone area of clean-ice and debris-covered area was misclassified as debris-covered area possibly owing to two reasons (1) no change occurred in slope near the transitional zone area of clean-ice and debris-covered area and (2) the spatial resolution of ASTER thermal data (90 m) limits to differentiate clean-ice and debris-covered area at their junctions. These areas were removed from the clean-ice vector polygon map using the erase function of the overlay operation. Some small polygons were found existing outside Gangotri Glacier. Finally, these misclassified small polygons were removed using an area threshold of less than 0.25 km².

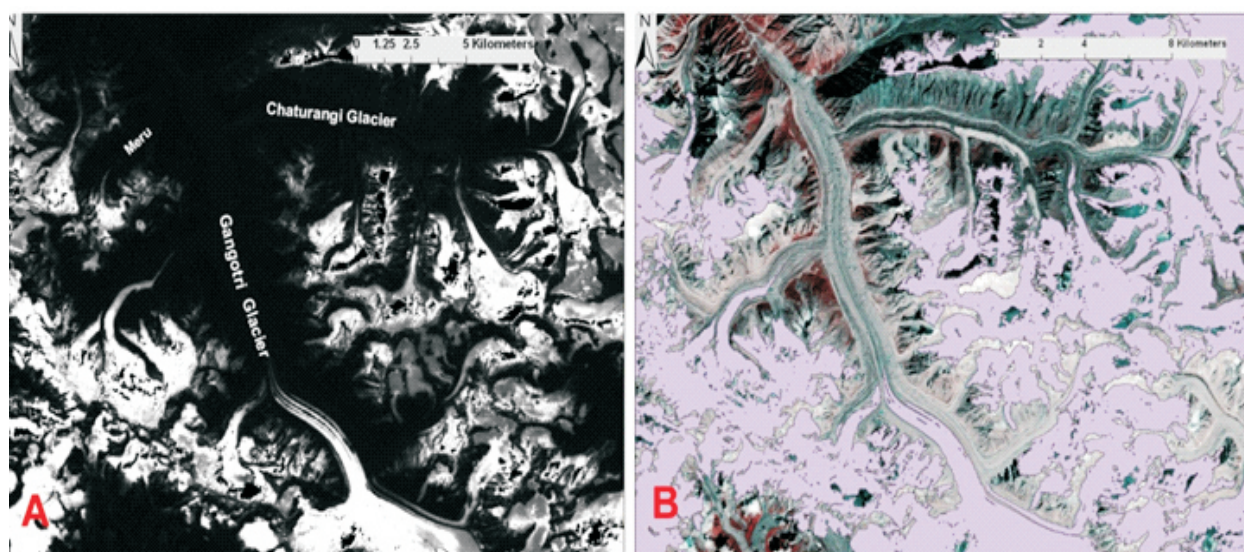


Figure 4(a) Band ratio imagery of ASTER data based on bands 3 and 4, (b) Vector layer derived from band ratio overlaid on ASTER FCC.

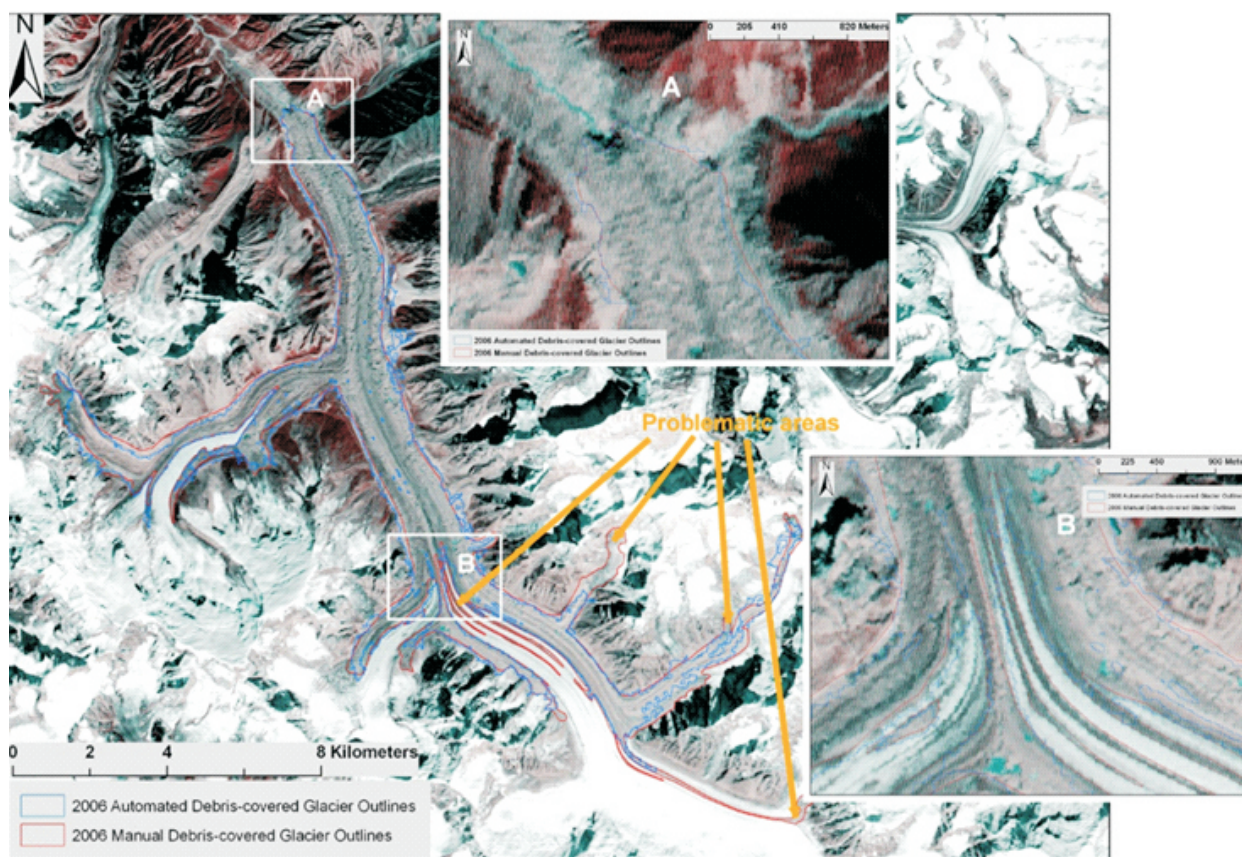


Fig. 5 Comparison between automated and manually digitized outlines of the Gangotri Glacier.

This threshold is justified by the fact that debris-covered glaciers are usually larger than clean ice glaciers and almost no debris occurs on glacierets and small hanging glaciers. A threshold of 0.1 km² for clean-ice glaciers was used for several glacier inventories, e.g., for the Swiss Alps (Paul et al 2002).

Results and Discussions

The semi-automated debris-covered glacier outline of Gangotri Glacier derived from 2006 ASTER data was 5.04% smaller than the manually outlined debris-covered glacier area from the Cartosat-1 high-resolution imagery of the same year. The major problem occurs near the transitional zone between the ablation and accumulation zones near the tributary Ghanohim Glacier, where a debris-covered strip about two km long and 80m wide was not mapped using this technique (Fig. 5).

The results about cluster analysis of slope, plan and profile curvature were promising in case of

the largest Gangotri Glacier. However, near Bhagirathi peaks results of reclassified cluster analysis also covered some part of lateral moraine. Visual interpretation of Cartosat-1 data suggest that post depositional work by mass-movement activity covered the lateral moraine up to glacier valley bed, not detected by ASTER DEM (Fig. 6). It was also noticed post depositional mass-movement activity on the lateral moraine during the field work.

Slope was the key morphometric parameter for the intended purpose. It can assist in the delineation of a debris-covered snout where end moraines do not exist due to discontinuity in slope between a large snout and the pro-glacier area. However, the threshold values differ depending on glacier type and height of snout cave, 'e. g.', it varies between 12° for Khumbu Glacier/Himalayas (Bolch et al 2007), 24° for Oberaletschgletscher/Swiss Alps (Paul et al 2004), less than 15° for Samudra Tapu Glacier/Himachal Himalayas (Shukla et al 2010)

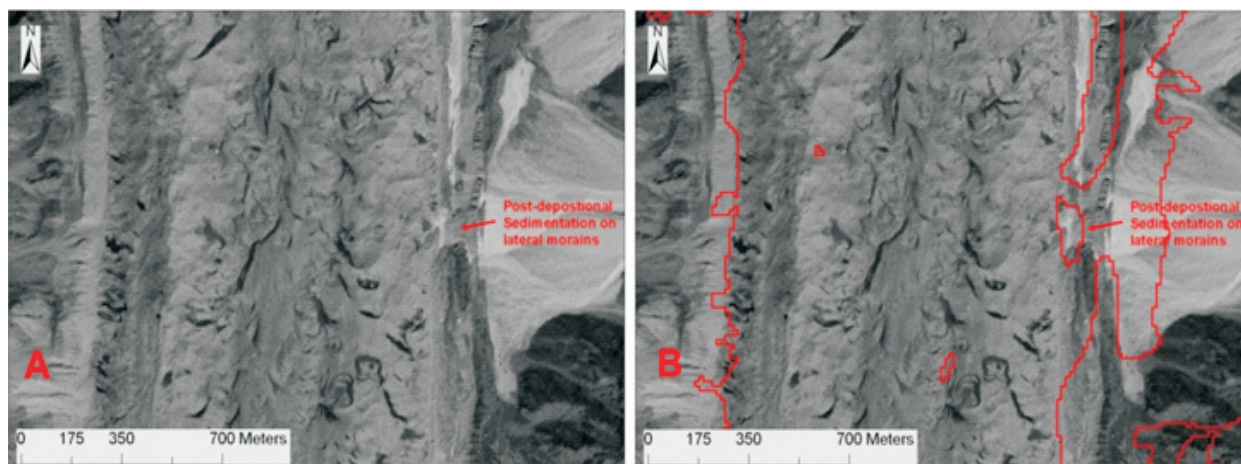


Figure 6: (a) Cartosat-1 imagery, (b) Vector layer derived from reclassified cluster analysis overlaid on Cartosat-1 imagery.

and 18° for Gangotri Glacier/Garhwal Himalayas (Fig.7). The visual inspection on high resolution datasets and field work confirm the great relevance of thresholding of slope method for detection of debris-covered snout. The error matrix generated by Shukla et al (2009) based on supervised classification reveals that 17% pixels of other categories has been misclassified as mixed ice debris (MID). Keshri et al (2009) estimated 90% and 94% producer's and user's accuracy respectively for debris class. However, this debris class also misclassified rocky cliffs face, not considered as a separate class during validation.

Comparison between the glacier boundaries of Gangotri Glacier derived from the approach developed by us our developed approach by us using ASTER (2006) and glacier out erived from high resolution Cartosat-1 (2006) suggest an uncertainty of about $\pm 5\%$. Delineation of debris-covered glacier from single band Cartosat-1 satellite imagery needs interpreter efficiency of identification of glacial features. Image enhancement of 10 bit data of Cartosat-1 appears to be supportive in distinguishing glacial features. In the present exercise the Cartosat-1 imagery was enhanced using linear technique followed by a cross check of results during field verification in some areas. The uncertainty based on a buffer method (Granshaw and Fountain 2006, Bolch et al 2010)

suggests $\pm 2.2\%$ mapping error for Cartosat-1 data. This reveals a total absolute mapping uncertainty is about $\pm 5.4\%$ from developed semi-automatic approach based on ASTER (2006) after the validation from Cartosat-1 (2006).

Depositional works by other geomorphic processes such as debris flow/mass movement are a great hindrance in the automated mapping of debris-covered glaciers. The debris-covered boundaries could not be detected accurately by the morphometric parameters derived from the ASTER DEM in some instance due to post depositional activity. The post-depositional sedimentation by mass movement activity is a commonly found process in the polygenetic environment of the Himalayas (Benn and Owen, 2002). The field-based geomorphologic study by Barnard et al (2004) has been confirmed that upper Bhagirathi valley is very sensitive to post-depositional sedimentation by mass movement and glacio-fluvial processes on lateral slopes of mountain terrain.

Temperatures of debris-covered ice, snow, clean ice and surrounding moraine materials vary widely owing to their internal structure and chemical properties (Mihalcea *et al* 2006). However, cold debris and sand near the glacier snout has been miss-classified as debris-covered glacier during the mapping from thermal data (Shukla *et al.*, 2010). We also

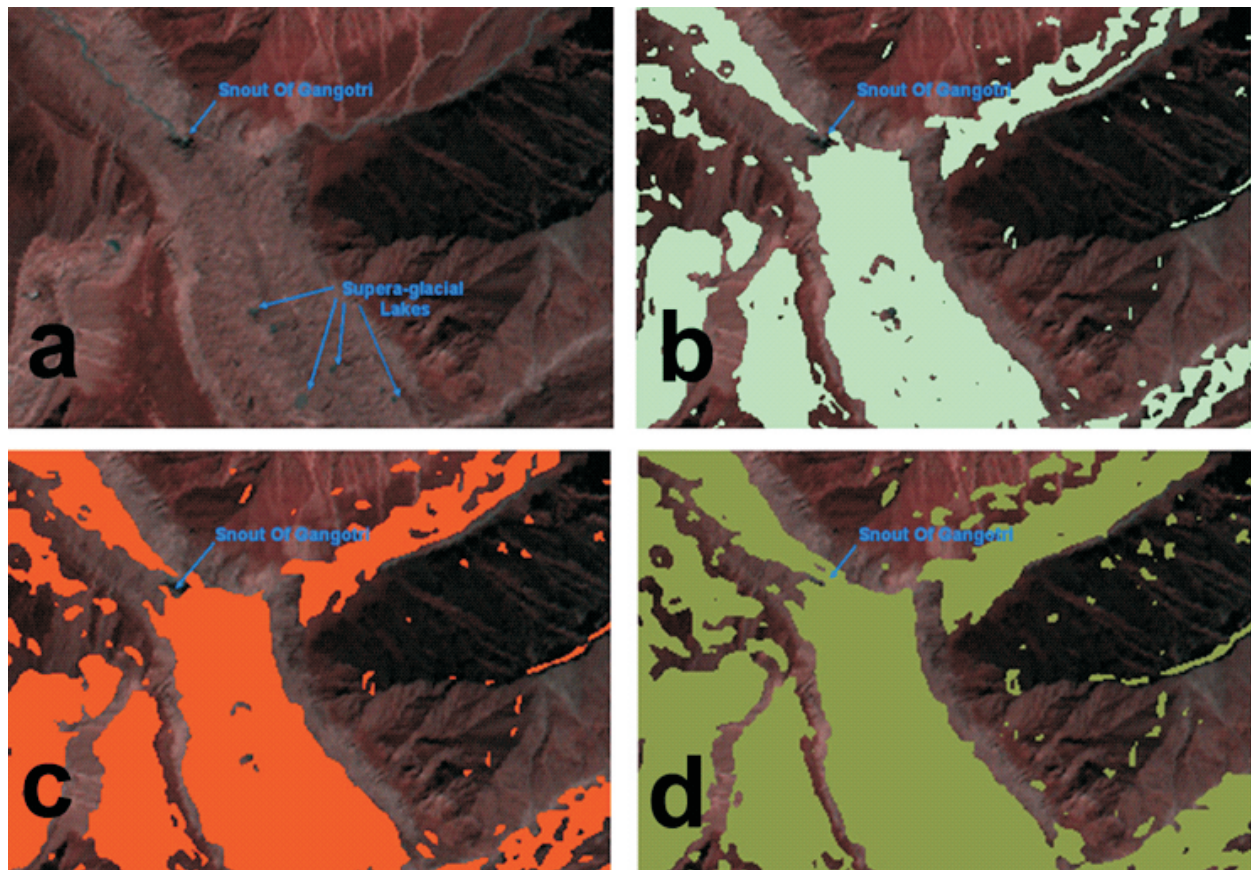


Figure 7: Average optimum slope calculations from ASTER DEM for Gangotri glacier (a) FCC of ASTER image, (b) 15 degree slope (light green colour), (c) 18 degree slope (orange colour), (d) 25 degree slope (dark green colour).

recognize similar results using ASTER and ETM+ thermal data. This misclassified information can be corrected using geomorphometric parameters. The different slope values are helpful in segregating the tributary hanging glacier from main valley glacier. Morphometric parameters such as slope, plan and profile curvatures derived from the ASTER DEM allows the mapping of debris-covered glaciers. Profile curvature enables the lateral moraines to be identified whereas plan curvature allows the differentiating of the glacier front to the almost flat valley floor of the direct glacier forefield. Previous studies have recognized great potential of plan and profile curvature for identifying the margins of the snouts of valley glaciers (Bishop *et al.*, 2001, Bolch and Kamp 2006; Bolch *et al.* 2007).

We noticed that during the selection of threshold for single thermal band of ASTER is a crucial

step. Increase or decrease of the threshold value of 0.1 influences significantly the enlargement or reduction of glacier area and its surrounding coverage. It appears that shadow areas strongly affect the single thermal band thresholding which can hamper the automatic mapping of debris-covered areas. Thresholding procedure of satellite images is scene-dependant and subjective in nature (depends on the interpreter). Visually detection of debris-covered ice may be strongly enhanced by utilizing stereo-viewing techniques on the stereo images e.g. using ASTER bands 3N and 3B (Racoviteanu *et al* 2009).

The present approach with an uncertainty of about 5% is promising even to map and monitor other large debris-covered glaciers such as Bada Shigri Glacier (Himachal Himalayas). This approach can further ameliorate using high resolution DEMs derived from high resolution

data such as Cartosat or TanDEM-X and high-resolution multi-spectral data. However, currently only Landsat ETM+ thermal band has higher spatial resolution as compared to other satellite programs. Therefore there is a need to improve the thermal sensor spatial resolution.

Conclusions

The results from mapping the debris-covered Gangotri Glacier confirm the strong potential of the present approach based on the ASTER DEM and thermal data from its unique large cave at the snout and its orientation from southeast to northwest in 2006. The high resolution Cartosat-1 imagery was helpful for the interpretation of polygenetic complex mountainous landscape. The problematic areas that were not mapped by the present approach were closely associated with resolution of ASTER data (Fig. 5). The post-depositional sedimentation by debris flow was appeared as a great hindrance for the automated mapping of debris-covered glaciers in the polygenetic environment of the Himalayas. The shadow areas strongly affect the single thermal band thresholding which can hamper the automatic mapping of debris-covered areas. Thresholding procedure is scene-dependant and subjective in nature (depends on the interpreter). Thresholding of slope has a great potentiality to map debris-covered glacier snouts. However, the thresholds have to be carefully selected. The semi-automated debris-covered mapping approach presented in this paper could be extended to larger debris-covered glaciers in the Himalayas and other mountain regions. However, care must be taken during the selection of thresholds and cluster groups due to regional setting of relief, quantity of debris load, orientation, and climatic conditions vary considerably throughout the Himalayas and other mountains regions and even within one basin.

Acknowledgments

Thanks are due to Director of Wadia Institute of Himalayan Geology for the support during this work and especially to Dr. D. P. Dobhal for his

constant support. Thanks are also due to Dr. T. Bolch, Glaciology, Geomorphodynamics and Geochronology, Department of Geography, University of Zurich who was instrumental for guidance and support. We also thank to Mrs. Manorama Sethi, Central Soil Salinity Research Institute, Karnal for her support and providing laboratory facilities.

References

- Ahmad, S. and Hasnain, S. I. (2004), 'Analysis of satellite imageries for characterization of glacio-morphological features of the Gangotri Glacier, Ganga headwater, Garhwal Himalayas', In **Proceedings: Workshop on Gangotri Glacier**, D. Srivastava, K.R. Gupta. & . S. Mukerji (Ed.), Geological Survey of India, 80, pp. 61-67.
- Barnard, P. L. *et. al.* (2004), 'Style and timing of glacial and paraglacial sedimentation in a monsoon-influenced high Himalayan environment, the upper Bhagirathi Valley, Garhwal Himalaya', **Sedimentary Geology**, pp.199–221.
- Benn, D. I. and Owen, L. A. (2002), 'Himalayan glacial sedimentary environments: A framework for reconstructing and dating the former extent of glaciers in high mountains', **Quaternary International**, 97, pp.3–25.
- Bhambri, R. and Bolch, T. (2009), 'Glacier Mapping: A Review with special Reference to the Indian Himalayas', **Progress in Physical Geography**, 33, pp.672–704.
- Bhambri, R., *et. al.*, (2011), 'Glacier changes in the Garhwal Himalayas, India 1968-2006 based on remote sensing', **Journal of Glaciology** 57(203), pp.543-556.
- Bishop, M. P., *et. al.* (2001), 'Terrain analysis and data modeling for alpine glacier mapping', **Polar Geography**, 25, pp.182–201.
- Bolch, T., *et. al.* (2007), 'Automated delineation of debris-covered glaciers based on ASTER data, In **GeoInformation in Europe**', M. A. Gomasasca (Ed.), pp. 403–410 Millpress, Netherlands.
- Thayyen, R.J. and J.T. Gergan (2010), 'Role of glaciers in watershed hydrology: a preliminary

study of a 'Himalayan catchment', **Cryosphere**, 4(1), pp.115–128.

Dobhal, D.P., et. al. (2008), 'Mass balance studies of the Dokriani Glacier from 1992 to 2000, Garhwal Himalaya, India'. **Bull. Glacier Res.**, 25, pp.9–17.

Bolch, T. and Kamp, U. (2006), 'Glacier mapping in high mountains using DEMs, Landsat and ASTER data. Grazer Schriften der Geographie und Raumforschung', 41 (**Proc.8th Int. Symp. on High Mountain Remote Sensing Cartography**, La Paz, Bolivia), pp 37- 48.

Bolch, T., et. al. (2010), 'Landsat-based glacier inventory of western Canada, 1985-2005', **Remote Sensing of Environment**, 114, pp.127-137. doi:10.1016/j.rse.2009.08.015.

Chaujar, R. K., et. al., (1993), 'Glacial geomorphology of the Gaumukh – the source of Ganga, with reference to its present state of environment', **Seminar on Ganga in the Service of the Nation**, University of Roorkee, pp.12–13 September 1993, II1–II14.

Conrad, O. (2006), SAGA - program structure and current state of implementation. In **SAGA-Analysis and Modelling Applications**. pp 39-52, Böhner, J., McCloy K.R. and Strobl, J. (Eds.), Göttinger Geographische Abhandlungen,

Granshaw, F.D. and A.G. Fountain (2006), 'Glacier change (1958– 1998) in the North Cascades National Park Complex, Washington, USA'. **Journal of Glaciology**, 52, pp.251–256.

Kääb, A. (2002), 'Monitoring high mountain terrain deformation from repeated air- and spaceborne optical data: examples using digital aerial imagery and ASTER data', **ISPRS-Journal of Photogrammetry and Remote Sensing**, 57, pp.39–52.

Kamp, U., et. al. (2005) 'Geomorphometry of Cerro Sillajhuay, Chile/Bolivia: comparison of DEMs derived from ASTER remote sensing data and contour maps', **Geocarto International**, 20, pp.23-34.

Kargel, J., et. al. (2005), 'Multispectral imaging contributions to global land ice measurements

from space', **Remote Sensing of Environment**, 99, pp.187- 219.

Keshri, A. K., et. al. (2009), 'ASTER ratio indices for supraglacial terrain mapping', **International Journal of Remote Sensing**, 30, pp.519–524.

Mihalcea, C., et. al. (2007), 'Using ASTER satellite and ground-based temperature measurements to derive supraglacial debris cover and thickness patterns on Miage Glacier (Mont Blanc massif, Italy)', **Cold Regions Science and Technology** doi: 10.1016/j.coldregions.2007.3.004

Mihalcea, C., et. al. (2006), 'Ice ablation and meteorological conditions on the debris-covered area of Baltoro Glacier (Karakoram, Pakistan)', **Annals of Glaciology**, 43, pp.292–300.

Naithani, A.K., et. al. (2001), 'Geomorphological evidences of retreat of the Gangotri glacier and its characteristics', **Current Science**, 80, pp.87-94.

Paul, F., et. al., (2009), 'Recommendations for the compilation of glacier inventory data from digital sources', **Annals of Glaciology**, 50, pp.119-126

Paul, F. et. al. (2004), 'Mapping of debris-covered glaciers using multispectral and DEM classification techniques', **Remote Sensing of Environment**, 89, pp.510-518.

Paul, F., et. al. (2002), 'The new remote sensing derived Swiss glacier inventory: I Methods', **Annals of Glaciology**, 34, pp.355-361.

Racoviteanu, A.E., et. al. (2007), 'Evaluating digital elevation models for glaciologic applications: An example from Nevado Coropuna, Peruvian Andes', **Global Planet Change**, 59, pp.110-125.

Racoviteanu, A.E. et. al. (2009), Challenges and recommendations in mapping of glacier parameters from space: results of the 2008 Global Land and Ice Measurements from Space (GLIMS) workshop, Boulder, Colorado, USA. **Annals of Glaciology**, 50, pp.53-69.

Ranzi, R. et al. (2004), 'Use of Multispectral ASTER images for mapping debris-covered glaciers within the GLIMS Project', **IEEE**

International Geoscience and Remote Sensing Symposium, pp.1144-1147.

Raup, B.H. *et. al.* (2007), 'Remote Sensing and GIS Technology in the Global Land Ice Measurements from Space (GLIMS) Project', **Computers and Geosciences**, 33, pp. 104-125.

Shroder, J.F. *et. al.* (2000), 'Debris-covered glaciers and rock glaciers in the Nanga Parbat Himalayas, Pakistan', **Geografiska Annaler**, pp.17-31.

Shukla, A. *et. al.* (2009), 'Estimation of debris cover and its temporal variation using optical satellite sensor data: a case study in Chenab basin, Himalaya', **Journal of Glaciology**. 55, pp.444-452.

Shukla, A. *et. al.* (2010), 'Synergistic approach for mapping debris-covered glaciers using optical-thermal remote sensing data with inputs

from geomorphometric parameters', **Remote Sensing of Environment**, 114, pp.1378-1387.

Toutin, T. (2008), 'ASTER DEMs for geomatic and geoscientific applications: a review', **International Journal of Remote Sensing**, 29, pp.1855-1875.

Taschner, S. and Ranzi, R. (2002), 'Comparing opportunities of Landsat-TM and ASTER data for monitoring a debris-covered glacier in the Italian Alps within the GLIMS project'. **IEEE transactions on geoscience and remote sensing symposium**, June (pp.24- 28).

Zevenberg, L. W. and C. R. Thorne (1987), 'Quantitative analysis of land surface topography'. **Earth Surface Processes and Landforms**, 12, pp.47-56.

(**Rakesh Bhambri** and **Ravinder Kumar Chaujar** are associated with Centre for Glaciology, Wadia Institute of Himalayan Geology and **Subhash Chandra Kulshreshtha** is the chairman, Shri Ram Group of Colleges, Muzaffarnagar (UP),

Email: rakeshbhambri@gmail.com)

MISCELLANEOUS PAPERS

छत्तीसगढ़ में जनसंख्या प्रदे I

अनुसुइया बघेल

सारांश

प्रस्तुत अध्ययन 2001 के जनगणना पर आधारित है। छत्तीसगढ़ में जनसंख्या प्रदे I के निर्माण के लिए 16 जिलों को इकाई माना गया है। अध्ययन हेतु 11 चरों को चुना गया है। इसके आधार पर छत्तीसगढ़ प्रदे I को चतुर्थ कारक तक के प्रदे I का निर्माण किया गया है। ये चारों कारक मिलकर 84.9 प्रति शत भिन्नता की व्याख्या करते हैं। पांचवे कारक का भार 1.0 से कम है जो 10 प्रति शत से कम भिन्नता की व्याख्या करता है। अतः पांचवे कारक को छोड़ दिया गया है। प्रथम कारक 39.9 प्रति शत, द्वितीय कारक 23.1 प्रति शत, तृतीय कारक 15.6 प्रति शत, चतुर्थ कारक 9.3 प्रति शत भिन्नता की व्याख्या करते हैं। इन चारों कारकों के आधार पर चार मानचित्र का निर्माण किया गया है और क्षेत्र को छः विभिन्न भागों में तीन धानात्मक और तीन ;णात्मक बांटा गया है। प्रथम कारक में छः चर शामिल हैं जिसका भार +.65 से -.95 है। चार चर जनसंख्या का घनत्व, साक्षरता, नगरीय जनसंख्या, अनुसूचित जाति, का भार धानात्मक और अनुसूचित जनजाति एवं कृषि जनसंख्या का भार ;णात्मक है। प्रथम कारक में धानात्मक में सर्वाधिक दुर्ग जिला और ;णात्मक में दत्तेवाड़ा जिला का स्थान प्रथम है। प्रथम कारक के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या संकेत किया गया है। द्वितीय कारक में दो चर कुल प्रजननता दर और आश्रित जनसंख्या शामिल हैं। ये दोनों धानात्मक चर हैं। द्वितीय कारक के अन्तर्गत धानात्मक में सर्वाधिक जांजगीर-चांपा जिला और ;णात्मक में कोरिया जिला का प्रथम स्थान है। द्वितीय कारक के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या वी) किया गया है। तृतीय कारक के अंतर्गत दो चर लिंगानुपात और प्रवास शामिल हैं। इन दोनों चरों का भार धानात्मक है। धानात्मक मूल्य राजनांदगांव जिले में सर्वाधिक और ;णात्मक मूल्य दत्तेवाड़ा जिला में सर्वाधिक है। तृतीय कारक के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या की गति गति रखा गया है। चतुर्थ कारक के अंतर्गत केवल एक ही चर शिशु मृत्युता दर शामिल है जिसका भार धानात्मक है। धानात्मक मूल्य सर्वाधिक जपपुर जिला और ;णात्मक मूल्य दत्तेवाड़ा जिला में सर्वाधिक है। चतुर्थ कारक के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या का स्वास्थ्य रखा गया है।

Keywords -Factor, Component, Eigen value, Factor Loading, Variance, Communalities.

प्रस्तावना

जनसंख्या प्रदे I की अवधारणा जनसंख्या भूगोल में एक नवीन विकास है। इसके अन्तर्गत क्षेत्र विशेष में जनसंख्या के अन्तर्सम्बन्धित विशेषताओं को पहचानकर अन्तर्सम्बन्धित व्याख्या की जाती है। जनसंख्या प्रदे I का निर्माण जनसंख्या की विशेषताओं के समानता के आधार पर किया जाता है। इसका सर्वप्रथम अध्ययन 1959 में एकरमैन ने किया है। इन्होंने वि.व. को जनसंख्या एवं संसाधन के अन्तर्सम्बन्धों के आधार पर पाँच श्रेणियों- अमेरिकन सदय, यूरेशियन सदय, चीन सदय, बाजील सदय एवं आर्कटिक सदय में रखा। जेलिंस्की (1966) ने आनुवांशिक विधि अपनाकर वि.व. के जनसंख्या प्रारूपों को संसाधनों के संदर्भ में सीमांकित किया। ब्लैकर (1960) ने जन्मदर और मृत्युदर के आधार पर वि.व. के दे.गों को पाँच जनसंख्या प्रारूपों में विभाजित किया। इन्होंने वि.व. के दे.गों को 'ची' स्थिरता की अवस्था, 'घ' बढ़ने वाला, 'धीरे-धीरे' बढ़ने वाला, 'नीची' स्थिरता की अवस्था और 'घटने वाली' अवस्था में रखा है। इस प्रकार जनसंख्या प्रदे I पर सीमित अध्ययन हुआ है। पिछले दस वर्षों में मानव भूगोल में सर्वाधिक उपयोग की जाने वाली तकनीक कारक वि.लेषण (Factor Analysis) है। मानव भूगोल में बेरी एवं उनके साथियों ने कारक वि.लेषण विधि तंत्र

का उपयोग किया है। यीट्स, (1968) यह आर्थिक विकास के आधारभूत माप के रूप में परीक्षण करता है (बेरी, 1960) वर्तमान में कारक नगरीय वि.लेषण के द्वारा सामाजिक क्षेत्र वि.लेषण का विस्तार किया (बेरी, एवं रिज, 1969, बेरी 1971) वास्तव में भूगोल कोई अलग-थलग विषय नहीं बल्कि अन्य सामाजिक विज्ञानों की तरह भूगोल में भी कारक वि.लेषण एक महत्वपूर्ण परिणाम दे सकता है (रयमेल, 1967)।

प्रदे I के विकास स्तर के मापन हेतु विभिन्न विद्वानों ने सैन)ांतिक एवं मात्रात्मक विधियाँ उपयोग में लाई हैं। बेरी और फ्रीडमैन (1966) ने मूल संघटक वि.लेषण (Principal Component Analysis) के आधार पर विकास के संयुक्त सूचकांक निकाले हैं।

“कारक वि.लेषण व्यावहारिक विज्ञानों (Behaviour Sciences) में परीक्षण-परिणामों के वि.लेषणार्थ विकसित किया गया था, किन्तु इसका उपयोग उन समस्याओं जिनमें विभिन्न व्यक्तिगत इकाईयों, जनसंख्या या क्षेत्र के लिए अनेक चर उपलब्ध हो, में किया जा सकता है। फलतः यह वि.लेषण उन समस्याओं के भौगोलिक वि.लेषण हेतु सुसंगत होता है, जिसके लिए आँकड़े

आव्यूहों (matrix) आकार में संयोजित किए जा सकते। भौगोलिक दृष्टांतों में चर (Variables) प्रायः व्यक्तिगत क्षेत्र अथवा वस्तु के गुण होते हैं, जो वि लेषण में निहित सम्पूर्ण क्षेत्र अथवा समस्या को निर्मित करते हैं। वस्तुतः कारक वि लेषण क्षेत्र अथवा उच्चतम वि लेषण में अंतरों की मात्रात्मक - गणना का प्रयास करता है। कारक वि लेषण, उन वि लेषणों को अवलोकित करने का प्रयास करता है, जो सामान्य रूप से चर स्वतः धारण करते हैं और जो उसके अंतर्सम्बन्धों में प्राप्त होता है। इनके द्वारा समस्याओं को कूलक प्रतिच्छेदनों (Intersection of Sets) के रूप में विचार करने में सहायता मिलती है'' (कोल एवं किंग, 1968, अहमद, 1965) ने भारतीय नगरों के संदर्भ में कारक वि लेषण का उपयोग किया है। गैरीसन एवं मार्बल (1963) ने यातायात जाल के अभिगम्यता (Connectivity) के अध्ययन में कारक वि लेषण का उपयोग किया है। संभवतः सर्वप्रथम हैन्सेल (1966) ने कारक वि लेषण का उपयोग बारबाडोस के कृषि के संरचना में जनाकिकीय कारक नामक गोधा पत्र में किया है, जो ब्रिटीश ज्याग्रफिकल जर्नल में प्रकाशित हुआ है। उन्होंने आँकड़ों 32 चर 116 फॉर्म सैम्पल से एकत्र किए। यह उदाहरण कारक वि लेषण के लिए उपयोग तकनीक है, के उपयोग के लिए भूगोल वेत्ताओं को सलाह दिया।

छत्तीसगढ़ राज्य में जनसंख्या प्रदे 1 के निर्माण के लिए कारक वि लेषण (Factor Analysis) विधि का उपयोग किया गया है। कारक वि लेषण विधि उन आँकड़ों के लिए अधिका उपयोगी होता है, जिसमें निकर्षों (criteria) तथा चरों (Variables) की संख्या अधिक होती है तथा आँकड़ों विभिन्न परिमाण (Magnitude) तथा परिसर (Range) वाले होते हैं। यह अन्तर्सम्बन्धित चरों को विभिन्न समूहों में बाँटता है, और विभिन्न समूहों के अन्तर्सम्बन्धित चरों के आधार पर विभिन्न जनसंख्या प्रदे 1 का निर्माण किया गया है। प्रत्येक स्तर के जनसंख्या प्रदे 1 उससे सम्बन्धित चरों के स्थानिक प्रतिरूप को स्पष्ट करता है।

जनसंख्या प्रदे 1 में पदानुक्रम होता है। जिसमें अन्तर्सम्बन्धित चरों के आधार पर विभिन्न स्तर के प्रदे 1ों का निर्माण किया जाता है। जनसंख्या प्रदे 1 में चरों की संख्या में कमी अथवा वर्ग से परिवर्तन होता है।

कारक वि लेषण (Factor Analysis) : सहसम्बन्धा आव्यूहों (व्युत्पन्नसंज्ञपद डंजतपग) ऐसा आँकड़ा प्रदान करता है, जिसके द्वारा कारक तथा भार (Loading) की गणना की जाती है। यह आव्यूह (Matrix) सम्पूर्ण संभव चर युग्मों (Pairs of Variables) के बीच सम्बन्धा की माप प्रदान करता है।

सहसम्बन्धा गुणनघूर्ण (Product moment correlation) की अगली गणना समाश्रयण रेखा प्रदान करती है। दो चरों के संदर्भ में इसका अंकन सरल होता है। यदि तीन चर अन्तर्सम्बन्धित हो तो, बिन्दु प्रकीर्णन (बिखराव) त्रिविमीय स्वरूप में देखना संभव होता है। तीन से अधिक चरों से संबंधित अवस्थाओं में चित्रात्मक

प्रदर्शन संभव नहीं होता है, किन्तु इस प्रकार का वि लेषण गणितीय रूप में द आयाम प्रयोग कर किसी भी संख्या में चरों के लिए जारी रखना संभव होता है, तथापि 20 चरों से अधिक होने पर गणना अत्यन्त लम्बी हो जाती है। बहुविमीय बिन्दु प्रकीर्णन द्वारा सुष्ठुतम आसंजन कक्ष (गोले वीडिमेज पिज) की सहायता से इसका कुछ आभास प्राप्त किया जा सकता है।

कारकों (Factor) के सहसम्बन्धा - आव्यूह द्वारा प्राप्त किया जाता है और वे बहु - विमितीय में बिन्दु - प्रकीर्णन को परिभाषित करने के लिए आवश्यक अक्षों की लम्बाई पर आधारित होते हैं। यदि वे निकटतम संयोजित हैं तो अतिदीर्घवृज (Hyperellipsoid) की अक्ष लम्बी होगी और अधिकांश बिन्दु इसके निकट ही स्थित होंगे। यह प्रथम कारक पर, उच्च कारक मान प्रदान करेगा। कारक द्वारा आगणित चर - परिवर्तिता - प्रतिात, कारक मान में 100 से गुणा कर उसे चरों की संख्या में विभाजित कर निकाला जा सकता है। यही नियम दूसरे एवं अन्य अनुवर्ती चरों के लिए भी प्रयुक्त होता है। इसी प्रकार अनुवर्ती कारकों को क्रम 1: जोड़ते हुए एक संचयी प्रतिात की गणना की जा सकती है।

द्वितीय कारक, प्रथम कारक अक्ष के लम्बकोणीय (Orthogonal), अक्ष की लंबाई से संबंधित होता है। द्वितीय कारक की स्थिति इस प्रकार निश्चित की जाती है कि प्रथम अक्ष से दूर स्थित बिन्दुओं की दूरी द्वितीय कारक अक्ष के समीप हो। इसीलिए द्वितीय कारक प्रथम से अलग भार प्रदर्शित करता है। द्वितीय कारक - अक्ष की लम्बाई, सामान्यतः प्रथम कारक अक्ष से छोटी होती है। जब अन्य चरों की तुलना में सभी चरों के बंटन पूर्ण यादच्छिक (Random) हों और सभी गुणांक न्यून मान प्रकट करते हों, तो ऐसी अवस्था में सभी कारकों के अक्ष तथा उनके मान लगभग समान होंगे।

तृतीय कारक अक्ष अन्य दो पर लम्बकोणीय होता है। कारक आँकड़ों की विभिन्नता सम्पूर्ण चरों के प्रभाव को संक्षेपित करता है। किन्तु च घूर्णन (Rotation) के प्रत्येक स्तर पर प्रत्येक चर, किस प्रकार कारक अक्षों से संबंधित है, इसके लिए आगे वि लेषण की आवश्यकता है। यह वि लेषण प्रत्येक चर पर कारक भार प्रदान करता है। कारकों का निर्वचन व्याख्या कारक भार द्वारा प्रदर्शित चरों एवं कारकों के संबंधों की कितनी पराश्रित होता है।

कारक भार (Factor Loadings) मध्य चरों एवं कारकों के मध्य सहसम्बन्धा की माप करता है। प्रत्येक चर पर कारक भार सहसम्बन्धा गुणांक से निकट सम्बन्धा रखता है। यदि गुणांक उच्च है तो उच्च कारक भार होगा। अनेक चरों की अवस्था में, यदि सभी उच्च भार धारण करते हैं। तो वे सभी कारक अक्ष (Factor axis) के समीप होंगे और आपस में भी वे उच्च अन्तर्सम्बन्धित होंगे। इसका तात्पर्य यह है कि उनमें अधिकांश समानता है तथा उनकी वि लेषणाएँ क्षेत्र परिवर्तिता को आँकती है। यह एक उच्च प्रथम कारक का मान प्रदान करेगा। संघटक

Table 2: Correlation Coefficient Matrix

VARIABLES	SEX RATIO	DENSITY	LITERACY	URBAN	MIGRA	TFR	IMR	SC	ST	DEPENT	AGRI
SEX RATIO	1	-0.113	-0.086	-0.634	0.026	0.096	0.154	-0.173	0.025	-0.066	0.66
DENSITY	-0.113	1	0.573	0.419	0.163	0.038	-0.097	0.813	-0.763	0.146	-0.38
LITERACY	-0.086	0.573	1	0.335	0.3	-0.174	0.184	0.386	-0.589	-0.233	-0.37
URBAN	-0.634	0.419	0.335	1	0.363	-0.446	-0.099	0.371	-0.381	-0.334	-0.87
MIGRATI	0.026	0.163	0.3	0.363	1	-0.398	0.134	0.185	-0.473	-0.427	-0.26
TFR	0.096	0.038	-0.174	-0.446	-0.398	1	0.174	0.149	-0.038	0.702	0.575
IMR	0.154	-0.097	0.184	-0.099	0.134	0.174	1	-0.301	0.016	-0.129	0.31
SC	-0.173	0.813	0.386	0.371	0.185	0.149	-0.301	1	-0.804	0.432	-0.41
ST	0.025	-0.763	-0.589	-0.381	-0.473	-0.038	0.016	-0.804	1	-0.252	0.311
DEPENDENT	-0.066	0.146	-0.233	-0.334	-0.427	0.702	-0.129	0.432	-0.252	1	0.277
AGRI	0.66	-0.377	-0.373	-0.869	-0.264	0.575	0.31	-0.414	0.311	0.277	1

वि लेषण (Component Analysis) में सभी Factor को सामान्य भिन्नता (Common variation) के अन्तर्गत मानते हैं। कारक भार का एक गुण यह है कि उच्चतम कारक भार धारण करने वाले कारकों को अत्यन्त महत्वपूर्ण कारक के रूप चुना जा सकता है। ये चर क्षेत्र के विशेष सूचना के रूप प्रयोग किए जा सकते हैं। यदि क्षेत्रों के बीच भिन्नता का सांख्यिकीय परीक्षण एवं उनमें सार्थक अन्तर निश्चित करना इच्छित हो तो इन चरों के लिए प्रसरण वि लेषण परीक्षण (Analysis of Variance Test) का प्रयोग किया जाना चाहिए।

कारक भार का उपयोगी परिणाम विभिन्न क्षेत्रों में भिन्नता उत्पन्न करने वाले कारकों की प्रकृति को इंगित करना होता है। और अनेक क्षेत्रों के पथक वि लेषण करने पर यह संभव होता है कि प्रत्येक चुने हुए विभिन्न चरों में भिन्नता से किस प्रकार मेल खाते हैं। व्यक्तिगत कारक भारों की जाँच कर प्रत्येक क्षेत्र को उपक्षेत्रों में विलग किया जा सकता है।

व्यक्तिगत कारक भार से कारकों में भिन्नता हेतु क्षेत्र का ज्ञान होता है। प्रथम एवं द्वितीय कारक पर व्यक्तिगत भारों के बीच सम्बन्धों के विचार करने की एक उपयोगी विधि इन मानों को ग्राफ पर एक दूसरे के लिए अंकित करना है। इस प्रकार कारक वि लेषण महत्वपूर्ण चरों के आधार पर क्षेत्रों अथवा वि लेषण हेतु प्रयुक्त अन्य इकाइयों के बीच सार्थक अन्तरों के निर्धारण की उपयोगी विधि प्रदान करता है। मूल संघटक वि लेषण और कारक वि लेषण का उपयोग विद्वानों के लगभग एक समान विधि के रूप में किया है। किन्तु दोनों विधियों में कुछ मूलभूत अंतर है। जिसका गणितीय अंतर को कैटल (1952, फुचर,

1954 और हारमेन, 1960) ने बताया है। मूल संघटक वि लेषण (Principal Component Analysis) और कारक वि लेषण (Factor Analysis) में सूक्ष्म अंतर पाया जाता है, चूँकि दोनों विधियाँ आधारभूत रूप में अनेक अवलोकनों हेतु विभिन्न चरों के सम्बन्धों के अध्ययनार्थ समान क्रिया विधि का प्रयोग करती है। अतः उनमें अंतर का प्रयत्न नहीं किया जाता है।

कारक वि लेषण के चरण (The Stages of Factor Analysis)

कोल एवं किंग (1968) ने कारक वि लेषण के निम्नलिखित चरण बताये हैं -

क्षेत्र का चुनाव (The Choice of Areas) क्षेत्र के लिए विशेष इकाई का चयन आवश्यक होता है।

1. चरों का चुनाव (The Choice of Variable) जहाँ तक संभव हो चर स्वतंत्र होना चाहिए।
2. आँकड़ों आव्यूहों में व्यवस्थित करना (The Arranging of the data in matrix) आव्यूह पूर्ण होने चाहिए। आँकड़े न्यून में नहीं होना चाहिए। यदि आँकड़े न्यून हैं तो उसको न्यूनतम अंक प्रदान करें।
3. माध्य एवं मानक विचलन की गणना (The calculations of the means and standard deviations) व्यक्तिगत मानों में भिन्नता की मात्र ज्ञात करने के लिए माध्य एवं मानक विचलन एक उपयोगी मार्गद कि होता है। ये दोनों सहसम्बन्धा की मात्र को दर्शाते हैं।
4. सहसम्बन्धा आव्यूह (Correlation Matrix) सहसम्बन्धा आव्यूह सभी चरों के बीच सम्बन्धा की मात्र को बताता है।
5. कारक (Factor) कारक जो सहसम्बन्धा को व्यक्त करता है,

Table 1: Demographic Data: Centroid Method

Districts	SEX	DENSITY	LITERACY	URBAN	MIGRA	TFR	IMR	SC	ST	Dependent	AGRI
Koriya	947	89	63.4	29.9	34.4	3.8	69	8.2	44.4	77.8	61.8
Surguja	972	125	55.4	7	29	4.43	70	4.8	54.6	84.9	81.3
Bilaspur	975	241	63.7	24.2	30.9	4.41	65	18.5	19.9	82.5	67.2
Korba	964	153	63.2	36.3	38.9	4.05	82	10	41.5	76.4	56.9
Janjgir	999	342	66.3	11	29.2	4.61	64	22.5	11.6	87.3	78.0
Jashpur	998	127	65.4	4.6	28.6	4.4	91	4.9	63.5	79.6	84.1
Raigarh	995	179	70.5	13.4	33.1	3.56	54	14.3	35.4	80.2	59.2
Kawardha	1002	138	55.4	7.7	30.3	4.64	75	12.7	10.3	90.9	85.2
Rajnandgoan	1024	159	77.6	18.1	33	4.1	83	9.9	26.7	77.9	78.1
Durg	982	328	75.8	38.1	38	3.74	74	12.8	12.4	73.9	60.8
Raipur	980	230	69	30.5	35.4	4.04	42	16.2	12.1	79.9	55.9
Mahasamund	1019	180	67.6	11.4	51.2	3.99	84	12.1	2.7	76.4	80.3
Dhamtari	1005	208	75.2	13.3	31.4	3.86	75	7	26.4	76	75.8
Kanker	1006	100	73.3	4.9	33	4.33	64	4.3	56	74.8	83.1
Bastar	1009	87	45.5	10	26.3	4.08	79	3	66.5	77.7	76.8
Dantewara	1017	41	30	7.2	31.9	3.98	52	3.4	78.6	77.6	86.6

और आइगन मान (Eigen value) पर आधारित होता है।

- कारक भार (Factor Loading) प्रत्येक चर सहसम्बन्धा गुणांक (Correlation Coefficient) से घनिष्ठ रूप से संबंधित होता है।
- व्यक्तिगत कारक भार (The Individual Factor Weightings) व्यक्तिगत कारक भार प्रत्येक कारक भिन्नता को बताता है।

प्रदे 1 के निर्माण के लिए 11 चर चयनित किए गए। ये 11 चर निम्नलिखित हैं :-

- लिंग अनुपात
- जनसंख्या का घनत्व
- साक्षरता दर
- नगरीय जनसंख्या
- प्रवास की मात्रा
- कुल प्रजननता दर
- मृत्यु दर
- अनुसूचित जाति जनसंख्या
- अनुसूचित जनजाति जनसंख्या
- आश्रित जनसंख्या
- कृषक एवं कृषि श्रमिक इन सभी 11 चरों को आव्यूहों (Matrix) में सारणीकृत कर लिया गया। सभी चरों के मान को मानकीकृत मूल्यों (Standard Score Matrix) में बदला गया है। चरों को गुणनघूर्ण (Product Moment) विधि द्वारा संबंधित कर उन्हें एक सहसम्बन्धा आव्यूहों (Correlation Matrix) में परिणित किया गया।

सहसम्बन्धा आव्यूहों (Correlation Matrix) के आधार पर प्रत्येक चर का योग ($\sum$ तप) कर लिया गया तत्पश्चात् सभी चरों का कुल योग ($\sum$ प) कर लिया गया। कुल योग का वर्ग ($\sum$ ज) से प्रत्येक चर के योग को भाग दिया गया है, जो कारक भार

(Factor Loading), (प) कहलाता है। इन भार (Loading) के वर्ग के योगकर आइगन मूल्य (Eigen Value) प्राप्त किया गया है।

प्रस्तुत अध्ययन में चार कारक (Fourth Component) तक के आइगन मूल्य (Eigen Value) को व्यक्तिगत कारकों को भार प्रदान करने के लिए चयन किया है। ये चारों आइगन मूल्य (Eigen Value) प्रथम कारक (First Component) के लिये 4.060, द्वितीय कारक (Second Component) के लिए 2.541, तृतीय कारक (Third Component) के लिए 1.718 और चतुर्थ कारक (Fourth Component) के लिए 1.018 मूल्य प्राप्त हुआ। पांचवे कारक के आगे आइगन मूल्य (Eigen Value) 1.00 से कम है। अतः अध्ययन में चतुर्थ कारक (Fourth Component) तक शामिल किया गया है। ये सभी कारक 10 प्रतिशत से अधिक भिन्नता की व्याख्या (Explain) करते हैं। ये चारों कारक क्रमशः 39.9%, 23.1%, 15.6% और 9.3% भिन्नता की व्याख्या करते हैं। ये चारों कारक मिलकर सम्मिलित रूप से 84.9% भिन्नता की व्याख्या करते हैं। जबकि शेष 15.1% भिन्नता की व्याख्या ये चारों कारक के द्वारा अनुत्तरित रह जाता है।

प्रत्येक कारक (Component) के विलेषण के लिए प्रत्येक चर के भार (Loading) को व्यक्तिगत मान (Individual Values) से गुणा किया गया है। ये व्यक्तिगत मान ही मानकीकृत मूल्य होंगे। कारक विलेषण की गणना में यह मान लिया जाता है कि

Table 3: Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.060	36.906	36.906	4.060	36.906	36.906
2	2.541	23.103	60.009	2.541	23.103	60.009
3	1.718	15.620	75.629	1.718	15.620	75.629
4	1.018	9.257	84.886	1.018	9.257	84.886
5	.696	6.330	91.216			
6	.359	3.262	94.478			
7	.275	2.496	96.974			
8	.156	1.417	98.391			
9	.115	1.042	99.433			
10	3.865E-02	.351	99.784			
11	2.376E-02	.216	100.000			

Table 4: Component Matrix

VARIABLES	Components			
	1	2	3	4
SEX RATIO	-.453	.178	.654	-.488
DENSITY	.750	.472	.133	-3.905E-02
LITERACY	.649	6.774E-02	.447	.203
URBAN	.818	-.339	-.231	.214
MIGRATION	.490	-.292	.530	-.155
TFR	-.380	.777	-6.035E-02	.324
IMR	-.186	-4.460E-02	.605	.720
SC	.722	.613	-8.278E-02	-.177
ST	-.750	-.491	-.319	7.915E-02
DEPENDENT	-.151	.855	-.349	7.098E-02
AGRICULTURE	-.822	.356	.373	-3.957E-02

1. अन्तर्संबंधात चरों के आव्यूहों (Matrix) में कुछ सामान्य सर्वनिष्ठ कारक सम्पूर्ण आँकड़ोंमें विद्यमान रहते हैं, जो कारक वि लेषण द्वारा निस्सारित एवं प्रकट किये जाते हैं।

2. कुल भिन्नता (Total Variance), कारक भिन्नता (Component Variance) और असामान्य तथा त्रुटि भिन्नता (Unique and Error Variation) का योगफल होता है।

3. चरों के सहसम्बन्धा उनके सामान्य कारक भार द्वारा
- आगणित होते हैं। इस प्रकार सहसम्बन्धा आव्यूह (Correlation Matrix) आँकड़ा प्रदान करता है, जिसकी सहायता से कारक भार (Factor Loading) की गणना की जाती है।

4- चरों का चुनाव अत्यन्त महत्वपूर्ण होता है, यदि सामान्य प्रसरण नहीं है तो परिणाम संतोषप्रद नहीं होते। अतः चरों के चुनाव से पूर्व सर्तकता पूर्वक मनन आव यक हो जाता है।

Table 5: Population Regions

Variables	Factor I (Population Concentration)	Factor Loadings
1	Population Density	.750
2	Literacy	.649
3	Urban Population	.818
4	Scheduled Caste	.722
5	Scheduled Tribes	-.750
6	Agriculture Population	-.822
Factor II (Population Growth)		
1	Total Fertility Rate	.777
2	Dependency Ratio	.855
Factor III (Dynamics of Population)		
1	Migration	.530
2	Sex Ratio	.654
Factor IV (Population Health)		
1	Infant Mortality Rate	.720

Table 6: Component Scores

Districts	Components			
	I	II	III	IV
Koriya	0.403	-3.994	-1.924	0.743
Surguja	-5.557	0.005	-1.716	0.464
Bilaspur	1.676	1.624	-1.177	0.017
Korba	1.592	-3.496	-0.470	1.238
Janjgir	1.132	5.204	0.042	-0.689
Jashpur	-5.923	-0.794	1.171	1.276
Raigarh	1.623	-1.753	-0.460	-1.746
Kawardha	-4.013	3.887	-0.115	-0.102
Rajnandgoan	-0.825	-0.567	3.146	0.114
Durg	5.852	-2.186	1.562	0.175
Raipur	4.434	-0.396	-1.482	-1.589
Mahasamund	0.823	-0.896	4.718	-0.929
Dhamtari	-0.326	-1.492	2.168	-0.217
Kanker	-4.233	-1.850	1.453	-0.479
Bastar	-7.636	-2.709	-0.909	-0.376
Dantewara	-10.117	-3.349	-2.425	-2.904

5. चूंकि ये सभी आँकड़े एक ही मापक पर नहीं होते। अतः प्रयोग से पूर्व इन्हें मानकीकृत (Standardization) कर लेना चाहिए।

छत्तीसगढ़ प्रदेश में जनसंख्या प्रदेश I

छत्तीसगढ़ राज्य में जनसंख्या प्रदेश I कारक वि लेषण (Factor Analysis) के आधार पर बनाया गया है। इस हेतु 2001 की एक जनगणना से प्राप्त 11 चरों के आँकड़ों को आधार माना गया है।

जनसंख्या प्रदे I का निर्माण प्रदे I के 16 जिलों के आधार पर किया गया है। इस हेतु चतुर्थ कारक (Fourth Factor) तक प्रदे I का निर्माण किया गया है। पांचवे चर का आइगन मूल्य (Eigen Value) 1.0 से कम होने कारण छोड़ दिया गया है। 1.0 से कम आइगन मूल्य 10% से कम भिन्नता (Variation) की व्याख्या करता है।

प्रस्तुत अध्ययन में छत्तीसगढ़ के 16 जिलों के 11 चयनित चरों के आँकड़ों को संकलित कर वि लेषण किया गया है। इन चरों के औसत मान, प्रमाप विचलन ज्ञात कर सहसम्बन्धा आव्यूहों (Correlation Matrix) की गणना की गई है। इन सहसम्बन्धों की सार्थकता “टी परीक्षण” द्वारा किया गया है तथा आइगन मूल्य (Eigen Value) और आइगन वेक्टर (Eigen Vector) ज्ञात किया गया है जिससे भारित कारक (Loaded Value) का आंकलन किया गया। यह आइगन मान ही कारक (Factor) मान है। अवरोही क्रम में विभिन्न आइगन मान को क्रम I: प्रथम, द्वितीय, तृतीय और चतुर्थ कारक में माना गया है।

उपयुक्त 11 चरों में से जनसंख्या का घनत्व, साक्षरता, नगरीय जनसंख्या अनुसूचित जाति, अनुसूचित जनजाति एवं कृषि जनसंख्या, जनसंख्या संकेतन से संबंधित है। जबकि कुल प्रजनता दर और आश्रित जनसंख्या जनसंख्या वी) को दर्शाता है। लिंग अनुपात और प्रवास जनांकिकीय गति गतिता को दर्शाता है। IJ मृत्युता दर जनसंख्या स्वास्थ्य से संबंधित है। विभिन्न चरों के मध्य सहसम्बन्धा से निम्नलिखित निष्कर्ष प्राप्त किए जा सकते हैं जो जनसंख्या प्रदे I के निर्माण में सहायक सि) हो सकता है।

1. कृषि जनसंख्या में नगरीय जनसंख्या कम होता है।
2. अधिक घनत्व के क्षेत्र में कुल प्रजनता दर अधिक है।
3. अनुसूचित जाति और अनुसूचित जनजाति का वितरण प्रारूप विपरीत है।
4. अनुसूचित जाति जनसंख्या घनी जनसंख्या के क्षेत्रों में अधिक है।
5. अनुसूचित जनजातिय क्षेत्रों में साक्षरता कम है।
6. अनुसूचित जनजातिय क्षेत्रों में प्रवास कम है।

प्रथम कारक का मान 4.060 है जो 36.9 प्रतिशत भिन्नता को स्पष्ट कर सकता है। द्वितीय कारक का मान 2.541 है जो 23.1 प्रतिशत भिन्नता को समाहित रखता है। प्रथम चार कारक 84.9 % आँकड़ों में भिन्नता की व्याख्या करता है। इन 11 चरों के 84.9 % आँकड़ों में भिन्नता की व्याख्या 4 मानचित्र के माध्यम से किया गया है।

संघटक स्कोर (Component Scores) -

सभी कारकों (Factors) के मानचित्र निर्माण के लिए सभी संघटक (Component) के प्रत्येक चर (Observation) के मूल्य (Scores) की गणना आवश्यक है। “वास्तव में ये मूल्य (Scores) जिलों के प्रत्येक चर को उसके संघटक भार

(Component Loading) से गुणा कर प्राप्त किया जा सकता है। प्रत्येक चर के आँकड़े मानकीकृत आँकड़े होंगे। प्रत्येक संघटक (Component) के भार (Loading) को Wiegth के रूप में लिया जाएगा” (यीट्स, 1968)।

किसी भी प्रेक्षित इकाई (Observation Unit) के उच्चतम स्कोर (Highest Score) उस विशेष संघटक के उच्च संकेतन (Highest in Concentration) को बताता है। इसके विपरीत न्यूनतम स्कोर (Lowest Score) इसके विपरीत परिणाम को दर्शाता है। उच्च ;णात्मक स्कोर ;णात्मक भार (Negative Loadings) को दर्शाता है।

इसी तरह से प्रत्येक संघटक (Component) को उसके भार (Loading) से गुणा कर सभी संघटक (Component) के गुणनफल का योग संघटक स्कोर (Component Score) प्राप्त किया जा सकता है। प्राप्त संघटक स्कोर (Component Score) को 6 वर्ग तीन धनात्मक और तीन ;णात्मक में विभाजित कर छायाविधि (Choropleth) द्वारा मानचित्र का निर्माण किया गया है।

प्रथम कारक वि लेषण (First Factor Analysis) :-

प्रस्तुत अध्ययन में प्रथम कारक 36-9% भिन्नता की व्याख्या करता है। प्रथम कारक के अर्न्तगत 6 चरों का भार (स्वंपदह) बहुत अधिक (Strong) +65 या -65 से अधिक है। इसमें चार चर - जनसंख्या का घनत्व, साक्षरता, नगरीय जनसंख्या एवं अनुसूचित जाति जनसंख्या का भार धनात्मक (Positive) है। णे दो चर - अनुसूचित जनजाति जनसंख्या एवं कृषि जनसंख्या का भार ;णात्मक (Negative) है।

इनमें जनसंख्या का घनत्व, साक्षरता और नगरीय जनसंख्या एक-दूसरे से घनिष्ट रूप से संबंधित है। इसी तरह अनुसूचित जनजाति जनसंख्या और कृषि जनसंख्या आपस में घनिष्ट रूप से संबंधित है। ये 6 कारक जनसंख्या संकेतन को व्यक्त करते हैं, अतः प्रथम कारक पर आधारित मानचित्र का नामकरण जनसंख्या संकेतन (Population Concentration) किया गया है।

प्रथम कारक वि लेषण के अर्न्तगत छत्तीसगढ़ बेसिन छत्तीसगढ़ के मध्य भाग में सभी संघटक स्कोर (Component Scores) अधिक है। इसमें से दुर्ग +6.12 का प्रथम एवं रायपुर +4.59 का द्वितीय स्थान है। उल्लेखनीय है कि रायपुर जिले में सभी संघटक स्कोर (Component Scores) धनात्मक (Positive) है। दुर्ग जिले में IJ मृत्युता दर को छोड़, सभी संघटक स्कोर धनात्मक है। ज Iपुर, जिले में साक्षरता को छोड़, बस्तर में कुल प्रजनता दर को छोड़, दत्तेवाड़ा जिले में कुल प्रजनता दर और IJ मृत्युता दर, एवं सरगुजा जिले में लिंगानुपात एवं IJ मृत्युता दर छोड़, सभी संघटक स्कोर (Component Scores) ;णात्मक (Negative) है। इसी तरह कवर्धा जिले में अनुसूचित जाति और अनुसूचित जनजाति को छोड़ और कांकेर जिले में साक्षरता एवं

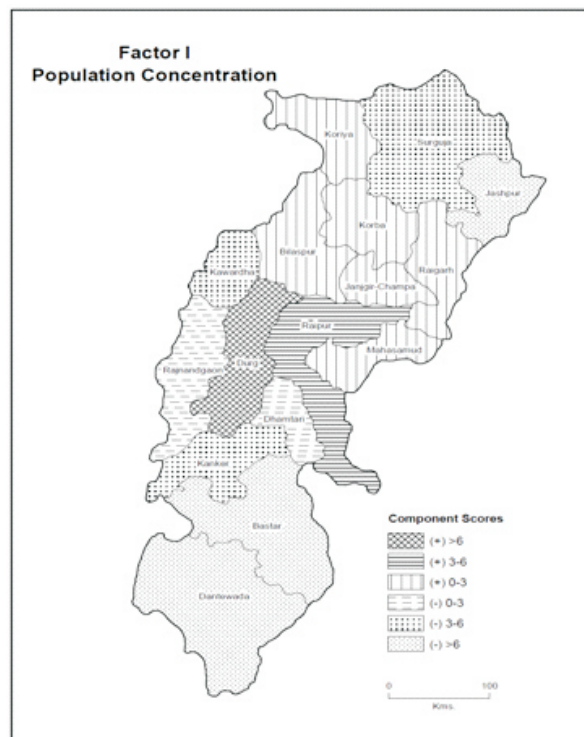
FIG मर्त्यता दर को छोड़ सभी संघटक स्कोर (Component Scores) णात्मक (Negative) है।

प्रथम कारक वि लेषण के अंतर्गत संघटक स्कोर (Component Scores) दत्तेवाड़ा जिले में -10.3 सर्वाधिक है। यह स्कोर बस्तर जिला में -7.06, ज।पुर जिले में -6.1 और सरगुजा जिले में -5.7 है। णात्मक संघटक स्कोर (Negative Component Score) छत्तीसगढ़ के उत्तरी भाग सरगुजा, एवं ज।पुर जिले में है।

प्रथम कारक का स्कोर बेसिन के मध्य भाग में धानात्मक है। जहाँ सम धारातल, यातायात के साधन, जनसंख्या का घनत्व, नगरीय जनसंख्या का अनुपात तथा साक्षरता अधिका है। इसके विपरीत प्रदेश के उत्तरी एवं दक्षिणी भागों में विषम धारातल, घने वन के कारण यातायात के साधनों की कमी है। अतः इन क्षेत्रों में अनुसूचित जनजातियों की संख्या अधिका है, जो कृषि पर आधारित जनसंख्या है।

प्रथम कारक में कृषि जनसंख्या का संघटक सूचकांक (Component Index) रायपुर जिले में सर्वाधिक +1.11 है। नगरीय जनसंख्या का संघटक सूचकांक दुर्ग जिले में सर्वाधिक +1.30 है। साक्षरता का संघटक सूचकांक राजनांदगांव जिले में सर्वाधिक +1.26 है। प्रवास संघटक सूचकांक महासमुंद जिले में सर्वाधिक +1.45 है। जनसंख्या घनत्व +1.33 तथा अनुसूचित जातियों +1.23 का संघटक सूचकांक जांजगीर-चांपा जिले में सर्वाधिक है। इसके विपरीत दत्तेवाड़ा जिले में साक्षरता -3.45 एवं जनसंख्या का घनत्व का संघटक सूचकांक -1.42 णात्मक में सबसे अधिका है। इसी तरह अनुसूचित जनजाति -1.95, अनुसूचित जाति -1.15, एवं कृषि जनसंख्या -1.18 का संघटक सूचकांक णात्मक में सबसे अधिका है। बस्तर जिले में जनसंख्या का घनत्व का -1.01, साक्षरता का संघटक अनुपात -1.98, अनुसूचित जाति का -1.47 एवं अनुसूचित जाति का संघटक अनुपात -1.20 है। ज।पुर जिले में अनुसूचित जनजाति संघटक अनुपात सर्वाधिक -1.36 है।

छत्तीसगढ़ बेसिन में जनसंख्या का संकेत अति उच्च पाया गया है। इसके विपरीत प्रदेश के उत्तर एवं दक्षिण विषम धारातल क्षेत्रों में जनसंख्या संकेत विरली है। बेसिन में जांजगीर-चांपा जिले में जनसंख्या का घनत्व 342 और दुर्ग जिले 328 व्यक्ति प्रति वर्ग कि.मी. है। साथ ही इन क्षेत्रों में वैश्विक संस्थानों की संख्या अधिका होने से साक्षर जनसंख्या का प्रति 100 प्रति 100 से अधिका है। साक्षर जनसंख्या राजनांदगांव जिले में 77.6 प्रति 100, दुर्ग जिले में 75.8 प्रति 100, धामतरी जिले में 75.2 प्रति 100, कांकर जिले में 73.3 प्रति 100 और रायगढ़ जिले में 70.5 प्रति 100 है। इसके विपरीत राज्य के दक्षिणी भाग में दत्तेवाड़ा जिला में 30.0 प्रति 100 तथा बस्तर जिले में 45-5 प्रति 100 जनसंख्या ही साक्षर है।



राज्य के मध्यवर्ती मैदानी क्षेत्र में सम धारातल के कारण यातायात के साधनों का विकास हुआ है जिससे औद्योगिकरण को प्रोत्साहन मिला है। इन क्षेत्रों में भिलाई में लौह इस्पात तथा उसके समीपवर्ती क्षेत्रों में कई छोटे-बड़े उद्योग स्थापित हैं जिससे नगरीकरण को बल मिला है। दुर्ग जिले में 38.0 प्रति 100, कोरबा में 36.3 प्रति 100 और रायपुर में 30.0 प्रति 100 जनसंख्या नगरों में निवास करती है। इसके विपरीत कांकर में 4.9 प्रति 100, सरगुजा में 7.0 प्रति 100, दत्तेवाड़ा में 7.2, और कवर्धा में 7.7 प्रति 100 जनसंख्या ही नगरों में रहती है।

घनी जनसंख्या के क्षेत्रों में अनुसूचित जाति जनसंख्या का संकेत अधिका है। जांजगीर-चांपा जिले में 22.5 प्रति 100 जनसंख्या अनुसूचित जातियों की है। इसके विपरीत अनुसूचित जनजाति जनसंख्या प्रदेश के उत्तरी एवं दक्षिणी भागों में केन्द्रित है। दत्तेवाड़ा जिला में 78.6 प्रति 100, बस्तर में 66.5 प्रति 100, ज।पुर में 63.5 प्रति 100, कांकर में 56.0 प्रति 100, सरगुजा में 54.0 प्रति 100, कोरिया में 44.4 और कोरबा में 41.5 प्रति 100 जनसंख्या अनुसूचित जनजातियों की है। उल्लेखनीय है कि अनुसूचित जनजातिय प्रधान क्षेत्रों में कृषि जनसंख्या का प्रति 100 भी अधिका है। दत्तेवाड़ा जिला में 86.6 प्रति 100, कांकर में 83.1 प्रति 100, सरगुजा में 81.3 और महासमुंद जिले में 80.3 प्रति 100 जनसंख्या कृषि पर आधारित है।

द्वितीय कारक (Second Factor):-

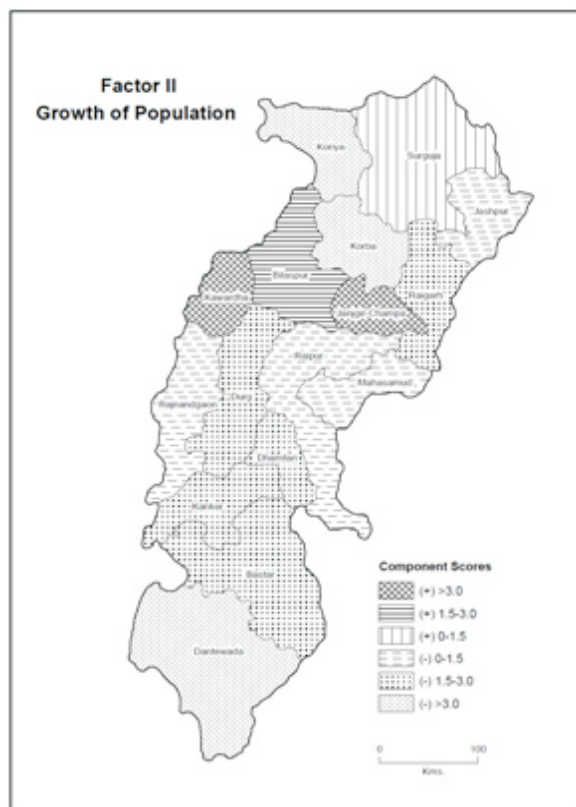
द्वितीय संघटक 23.1% की व्याख्या करता है। इसके अन्तर्गत दो चर कुल प्रजननता दर और आश्रित जनसंख्या शामिल हैं। इन दोनों चरों का भार (Loading) बहुत अधिका सुदृढ़ (Strong) है।

इन दोनों चरों का संघटक अनुपात क्रम I: +.777 एवं +.855 है। ये दोनों चर जनसंख्या वृद्धि (Population Growth) को व्यक्त करते हैं। अतः इसका नामकरण जनसंख्या वृद्धि (Population Growth) किया गया है।

द्वितीय कारक वि लेषण कुल प्रजननता दर और आश्रित जनसंख्या पर आधारित है। द्वितीय कारक के अन्तर्गत सभी संघटक स्कोर धनात्मक हैं। यही कारण है कि द्वितीय कारक का संघटक स्कोर धनात्मक में सर्वाधिक जांजगीर-चांपा जिले में +5.20 और कवर्धा जिले +3.89 का द्वितीय स्थान है। इसके विपरीत ;णात्मक में सर्वाधिक कोरिया जिले में -3.99 है। कोरिया जिले में िगु मर्त्यता दर को छोड़ सभी संघटक अनुपात ;णात्मक हैं। द्वितीय कारक के अन्तर्गत छत्तीसगढ़ के उत्तरी भागों में संघटक स्कोर ;णात्मक अधिक है। इसका अपवाद सरगुजा जिला है, जहां संघटक सूचकांक धनात्मक +0.0056 है।

द्वितीय कारक के अन्तर्गत कुल प्रजननता दर का संघटक अनुपात कवर्धा जिले +1.02 तथा जांजगीर-चांपा +0.95 जिलों में धनात्मक में अधिक है। जबकि धामतरी -1.08 , रायगढ़ -1.501 , कांकेर -1.13 , दुर्ग -1.29 और कोरिया जिले -0.942 में यह अनुपात ;णात्मक है। आश्रित जनसंख्या कवर्धा +1.723 , महासमुंद +1.380 और जांजगीर-चांपा +1.085 जिलों में धनात्मक में अधिक है। आश्रित जनसंख्या का संघटक अनुपात कोरबा जिले -.846 में ;णात्मक में सर्वाधिक है।

राज्य के दक्षिणी भागों में जनसंख्या की वृद्धि दर अधिक और



उत्तरी भाग में अपेक्षाकृत कम है। राज्य के उत्तरी भाग में कोरिया जिले में कुल प्रजननता दर 3.80, रायगढ़ में 3.56, और दुर्ग जिले में 3.74 है। इसके विपरीत दक्षिणी के जिलों में कांकेर जिले में कुल प्रजननता दर 4.33 और बस्तर जिले में 4.08 है। निरक्षर जनसंख्या जिसमें 0-6 वर्ष के बच्चे भी शामिल हैं, राज्य के दक्षिणी भागों में अधिक है।

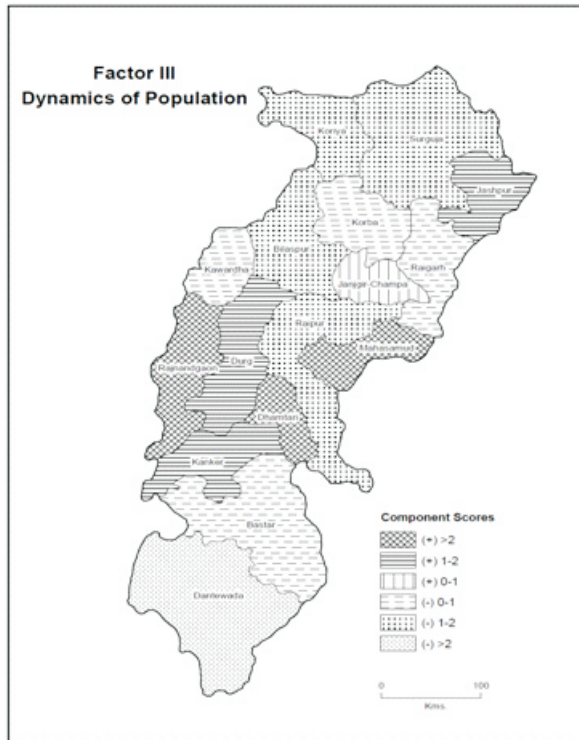
तृतीय कारक (Third Factor):-

तृतीय कारक में दो चर शामिल हैं, जिनका संघटक भार +.654 और +.530 है। ये दो चर लिंगानुपात और प्रवास हैं। ये दोनों चर मिलकर जनसंख्या गतिशीलता को व्यक्त करते हैं। अतः तृतीय कारक पर आधारित मानचित्र का नामकरण जनसंख्या गतिशीलता (Dynamics of Population) किया गया है। चूंकि प्रवास लिंग चयनात्मक होता है। अतः लिंगानुपात और प्रवास एक-दूसरे से घनिष्ठ रूप से संबंधित हैं। तृतीय कारक पर आधारित मानचित्र प्रतिरूप द्वितीय कारक के समान है। इसमें राज्य के पूर्वी एवं पश्चिमी भाग में संघटक सूचकांक धनात्मक और उत्तरी एवं दक्षिणी भागों में ;णात्मक है।

तृतीय कारक पर आधारित संघटक सूचकांक दंतेवाड़ा जिला में ;णात्मक में सर्वाधिक -2.425 है। इस जिले में नगरीय जनसंख्या, जनसंख्या का घनत्व, साक्षरता, प्रवास, िगु मर्त्यता और अनुसूचित जनजाति जनसंख्या संघटक अनुपात ;णात्मक है। संघटक अनुपात में ;णात्मक में कोरिया जिले -1.94 का द्वितीय स्थान है। इसके विपरीत महासमुंद जिले में संघटक अनुपात धनात्मक में सर्वाधिक +4.72 है। तृतीय कारक के अन्तर्गत धनात्मक संघटक सूचकांक में राजनांदगांव +3.15 और धामतरी +2.17 जिले का क्रम I: द्वितीय एवं तृतीय स्थान है। उल्लेखनीय है कि महासमुंद जिले में जनसंख्या के घनत्व, धामतरी जिले में प्रवास और राजनांदगांव जिले में जनसंख्या के घनत्व, और प्रवास को छोड़ सभी संघटक धनात्मक में हैं।

तृतीय कारक पर आधारित लिंगानुपात में संघटक सूचकांक राजनांदगांव में +1.21 एवं महासमुंद जिले में +1.05 है। जबकि कोरिया जिले में यह सूचकांक -1.206 है। प्रवास का संघटक सूचकांक महासमुंद +1.569 और धामतरी जिले +.382 में धनात्मक हैं जबकि बस्तर जिले -0.670 में ;णात्मक है।

राज्य के दक्षिणी भागों में स्थित जिलों में लिंगानुपात 1000 से अधिक है। लिंगानुपात राजनांदगांव जिले में 1024, महासमुंद में 1019, दंतेवाड़ा में 1017, बस्तर में 1009 और कांकेर में 1006, धामतरी में 1005 और कवर्धा में 1002 प्रति हजार है। इसके विपरीत कोरिया जिले में लिंगानुपात 947, कोरबा में 964, सरगुजा में 972, बिलासपुर में 975, रायपुर में 980 और दुर्ग



जिले में 982 प्रति हजार है। प्रवास चूँकि लिंग चयनात्मक होता है। अतः दक्षिण के जिलों में प्रवास भी अपेक्षाकृत अधिक है। महासमुंद जिले में प्रवास 51 प्रति तत से अधिक है। यह प्रति तत बस्तर में 26.3, ज।पु. में 28.0 और सरगुजा और ज।पु. जिले में 29.0 प्रति तत है।

चतुर्थ कारक (Fourth Factor):-

चतुर्थ कारक में केवल एक ही चर ि।मर्त्यता दर ामिल है। ि।मर्त्यता दर संघटक सूचकांक धानात्मक +.720 है। ि।मर्त्यता दर पर आधारित मानचित्र का नामकरण जनसंख्या स्वास्थ्य (Population Health) रखा गया है। चतुर्थ कारक में संघटक सूचकांक राज्य के पश्चिमी एवं उत्तरी भागों में धानात्मक है। चतुर्थ कारक वि.लेषण में भी ज।पु. +1.28, कोरबा +1.24, कोरिया +0.74, सरगुजा +0.46, राजनांदगांव +0.14, दुर्ग +0.175 और बिलासपुर +0.17 जिलों में संघटक सूचकांक धानात्मक में है। षे जिलों में यह िणात्मक में है।

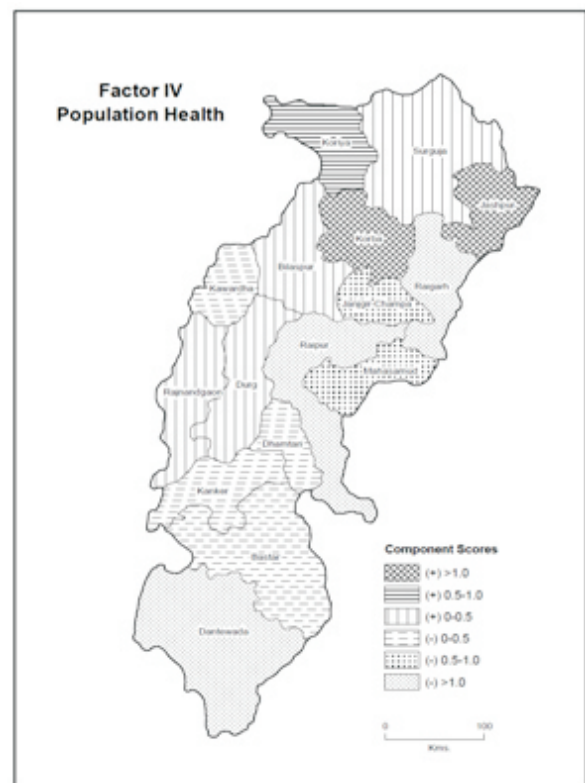
उल्लेखनीय है कि धानात्मक सूचकांक ज।पु. जिले में सर्वाधिक +1.28 और सर्वाधिक िणात्मक सूचकांक दंतेवाड़ा जिला में -2.90 है। िणात्मक सूचकांक में द्वितीय स्थान रायपुर जिले -1.59 का है। ज।पु. जिले में नगरीय जनसंख्या, आश्रित जनसंख्या एवं कृषि जनसंख्या को छोड़ सभी चर का संघटक अनुपात धानात्मक में है। इसके विपरीत दंतेवाड़ा जिला में जनसंख्या का घनत्व, प्रवास, अनुसूचित जाति एवं अनुसूचित जनजाति जनसंख्या को छोड़ षे संघटक सूचकांक िणात्मक में

है। ज।पु. जिले में ि।मर्त्यता दर का संघटक सूचकांक धानात्मक में सर्वाधिक +1.17 है जबकि िणात्मक संघटक सूचकांक में रायपुर जिले का प्रथम -1.68 एवं दंतेवाड़ा जिले का द्वितीय स्थान -1.10 है।

छत्तीसगढ़ प्रदेश के उत्तरी भाग में ि।मर्त्यता दर अपेक्षाकृत कम है। ि।मर्त्यता दर कोरिया जिले में 69, ज।पु. में 65, बिलासपुर में 64, रायगढ़ में 54, और रायपुर जिले में 42 प्रति हजार है। इसके विपरीत महासमुंद जिले में ि।मर्त्यता दर 84, धामतरी में 75, बस्तर में 79, राजनांदगांव जिले में 83, कवर्धा में 75 और ज।पु. में 91 प्रति हजार है।

निष्कर्ष -

प्रथम कारक जो 6 चर - जनसंख्या का घनत्व, साक्षरता, नगरीय जनसंख्या, अनुसूचित जाति, अनुसूचित जनजाति और कृषि जनसंख्या ामिल है के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या संकेतन किया गया है। प्रथम कारक के अंतर्गत जनसंख्या संकेतन बेसिन के मध्य भाग में सम धारातल है।



अधिक है। इसके विपरीत छत्तीसगढ़ के उत्तरी एवं दक्षिणी भागों में जनसंख्या विरली है। द्वितीय कारक जिसमें कुल प्रजननता दर और आश्रित जनसंख्या ामिल है, के आधार पर निर्मित मानचित्र का नामकरण जनसंख्या वृद्धि रखा गया है। द्वितीय कारक के आधार पर भी निर्मित प्रदेश के मध्य भाग में जनसंख्या का विकास अधिक है। किन्तु उत्तरी एवं दक्षिणी भागों में जनसंख्या का विकास अपेक्षाकृत कम है। तृतीय कारक

के अन्तर्गत लिंगानुपात और प्रवास शामिल है, के आधार पर निर्मित प्रदेश का नामकरण जनसंख्या की गति मिलता किया गया है। तृतीय कारक के आधार पर निर्मित प्रदेश का प्रतिरूप भी द्वितीय कारक के समान है। जनसंख्या की गति मिलता प्रदेश के मध्य भाग में अधिका है। इसके विपरीत उत्तरी एवं दक्षिणी भागों में जनसंख्या गति मिलता अपेक्षाकृत कम है। चतुर्थ कारक में िगु मर्त्यता दर शामिल है। िगु मर्त्यता दर के आधार पर निर्मित प्रदेश जनसंख्या स्वास्थ्य को व्यक्त करता है। इस मानचित्र के आधार पर प्रदेश के पश्चिमी एवं उत्तरी भागों में जनसंख्या का स्वास्थ्य निम्न और मध्य तथा दक्षिणी भागों में जनसंख्या का स्वास्थ्य उच्च है।

References

- Ackerman, E.A.C. (1959): "Population and Natural Resources" In Hauser P.M. and O.D. Duncan (eds.) **The Study of Population, An Inventory and Appraisal**, University of Chicago Press, Chicago.
- Ahmad, Q. (1965): **Indian Cities: Characteristics and Correlates**. The Univ. of Chicago, Deptt. of Geog., Res. Paper No. 102.
- Berry, B.J.L. (1958): **Shopping Centres and the Geography of Urban Areas, A Theoretical and Empirical Study of the Spatial Structure of Intra-Urban Retail and Service Business**. University of Washington, Ph.D. Thesis.
- Berry, B.J.L. (1960): "An Inductive Approach to the Regionalization of Economic Development." In **Essays on Geography and Economic Development**, Research Paper 62, Department of Geography, University of Chicago.
- Berry, B.J.L., (ed.) (1971): Comparative Factorial Ecology, **Econ. Geogr.** 47 Supl.): 2.
- Berry, B.J.L., and P. Ressa (1969): The Factorial Ecology of Calcutta, **Am. J. Social.**, Vol. 74, pp. 445-491.
- Berry J.L. & V.L.S. Prakasha Rao (1968): "Urban-rural duality in the Regional Structure of Andhra Pradesh", **Geographische Zeitschrift**, pp. 1-49.
- Blacker G. (1960): **An Economic Analysis of Fertility, Demographic Change in Developed Countries**, Princeton University Press, Princeton.
- Cattell, R.B. (1952): **Factor Analysis**, New York, Harper.
- Cattell, R.B. (1965): "Factor Analysis: An Introduction to Essentials I and II." **Biometrics**, 21, pp. 190-215, 405-435.
- Cole, John P. and Cuchlaine A.M. King, (1968): **Quantitative Geography: Techniques and Theories in Geography**, John Wiley & Sons LTD, London., pp. 288-305.
- Fisher, J.C. (1966): **Yugoslavia: A multinational State**, Chandler San Francisco.
- Fruchter, B.F. (1954): **Introduction to Factor Analysis**, New York, Van Nostrand.
- Garrison, W.L. and Marble, D.F. (1964): "Factor-analytic Study of the connectivity of a transportation network", **Reg. Sci. Assn. Papers** XII.
- Henshall J.D. (1966): "The Demographic factor in the structure of agriculture in Barbados", **Trans. Inst. Brit. Geog.**, Vol. 38, 18-95.
- Henshall J.D. and King L.J. (1966): "Some Structural Characteristics of Peasant agriculture in Barbados", **Eco-Geog.** 42, No. 1, 74-84.
- Haggett, Peter, Andrew D. Cliff and Allan Frey. (1977) : **Locational Methods**, Edward Arnold.
- Harman, H. (1960). **Modern Factor Analysis**, Chicago, The University of Chicago Press.
- King, Leslie J. (1969) : **Statistical Analysis in Geography**, Prentice- Hall, INC., Englewood Cliffs, N.J. pp. 165-193.
- Mabogunje, A.L. (1965): "Urbanization in Nigeria: A Constraint on economic Development"; **Economic Development and Cultural Change**, Vol. 13, pp. 413-438.
- Moser, C.A. and Scott, W. (1961): **British Towns. A Statistical Study of their Social Economic Differences**, Oliver and Boyd, Edinburgh and London.
- Rummel, R.J. (1967). Understanding Factor Analysis, **J. Conflict Resolut.** 2 : pp. 444-480.
- Stamp, D. (1964) : Discussion on P. Haggett's Paper: "Regional and Local Components in the distribution of forested areas in south-east Brazil : A multivariate approach", **Geog. J.** 130 Part 3.
- Taylor, Peter J. (1977) : **Quantitative Methods in Geography.. An Introduction to Spatial Analysis**, Houghton Mifflin Company. Boston. pp. 231-284.
- Wong, S.T. (1963) : "A Multi-variate Statistical Model for Predicting Mean Annual Flood in New England." **Annals Association of American Geographers**, 53, pp. 298-311.
- Yeates, Maurice (1968): **Introduction to Quantitative Analysis in Human Geography**, McGraw- Hill Book Company, New York., pp. 207-238.
- Zenisky, W (1966): **A Prologue to Population to Geography**, Englewood Cliffs, Prentice- Hall.

(Prof. Anusuiya Baghel is Professor of Geography, School of Studies in Geography, Pt R.S. University, Raipur
Email: anusuiya_baghel@yahoo.com)

Impact of Shoreline Shifting on Social and Environmental Aspects Using Remote Sensing & GIS Techniques

(A Study of Tajpur and Berakhana Mouza in Digha, West Bengal)

Jatisankar Bandyopadhyay, Ismail Mondal, Parthasarathi Chakrabarti, Kartic Bera

Abstract

The study examined the impact of changing High Water Line (HWL) on Socio- Environmental aspects in the context of CRZ Notification 2011. For this, a comparative study of changing High Water Line through space and time using cadastral map, LISS-III, IV Satellite images and Toposheet with ground truth verification, generation of land use/ land cover map with change detection, and Integration of socio economic data & spatial data under GIS platform have been performed. For obtaining a comparison of present day physical and cultural features of the study area satellite image and ground truth verification data with old Toposheet, cadastral survey and thereby analysis through remote sensing & GIS have been pressed into service. The study reveals migration of beach front dune towards inland, changing High Water Line, remobilized sand covering the cultivable land making them uncultivable, and conversion of cultivable land into wetland causing socio-economic imbalance in the area. Situation demand an alternative source of income by the land owner. Hoteliers are coming forward with hotel projects, promoting the tourism in the area. Such changes in this coastal stretch of CRZ III category, however, pose environmental threat which ultimately raising question of existence of CRZ notification.

Key-Words: Remote Sensing & GIS, Coastal tract, High Water Line Shifting, Shoreline Change, CRZ (Coastal Regulation Zone).

Introduction

The Coastal zone is a broad transitional area between the land and sea. The high water line is a boundary line between land and sea. Because of its dynamic natures, the shore line with high water line changes gradually (Chakrabarti & Chakraborti 1977). This change is provided by sequence of coastal process which is stormed cyclone coastal process sea level rise and seismic events involving a specific range of space and time cumulatively affects and over all change in High Water Line (HWL) geometry. Accurate determination of high water line change rate is important for development planning, hazard zoning, and erosion accretion studies of the coastal belt (Niyogi, 1970).

The study area

The study area is located between latitude: 21°38'20"N to 21°40'00"N and longitude: 87°36'40"E to 87°38'20"E in the Tajpur and Berakhana Mouza of Ramnagar-I block, Purba Medinipur District, West Bengal, India This area

is a part of the coastal plain estuary with the Jaldha creek and Pichaboni Rivers are flowing through the area .It mainly consists of sandy beaches, mud flat-costal dune inlet. The beach is under the action of waves, Tide, and long shore drift and also in some cases it is shaped by rip currents (Paul, 2002). The back shore zone is reworked by wind and storm surges or high waves. The result shows accelerated rate of erosion on the beach and unprotected eastern side is severely threatened by coastal dune retreat.

Objectives are to-

- find out the impact of changing High water line on socio-environmental aspects of the study area in space-time perspective,
- propose a development strategy in the context of CRZ notification.

Methodology

The changes of HWL shifting of the study area at cadastral level is done by using satellite image of

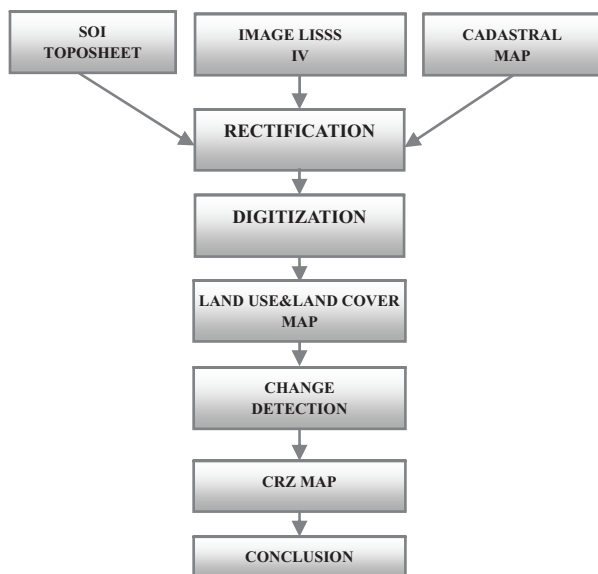


Fig. 1 Methodological steps

LISS -IV, Jan-08 and Oct-08, cadastral map of 1957 and as a base map SOI Toposheet of 1972. After geo-referencing of this satellite image with cadastral map, the high water line of study area is prepared (see Fig.1).

Economic activity: The salt pan present in the study area is basically man made economic activity (Fig.2).

Geomorphic features

Creek: A Saline Creek is the portion of a stream that is affected by the flow of ocean tides. Thus, this portion of the stream has variable salinity and electrical conductivity over the tidal cycle. Due to the temporal variability of water quality parameters within the tidally influenced zone, there are unique biota associated with tidal creeks. Creeks may often dry to a muddy channel with little or no flow at low tide, but often with



Fig. 2 Field photo of Salt Pan



Fig. 3 Field photo of Jaldha Creek

significant depth of water at high tide. Saline creeks are found dispersed all along the Indian coast (Chakrabarti 1995). Most of the creeks in the country are reported from the south eastern part of the coast and the predominant vegetation is mangroves. One of such creek is Jaldha creek is found in the study area (Fig. 3). High fishing activity in the study area is covered under Alampur fisheries project.

Result and Discussion

A land use/land cover map was prepared by visual interpretation of the Geo-referenced image. Depending upon present condition of the area according to field verification and the satellite imagery vulnerable points or area was marked. Vulnerability is found to be more in the eastern part of the study area. So single crop land in the high vulnerable eastern part and gradually shifting towards double crop in low vulnerable.

Accreted and eroded land of the study area is calculated after considering cadastral map, Toposheet and image by using ArcGIS 9.3 software. So it can be said that the Tajpur and Berakhana Mouza of Ramnagar I Block is under the erosional regime of the coastal tract.

Shoreline shift: From the Fig. 4 it is clearly observed that HWL shifted 250mt towards the land after considering HWL of cadastral map of 1957 and HWL of IRS LISS-IV Image 2008. The HWL is shifting towards land by 250mt is also confirmed by the ground truth verification. The beach is under the action of waves, tide and long shore drift and also in some cases it is shaped by rip currents. The back shore zone is reworked by

livelihood/livelihood sources for fishing community Conflict on the species selected, (iv) impacts on coastal geomorphology and Impacts due to use of non biodegradable materials, and (v) impacts due to natural disasters till maturity and Impacts on the stability of the beaches in neighboring areas.

Mitigation measure of the study area comprises of-

- compensation for land at replacement value and other R&R Assistance as per the entitlement framework.
- assistance to squatters / encroachers as per the policy and ensuring community participation and oversight.
- loss of access/restricted access to the coast due to project activities for the community and Land donation.
- impact on the present species composition and biodiversity of the area.

Conclusion

From the study it is cleared that the HWL shifted towards land by 250mt. Due this shift land erosion and biodiversity loss occurs. This leads to the loss of livelihood activity as well as land in the study area. So the CRZ notification is highly violated in the study area.

- Necessary steps may be taken up by the Environment and Forest Depts, to restore the converted cultivates land.
- Environment and Forest Dept. may take necessary action to acquire such cultivable land with remobilized sand to convert it into forest land.

- monitoring and mitigation and management steps in the study area must be taken due to changing scenario of High Water Line Shifting. It also includes the transparency and acceptance of proposed mitigation plan among the local people. Although there is violation of CRZ notification in some part of the study area but the livelihood activity of the local people must be taken care of before any punitive measure. The economic development and improvement of social security of the local people must be considered before any developmental activity.

Reference

GSI (1995), **A report on the Coastal zone Management Plan of Digha Planning Area**, Medinipur District, West Bengal, pp 1-25.

Chakraborti, P, and Chakraborti, A (1977): Mass-spring Damper system as mathematical model for the pattern of sand movement for eroding beach around Digha, West Bengal, India, **Journal Sedimentary Petrology** ,47(1), pp.311-330.

Chakraborti, P, (1995) :Evolutionary history of coastal Quaternaries of West Bengal plain, India –**Journal Indian Science Academy (INSA)** New Delhi, 5, pp.343-354.

Paul, A.K. (2002), **Coastal Geomorphology and Environmental: Sundarban Coastal Plain, Kanthi Coastal Plain and Subarnarekha Delta Plain**, acp publication, Kolkata.

Niyogi. D. (1970), **Geological background of beach erosion at Digha, WB**, pp 1-36.

(**Dr. Jatisankar Bandyopadhyay** is Assistant Professor and **Mr. Ismail Mondal** and **Mr. Kartic Bera** are Research Scholars in the Department of Remote Sensing & GIS, Vidyasagar University Paschim Medinipur, Midnapore-721102, West Bengal, **Dr. Parthasarathi Chakrabarti** is a Former Chief Scientist, Department of Science & Technology, Govt. of West Bengal.

E-Mails:, ismailmondal58@gmail.com, 4kbrsgis@gmail.com | psarathic@rediffmail.com)

Mapping of Recreational Spaces in a Planned City of Chandigarh Using Remote Sensing and GIS

Sanjeev Goel, Preeti Chauhan

Abstract

Recreational activities are an essential part of urban life and recreational spaces constitute an integral part of urban land use planning. In a planned city, a certain proportion of total land is reserved for the recreational activities to develop recreational spaces such as open parks, gardens, play grounds, forest cover areas, water bodies and tourist spots. On the basis of origin, these may be classified in to natural and artificial (man-made). Chandigarh, called as the 'City Beautiful' is known for its picturesque location at the Shiwalik foothills. It is one of the best experiments in urban planning and modern architecture in the twentieth century in India. It combines elegant architectural forms with wide tree-lined avenues, green belts and gardens. About 10 per cent of the total land area in the city is developed as the recreational spaces. 23 gardens of varying size and shape are located in different parts of the city. The present exercise is an attempt to map recreational spaces in the City of Chandigarh by using remote sensing and GIS techniques with of locational analysis of various open spaces and gardens in relation to the total population size and other socio-economic characteristics. For this purpose, database was generated by using satellite imageries, land use maps and topographical maps of the study area. To substantiate and cross check this data in ground, field visits to sampled sites were conducted. The data thus obtained were classified and various maps were prepared by using Arc GIS software.

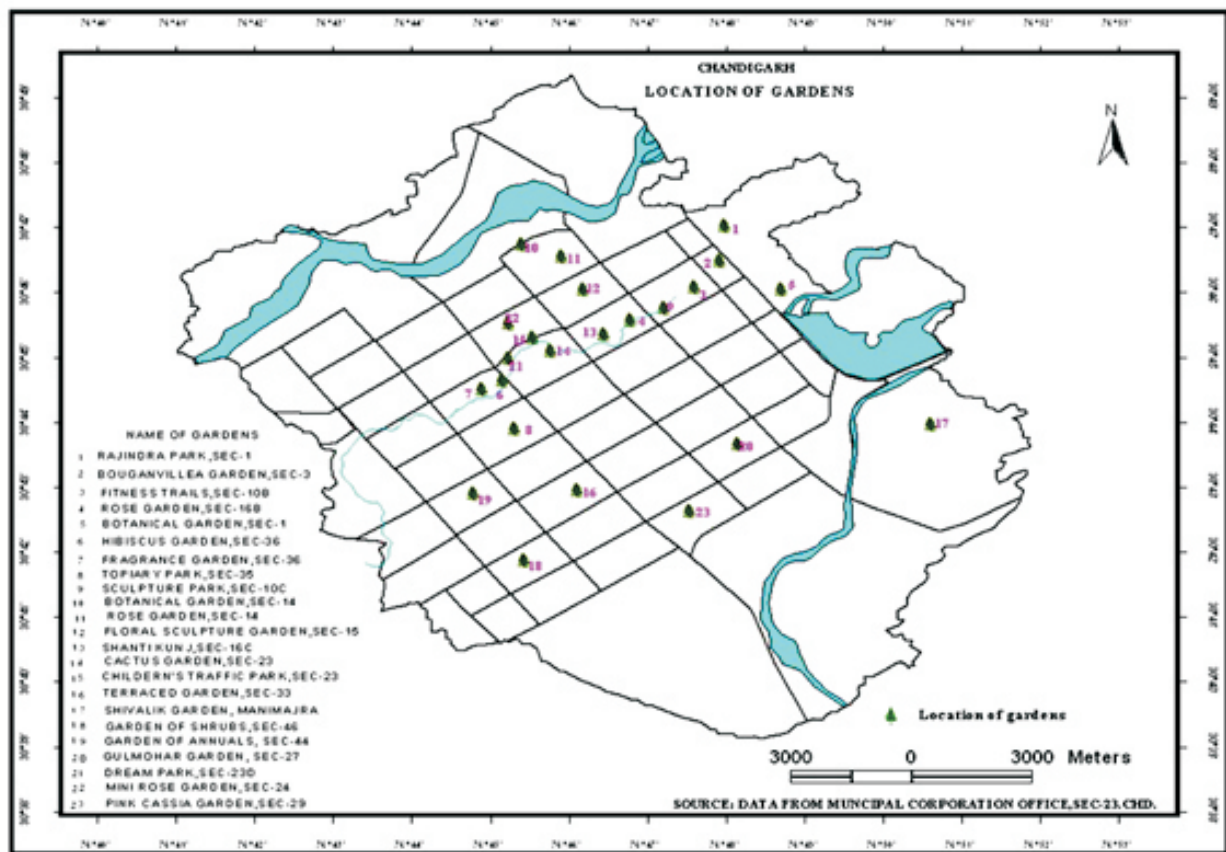
Introduction

The primacy of serving human needs is accepted by most recreation and park planner. However, little has been done to define 'what' these needs are or how recreation lands can be best designed to meet them. Most often recreation spaces and garden's design is determined by profit and by simply "waving a magic wand over the city map." A recreation and open space (garden) plan should be premised on the concept of 'openness' which means "open to choice, open to view and understanding, open to access, open to new perceptions of experience. It should be a system intimately connected with the overall environment and a community's daily life – not a specialized contrast to the city, but a functional part of it. It should be designed in the content of the whole- the pattern of other city uses and circulation, the setting, the constellations of living system. The design would necessarily be based on a comprehensive visual analysis of the community. It is fundamental that open-space

(garden) is meaningless except in relation to their use and to the characteristics and aspirations of their users. The design of individual open space should consider a variety and avoid garden stereotype. There is a need to design a pathway for walk. This has a potential and pre-requisite for enjoyment and healthy lifestyle, an ability to communicate the meaning of environment in totality. This needs a specialized pattern of open spaces/ gardens.

Definition

A garden may be defined as a ground laid out with flowers, trees and ornamental shrubs which is used for recreation purposes. The meaning of 'Garden' implies differently to everyone. To the Horticulturist it is a place for growing plants; to the Poet it suggests seclusion, rest, meditation, or perhaps gaiety; to the Architect it is a definite unit of design with certain aesthetic and utilitarian functions.



Chandigarh: Master Plan

Le Corbusier conceived the Master Plan of Chandigarh as analogous to human body, with a clearly defined head (the Capitol Complex, Sector 1), heart (the City Centre, Sector 17), lungs (the leisure valley, innumerable open spaces and sector greens), the intellect (the cultural and educational institutions), the circulatory system (the network of roads, the 7 Vs) and the viscera (the Industrial Area). The concept of the city is based on four major functions: living, working, care of the body and spirit and circulation. Residential sectors constitute the 4 living part whereas the Capitol Complex, City Centre, Educational Zone (Post Graduate Institute, Punjab Engineering College, Panjab University) and the Industrial Area constitute the working part. The Leisure Valley, Gardens, Sector Greens and Open Courtyards etc. are for the care of body and spirit. The Capitol complex comprises three architectural masterpieces: the Secretariat, the High Court and the Legislative Assembly, separated by large

piazas. In the centre of the Capital Complex stands the giant metallic sculpture – 'The Open Hand', which is the official emblem of Chandigarh. It signifies the city's credo of "open to give, open to receive".

Ample areas have been provided in the master plan of the city for parks. Out of total 20,000 acres acquired for the first phase, about 2000 acres are meant for development of parks. Chandigarh is essentially a garden city with almost every sector having a garden and open space in addition to the major recreational areas of the city. The major gardens of the city include Rajendra Park, Botanical garden, Rose garden and Leisure valley. These gardens are situated along a seasonal choe running through sectors 3, 10, 23, 36 and 42 (Fig. 1). Leisure valley was developed in the eroded stream bed, which contains a gorge 5 to 6 meter deep and 100 to 300 meters wide. Different gardens have been developed in this valley since its inception.

Rajendra Park: Situated in sector -1, It is a vast stretch of land about 400 acres, adjoining Secretariat building on the eastern side. Le Corbusier designed the landscape scheme of this park. It was started in 1954. It is commonly used for long walks, outdoor yoga, learning to drive and horse riding.

Fitness Trails and the Flower Garden: It is located in Sector 10. It covers a total land area of 94 acres, out of which 52 acres of land consisted of gorgeous seasonal flowers and the left out portion houses the mind-blowing sculptures of well-known artists. A part of Chandigarh fitness trail & flower garden is utilized for conducting various cultural events. The garden has a real scenic beauty and taking this into consideration, it was planned to combine the natural beauty and physical exercises. Eventually, a physical fitness trail park was set up over here in 1965. The garden was renovated in 1985.

Floral Sculpture Garden: It is a properly maintained garden in sector- 15. It is located in close proximity to the residential area.

Children's Traffic Park: Situated in sector- 23, it covers an area of 6.5 acres. This park is used to educate the children about the traffic rules and road safety measures. A concrete structure named 'Bal Bhawan' is a part of this park, which is used to organize different shows and programs for the welfare of the children.

Shanti Kunj: It is situated at a very peaceful place that is free from any noise and pollution. Therefore, it has been rightly named as Shanti Kunj. In this park, we find a large variety of plants, trees and shrubs, like vertical shaped trees, that providing shade, trees adapting themselves according to local environment and trees covered with flowers. Also, there are various herbal and medicinal plants which are used to cure diseases. A natural seasonal chow runs through the garden and divide the Shanti Kunj into five parts.

Terraced Garden: With an area of 10 acres, Terraced garden was built in 1979. It is located in Sector 33. The main attraction of terraced garden is the musical fountains, the first of its kind in the city. It serves as the main venue for organising the Chrysanthemum Show, an annual event.

Garden of Shrubs: Situated in sector – 46, it covers an area of 6.61 acres land. The main attractions of the garden are 50 varieties of ornamental shrubs, which blooms all the year round.

Garden of Annuals: It is situated on an over 5.50 acres land in Sector: 44. The main attraction of the garden is plantation of winter and summer annuals during the year.

Mini Rose Garden: It is situated in Sector- 24 on V-4 road near Police Station and spread over 3.50 acres land. Rare varieties of roses are found in this garden, which are exclusive to the varieties found in Rose Garden Sector-16, Chandigarh.

Bamboo Valley: Spread over an area of about 27 acres of land along the chow passing through Sector- 23, it was established in February, 2007. This garden has 15 species of trees besides bamboo groves along the seasonal names as Bamboo Valley. The main attraction of Bamboo Valley has a variety of rare trees, Flower beds, and different type of trees for shade, shrubs, garden huts, fountains, lights, footpaths & sprinkle system. The National Mission of Bamboo Application (NMBA) Govt. of India have evolved nationwide plan to use bamboo to create awareness in construction industry & checking the acceptability of same among general public. This technology has been used for the first time in Chandigarh. The following bamboo structures have been provided in the Bamboo Valley:

- Restaurant – It will be provided free of cost of NMBA under Govt. of India scheme.

- I'vee Rain shelters.
- One Milk Bar and One Food Kiosk.

Inventory of Gardens in Chandigarh

Inventory of gardens such as public facilities, natural resource, maintains of garden and other requirements. Different maps have been prepared for depicting public facilities such as drinking water, bench, rain shelter, toilet, information centre, museum in the garden.

Bougainvillea Garden, Sector- 3: It is located in sector 3 and covers an area of about 20 acres. This garden exhibits different varieties of bougainvillea flowers. Bougainvillea Park of Chandigarh was developed in 1976. There are about 65 distinct varieties of Bougainvillea shrubs planted over here. The park houses creepers covering a large collection of bowers, arches, pavilions and arcades. The popular annual Bougainvillea show is hosted here. Fitness tracks have also been laid over here. This garden is especially a centre of main attraction due to war memorial. Here names and years of wars are mentioned. In this garden, the sitting arrangement is very attractive. A round cemented shape like well covered with bougainvillea plant and inside the circle there is cemented bench is also main attraction.

Rose Garden, Sector- 16: Rose garden is the largest of its kind in Asia. It is named after one our our former President, Dr. Zakir Hussain. This beautiful garden was set up in 1967 with the support of Chandigarh's first Chief Commissioner, late Dr. M. S. Randhawa. Chandigarh rose garden contains more than 17,000 plants, 1600 varieties of roses and spread over an area of 27 acres. The rose garden also houses various trees of medicinal value, such as bel, bahera, harar, camphor and yellow gulmohar. Rose garden serves as the venue for hosting the annual festival of gardens, a major cultural event of the city. It is a three-day extravaganza that is held in the last week of February. Initially, this festival was called Rose

Festival and was started to motivate people to visit the rose garden and savor the marvelous sight of the blooms. Since then, Rose Festival of Chandigarh, has been gaining popularity. It also gives an opportunity to various companies to exhibit their products. Since 1997, it is known as the festival of gardens.

Botanical Garden, Sector- 14: The Botanical garden of Punjab University has distinctive varieties of plants. Here, cacti and succulent plants are found along with several evergreen and exotic plants. Also, one can find gorgeous lotus flowers over here. And also names are mention to the plants. A large variety of plants are found here. The Garden is properly maintained, around 5-6 gardeners are employed for maintenance of the garden. There are two water ponds consisting of a large variety of beautiful fishes.

Botanical Garden, Sector- 1: This botanical garden is located between the rock garden and Sukhna Lake and is spread on an area of 88 acres. The best part about this garden is the rare species of plants and small lily pools. Apart from these two botanical gardens, one more garden of such kind is in the process of establishment, where you'll be able to find indigenous plant species and trees of medicinal value.

Hibiscus Garden: Situated in sector- 36, it adjoins Dakshin Marg. It was opened in 1974. Different types of Hibiscus and shrubs are planted here which provide color throughout the year. About 40 different types of Hibiscus 8 shrubs are planted here which provide color throughout the year. The choe banks are also planted with bottle brush and bamboo groves.

Topiary Park: It is situated in Sector 35, an approximate area of 6 acres and was started in 1987. Many animal shapes created out of creepers and bushes attract the children to this park. A large variety of ornamental plants add to the park's charm.

Sculpture Park: It is situated in sector 10, sculpture of different shape are there. Many events are organised in this garden by the local administration, such as Chandigarh carnival in the month of November and Baisakhi festival in the month of April every year.

Fragrance Garden: famous for its distinctive aromatic and fragrant plants, the Garden is located in Sector 36 on southern side of the Hibiscus Garden. Some of the fragrant plants found here are Raat ki Rani, Demask Rose, Motia, Champa, Haar Shingar, Mehandi and varieties of Jasmine. Garden of fragrance also serves as a fabulous picnic spot. Tracks have been laid in the garden for the morning and evening walks.

Maintenance of Gardens in Chandigarh

Horticulture Department, Chandigarh Administration is facing problems to maintain landscape work under its jurisdiction due to shortage of manpower. The recruitment of daily wage workers on Muster Roll has been banned since 1992 by the Administration and since then hundreds of its malies have retired, resigned or expired. It is, therefore, required that maintenance work of important gardens be given to Private firms/parties on contract basis. The maintenance of landscape work has been categorized as below:

Category – A

- i) Rose Garden,
- ii) Museum & Art Gallery

Category – B

- I) Bougainvillea Garden, Sector-3, Chandigarh,
- ii) Leisure Valley, Sector-10, Chandigarh,
- iii) Bamboo Valley, Sector-23, Chandigarh,
- iv) Bulbus Garden, Sector-23D, Chandigarh,
- v) I.T. Park, Kishangarh, Chandigarh,
- vi) Green Belts in various sectors.

Category – C

- i) All V-2 and V-3 roads including its central strips,
- ii) Parks development under MPLAD Scheme in various sectors

Category – D

Reserve area of commercial sites / residential site, road land reservation, clearance of wild growth from the Rajindra Park and Mango Garden, Sector-1, Chandigarh

Future Gardens- To Promote Eco-Tourism in Chandigarh

Chandigarh serves as the Capital of both Punjab and Haryana States along with having the status of Union Territory. It is a transit city for the tourists visiting the states of Himachal Pradesh and Jammu & Kashmir. The city has well planned trees planted along the roads, architectural control buildings, man-made gardens as well as lake with natural back drop of Shiwalik Hills. The existing city gardens also require a lot of improvements to promote tourism. At present, there are very few gardens i.e. Bougainvillea Garden Sector-3, Leisure Valley Sector-10, Rose Garden Sector-16, Shanti Kunj Sector-16, Bamboo Valley Sector-23 and garden of unusual plants Sector-36 or have developed few green belts and named them as Terrace Garden, Topiary park or Fragrance garden etc. The existing gardens have lot of scope to add various features and there is a lot of space to develop new gardens with unique quality and principles (Fig. 6). These include:

1. Japanese Garden
2. Sunken Garden
3. Hanging Garden
4. Cactus Garden
5. Sculpture Garden
6. Garden of Palms
7. Garden of Coniferous
8. Indoor Botanical Garden
9. Cottage Garden

10. Transit Garden

11. Formal Gardens

Although the above gardens have different principals to development but the features to be added are more or less the same, such as plantation of trees, shrubs and creepers. Provision of footpaths, bowers, fountains, gardens, benches, rain shelters, garden lights, bridges, drinking water, bathrooms, eating joints and tube wells for irrigation are essential features to be developed in these future gardens. These may be discussed briefly as following:

1. Japanese Garden

Japanese have an art culture, that they love mountains, islands, rivers, lakes, bridges means natural form of landscape. So the development of Japanese culture garden dominance the natural forms of elements to be added. Bonsai

shape of plants and Ekebona i.e. Japanese style of flower arrangement. The flowing water, light house, tea huts are special features of Japanese garden. Pune City in Maharashtra has recently developed a Japanese garden in collaboration with Japanese art and culture. This garden covers an area of 35 acres and is totally man made. In Chandigarh, green belt of Sector-31 is best suited for Japanese Garden. The total area of this belt is about 12-15 acres with varying depth for 5 ft. to 25 ft.

2. Sunken Garden

Sunken garden stands for the garden below natural land surface. The area need not to be filled with soil to bring it to the level of road but developed as such. Thus, the earth filling cost can be saved. The green belt located in Sector-50 covering an area of about 12 acres with a 3-4 feet

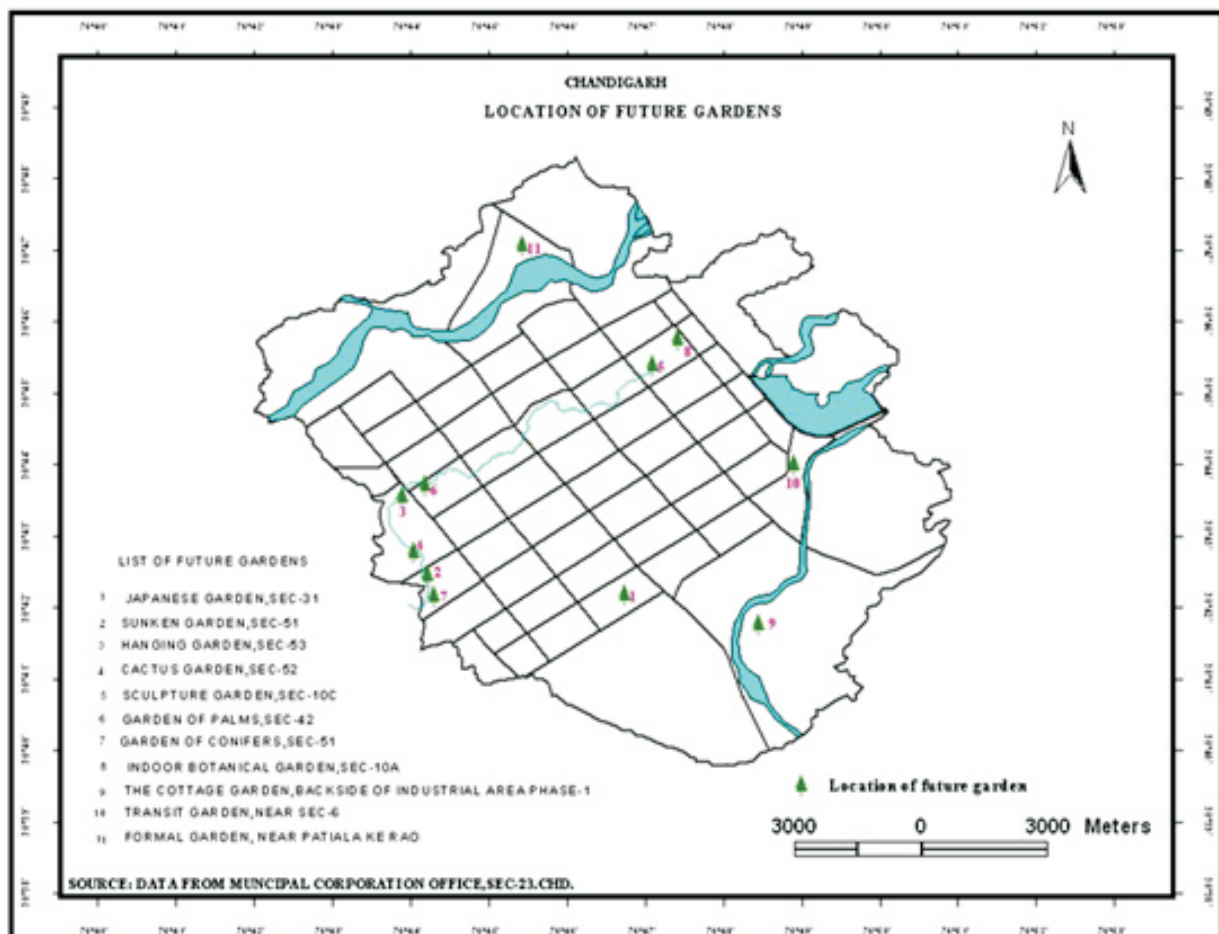


Fig. 2 Location of Future Gardens in Chandigarh

depth below the surface, requiring another three ft. digging to develop a garden. It may have terraces along its sides with a leveled low land in the centre. Such types of gardens are found in many cities in the world. Oman (Sultnate) in U.A.E. and Ooti (Governor's residence) in India are classic examples of Sunken Garden.

3. Hanging Garden

Hanging gardens of Babylonia in Iraq were one of the Seven Wonders of the World. Hanging gardens means planting of plants and shrubs at an elevation above the ground surface. One can enjoy the dropping forms of foliage and flower plants. A portion of the Leisure valley that exist in Sector-53 is the best suited place for the purpose. The roof top of all the Government buildings can be planted with dropping forms of plants to create the effect of hanging gardens.

4. Cactus Garden

Cactus and succulents are plants of arid zone having minimum water requirement. Cactus have various species i.e. Opuntia Cereus, Agave, Mammillaria, Aloe, Euphorbia, Furcuria's. Portulacaria, Sensiveria, Sedum etc. The HUDA Panchkula developed a beautiful Cactus Garden in Sector 5, Panchkula with a large variety of cactus plants. Now it has acquired the status of being the largest cactus garden in Asia. One such garden may be developed in Chandigarh also.



Fig. 8 Sculpture Garden, Sector 10

The potential site for the purpose is located in Sector-52 adjacent to the marble market.

5. Sculpture Garden

Leisure Valley of Sector 10 is the best suited site for Sculpture garden. The areas have already installed few models of Art and a water body (Fig. 8). The area is already being provided with a foot path. It needs strong fencing and railing, irrigation facilities for the trees and plants. The renowned artists of the city can also contribute their best in this regard. The approximate area is 20 acres.

6. Garden of Palms

It is a famous saying that Palms should have its roots in water and head in fire, means it needs lot of water or can withstand water logging conditions and tolerate high temperature. Palms are trees of Arabians. In Chandigarh region, the groups of dates trees can be seen, which indicates that palms can well adopt themselves to the local environment. More than 50 different species of palm are available in the city nurseries. The best suited site for the palm garden is in Leisure Valley, Sector 42. The total area allocated for the purpose is about 25 to 30 acres.

7. Garden of Conifers

Conifers are vertical shaped trees with needle type foliage and usually grown on hills. These can be mixed with evergreen vertical shaped trees to give high effect to the garden. The third phase sectors of the city have multistoried flats. Planting these trees in such areas and their surroundings will soften the harshness of the concrete facet. The portion of Leisure Valley passing through Sector-51 is the best suited for the development of garden of conifers. A large variety of conifers trees and shrubs are available in the nurseries located in the Shiwalik Hills, such as Pines, Taxodiums, Aurocaria, Juniperus, Deodars, Causorina's, Cyprus, Cupressuss, Grevillea etc.

8. Indoor Botanical Garden

It requires an area about one acre within a garden i.e. an additional element for public interest. It needs steel structure to be covered with fast growing climbers. To be kept trees, shrubs, indoor plants family wise grown in pots. Hanging plants to be planted in basket. The sprinkler mist of water will help to create micro environment inside the steel structure will grow the plant in a big way healthy. The design and site of structure for inside botanical garden is to be made with consultance of Architect Department. The proposed site is Sector 10 Leisure valley near the choe.

9. The Cottage Garden

The cottage is meant for meditation, for treatment of patients with the help of Indian traditional medicines and herbs. The best suited area which is easily accessible to local residents and tourists i.e. Sukhna choe backside of the Industrial Area, Phase-I. The area is naturally developed with forest cover and noise free environment. The size and design of the cottages to be prepared, will be determined by the Architects.

10. Transit Gardens

As already mentioned, Chandigarh is a transit city for the tourists of Himachal Pradesh and Jammu & Kashmir. The Hotel accommodation is very costly for the students and middle income tourists. It is, therefore, necessary that transit gardens be developed with all the facilities to accommodate the tourists coming in groups and with families. The forest area near the Golf Course, Sector 6 is best suited for the purpose.

11. Formal Garden

Chandigarh is considered to be a formal city due to its straight roads, cubical shaped buildings and grid pattern. Yet the city is not having any formal garden or Mughal style garden. The Yadvindra Mughal Gardens located in Pinjore are famous for their unique architectural design among the Indian as well as foreign tourists

originating from all over the World. It is, therefore, suggested to develop a garden with all the features of Mughal Architectural designs i.e. terraces, running water, high protecting wall or hedge, entrances, terminal buildings, baradari and formal plantation of trees, shrubs and hedges. The best suited site for the purpose is Patiala ki Rao choe from Khudda Lahora bridge to Dhanas village. It covers an area of about 2 to 2.5 km. in length and its entire width can be utilized.

Concluding Remarks:

With a rapid increase in urban population and expansion in urban area, there is a lot of pressure on urban resources and environment. In this regard, city gardens play an important role in maintaining the environment clean and green as well as keeping its residents healthy. City gardens are among the few places where people can go and enjoy their outdoor recreation. In Chandigarh, the city gardens have been an integral part of planning. There are 23 gardens of various size and shape in the city. These are main attraction for the tourists and local residents. The urban forestry in the city also contributes significantly in making the city attractive from tourism point of view. In general, the younger generation is found to be more inclined towards their contribution in urban greenery. People of the city show their keen interest in environmental activities and generously contribute towards 'Environment Fund'.

To promote eco-tourism, the Chandigarh Administration is planning for new theme based gardens. On the basis of analysis and evaluation, it is suggested that, though the facilities available in the city gardens are sufficient but they need proper maintenance, particularly in the gardens located in the southern sectors which lack basic facilities like drinking water and eating joints. Outdoor games for little kids may be planned keeping in view the available of space and natural beauty of the gardens. Provisions of transport facility, road network, footpaths and

space for parking of vehicles are other issues which need to be taken care of. Future gardens should be planned keeping in view the future projected population and its socio-economic composition.

References

De Souza, Alfred (1978), **The Indian City: Poverty, Ecology and Urban Development**, South Asia Books, New Delhi.

Evenson, Norma (1966), **Chandigarh**, University of California Press, Berkeley.

Gupta, S.K. (1974), 'Chandigarh- A Study of Sociological Issues and Urban Development in

India', **Architectural Design**, Vol. 44.

Kalia, Ravi (1987), **Chandigarh: The Making of an Indian City**, Oxford University Press, Delhi

Krishan, Gopal (1994), **Chandigarh 2020: Projections of Population and Class Structure**, A Report Prepared for U.T. Administration, Chandigarh.

Randhawa, M.S. (1967), **Landscaping Chandigarh**, Chandigarh Administration U.T.

Sarin, Madhu (1982), **Urban Planning in the Third World: The Chandigarh Experience**, Mansell Publishing Limited

(**Dr. Sanjeev Goel** and **Ms. Preeti Chauhan** are associated with Department of Geography, Panjab University, Chandigarh.

Email: sgoel22@gmail.com)

Author Index

A

A. Ganju	356
A. Ganju	375
A. Ganju1	351
A. Ganju1	346
A.K. Nigam	346
A.K. Nigam	351
Abhijit Pillai,	144
Ahalya Sukumar	157
Ahalya Sukumar	208
Ahalya Sukumar	245
Aji Pal Singh	28
Anu Kapur	
Anuradha Banerjee	228
Anusuiya Baghal	402
Arnab Kundu	383
Ashu Pasricha	290
Ashu Pasricha	299
Ashwagosha Ganju	32
Asim Kumar Goswami	160

B

B. Sukumar	157
B.K. Ramaprasad	133
B.Kartikeyan	127
B.Narender	144
B.Sukumar	208
B.Sukumar	245
Babita Bhardwaj	271
Baisakhi Sarkar	117
Balak Ram	220
Balak Ram	182
Balwan Singh	356
Bankim Shah	127

C

Chhanda Dey	201
-------------	-----

D

D. Gowtham Sai	333
D. K. Mandal	190
David G. Dickason	14
Debjani Mitra	197
Dharam Singh	139
Dinkar Srivastava	166

E

E. Saravanan	249
E. Saravanan	253
E. Saravanan	256

G

G. S. Lekshmi	249
G.S. Lekshmi	253
G.S.Lekshmi	256
Gaurav Sapra	313
Georg Gartner	41

H

H S Jassar	356
H.R. Betal	197

J

J. Shaji	367
J.S. Chauhan	182
J.S. Chauhan	220
Jaswant Raj Sharma	
Jatisankar Bandhopadhyay	413
Jatisankar Bandyopadhyay	201
Jatisankar Bandyopadhyay	265
Jawahar Lal Jain	46

K

K.S.S.Sekhar	127
Kamal Rampriti Dikshit	52
Kartic Bera	265
Kiyanoush Ghalavand	290
Kiyanoush Ghalavand	299

M

M. Chandrasekar.M	308
M. R. Bhutiyani	375
M. Sulfikkar	157
M.R. Bhutiyani	351
M.R. Bhutiyani1	346
M.Stalin	276
Mahima Chatranta	351
Mala Mukherjee	228
Manjush Koshy	367
Milap Punia	318

Milap Punia	383	S. Sandhya	208
Mohd. Mazhar Ali Khan	284	S.C. Chaturvedi	235
Mohd. Shahnawaz Khan	284	S.K. Mustak	261
N		S.K.Kulshrestha	390
N. Saniya	249	S.P. Aggarwal	338
N. Saniya	256	Sanjeev Goel	417
N.Saniya	253	Saroj Kumar Jha	59
Nadheer Bin Haneef. O	157	Satish Kumar	375
Nitish Thakkar	367	Satwant Kaur	346
		Satya Raj	327
		Shahnawaz	83
		Shiv Prasad Aggrawal	73
P		Siddharth Vora	367
P .Deepthi	245	Smita Bhutani	150
P. Deepthi	208	Sneh Nehra	271
P. K. Garg	338	Snehmani	338
P. S. Dhote	166	Snehmani	346
P.C.Moharana	176	Snehmani	351
P.K. Das	122	Snehmani	356
P.M. Sreekant	367	Snehmani	375
Parmod Bhardwaj	271		
Praveen K Thakur	338	T	
Preeti Chauhan	417	Tarun Vats	150
Preetika S. Sapra	313		
		V	
R		V. Dani	249
R. Anilkumar	308	V. Dani	253
R. D. Garg	338	V. Dani	256
R.S.Sujarose	256	V. Madha Suresh	276
Radha Raman	318	V.K. Dadhwal	144
Raj Gaurav	333	V.Raghu Venkataraman	144
Rajbala	166	Vinay Kumar Dadhwal	83
Rakesh Bhambri	390	Vineeta John	106
Ranjeet Kaur	318		
Ravinder Kaur	213	W	
Ravinder Kumar	390	Wilhelm Zoltan	96
Ravinder Kumar	52		
		Z	
S		Z.T. Khan	261
S. Indhira Gandhi	276		
S. K. Dewali	356		
S. Muralikrishnan,	144		
S. Sandhya	245		

OUR SPONSORS

UNIVERSITY GRANTS COMMISSION

Bahadur Shah Zafar Marg, New Delhi-110 002

INDIAN SPACE RESEARCH ORGANISATION

ISRO Headquarters, Antariksh Bhavan, New Bel Road,
Bengaluru- 550231(Karnataka)

DEPARTMENT OF SCIENCE AND TECHNOLOGY

Ministry of Science & Technology, Government of India,
New Delhi

SHRI RAM GROUP OF COLLEGES,

Muzaffarnagar, U.P. (India)

SKY ROCK CITY WELFARE SOCIETY (Regd).

SCO 2, First Floor, Cabin No. 3, Phase 2, Mohali, Punjab

CENTRE FOR SPACE SCIENCE & TECHNOLOGY EDUCATION IN ASIA & THE PACIFIC

C/o Indian Institute of Remote Sensing, Dehradun

SNOW AND AVALANCHE STUDY ESTABLISHMENT

Him Parisar, Sector – 37 A, Chandigarh

NIIT GIS LIMITED, ESRI INDIA

B1/H9, Mohan Co-op Industrial Estate, Mathura Road,
New Delhi 110 044

Also we salute

Dr. Jagtar Singh, I.R.S, Chief Commissioner, Income Tax, Maharashtra, Mumbai

Shri Nadim Akhtar, Senior Town Planner, HUDA, Panchkula

Shri V. K. Goyal, Senior Town Planner, Panchkula

Shri Kuldeep Singh Dhaliwal, Chief Town Planner, Govt. of Punjab, Chandigarh

Shri Harnaik Singh Dhillon, Senior Town Planner, Jalandhar and Amritsar

for their indispensable help to mobilise resources



J. Rennell's *Hindoostan*. (1782)

Courtesy : David G. Dickason

Price : Rs. 1800/- (Inland)
US \$ 40 (Foreign)