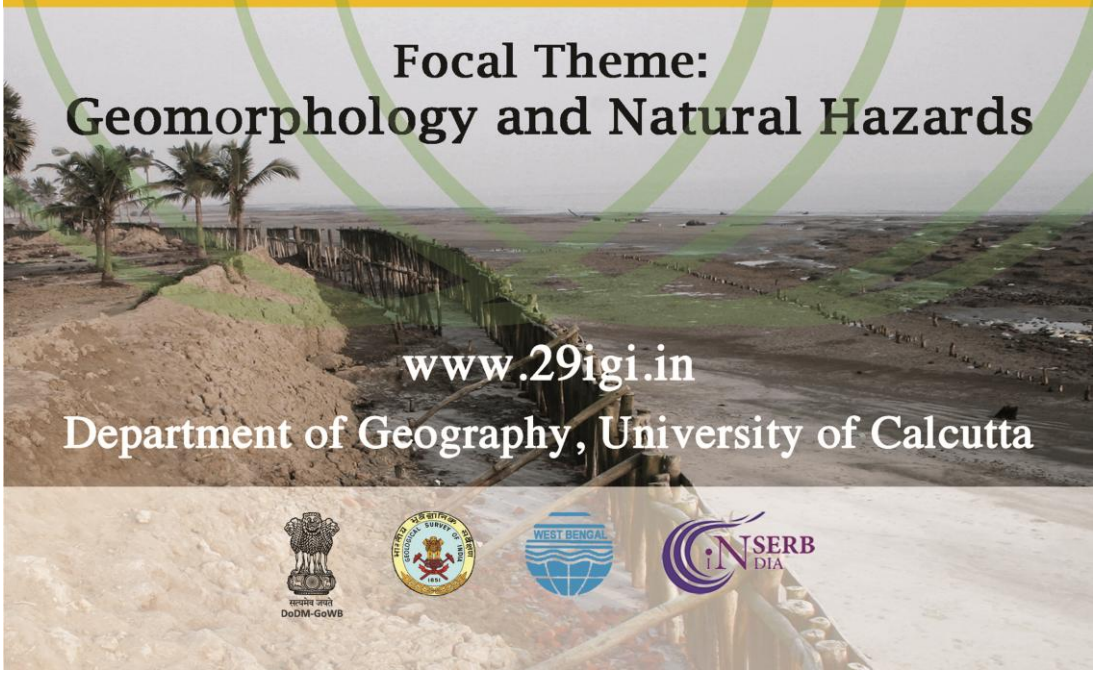
29th Conference of the
Indian Institute of
Geomorphologists (IGI)
Kolkata 2016

ABSTRACTS

29th Conference of the Indian Institute of Geomorphologists (IGI)

November 24 - 27, 2016, Kolkata

Focal Theme:
Geomorphology and Natural Hazards



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सत्यमेव जयते
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CONTENTS

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Message

The Department of Geography of this University was founded in 1941 by *Padmabhushan* Prof. S.P. Chatterjee and has stepped into its 75th year. In commemoration of the long and eventful period of its existence, the Department is hosting the 29th Conference of Indian Institute of Geomorphologists (IGI) between 24–27th November, 2016. The focal theme of this conference, *Geomorphology and Natural Hazards* will bring forth the most contemporary issues affecting different geographical regions. I am happy to announce this event as a befitting celebration of the Platinum Jubilee year of the Department. As planned, this event will bring together the foremost academicians of India and abroad conducting research in geomorphology and allied subject matters.

I wish the event a great success.

Ghosh 18/11/16

[**Ashutosh Ghosh**]

✧ THE IGI: AN INTRODUCTION ✧

Indian Institute of Geomorphologists (IGI) is the only national platform exclusively dedicated to the research and development in the field of geomorphology in India. The idea of forming the Indian Institute of Geomorphologists (IGI) was seeded at the International Conference of Geomorphology and Environment held at the University of Allahabad in 1987.

Now affiliated to the International Association of Geomorphologists (www.geomorph.org), the primary objectives of the IGI are • to bring all earth scientists dealing with geomorphology and allied disciplines on a common platform; • to hold annual conferences in different parts of the country; • to publish a research journal; • to encourage young scholars in doing research in geomorphology; and • to give emphasis on research related to human society and its welfare viz. environmental geomorphology, urban geomorphology, environmental hazards and their management on different spatial and temporal scales.

The academic exchanges of the IGI conferences go a long way in providing direction to the path of research in geomorphology in India. For the 29th Conference of the Indian Institute of Geomorphologists, 165 abstracts – including seven plenary lectures – are received for eight pre-announced focus areas having both national and international relevance in contemporary research in geomorphology. These are as follows.

✧ FOCUS AREAS OF THE 29TH IGI CONFERENCE ✧

1. Focal Theme: Geomorphology and Natural Hazards ✧ Abstract # 1 – 35

The focal theme of the 29th IGI Conference — Geomorphology and Natural Hazards — is contemporary and relevant to both Indian and global contexts. When incidents like the Nepal earthquake, the cyclone Hudhud or the Uttarakhand flash flood still loom large in our memory, discussions and deliberations on natural hazards are always pertinent. Such discussions aim to increase awareness among scientists, engineers, and planners about natural hazards, and to reduce damages to natural and human environments. Despite recent advances in hazard prediction and disaster-prevention engineering, damages inflicted through natural hazards continue to mount, especially in the Asia-Pacific region, where the number of fatalities and large economic losses impose a double burden. The question is, 'how should the countries across Asia develop and tackle the challenges related to the natural hazards?'

The Government of India has brought about a paradigm shift in the approach to disaster management. The new approach acknowledges the need to adopt a multi-dimensional and multi-disciplinary endeavour involving diverse scientific, engineering, financial, and social processes for risk reduction in the developmental plans and strategies. At this juncture, the role of Geomorphology attains relevance. Geomorphologists are now becoming increasingly involved not only in the understanding, mapping and modelling of earth's surface processes, but also in vulnerability analysis, risk assessment, and hazard management. Geomorphologists have considerable expertise in understanding the 'magnitude and

frequency' concepts applied to the earth sciences, and can suggest a framework for a comprehensive approach to natural hazards studies.

The 29th IGI Conference would provide a platform to the Geomorphologists of our country to share their knowledge about the contribution of geomorphology to the comprehension of hazards, and their experiences in linking geomorphology with other disciplines in vulnerability and risk analysis, disaster prevention and sustainability.

2. Focus Area: Tectonic and Structural Geomorphology ✧ Abstract # 36 – 40

The core of Tectonic Geomorphology lies in the interaction between the tectonic processes and the surface processes, which gives us a better understanding of how the surface of the earth evolves in regions of active tectonics. During the past few decades, the emergence of new dating techniques, process-oriented geomorphic studies, better reliability of past climatic records and paleoseismological evidences have gone a long way in determining rates of crustal movements, the age of landscape features, and in understanding the mechanisms and rates of geomorphic processes.

3. Focus Area: Landforms and Earth System Processes ✧ Abstract # 41 – 79

Process studies in Geomorphology provide an integrative approach to process dynamics and the evolution of landforms over cyclic and non-cyclic time, inheriting the imprints of past processes. The process-form relationship is the basic foundation for the quantitative assessment of geomorphic systems. Formulation of mathematical models through rational deduction and empirical analysis of observed data, to relate energy, mass, and time is the ultimate goal of Process Geomorphology.

4. Focus Area: Geomorphology in Ecology and Environment Management ✧ Abstract # 80 – 92

Biogeomorphology, as an interdisciplinary field, acts as the perfect coupling between the geomorphic and ecological components through feedbacks of differing strength and importance. Environmental management, on the other hand, is a multi-layered social construct, which investigates geomorphological processes and forms under the influence of human-environment interactions. Research in contemporary geomorphology should incorporate these dynamic bio-physical interactions with human activity, in order to predict the response of landscapes to human disturbance and climate change.

5. Focus Area: Application of Modelling and Geoinformatics to Geomorphological Studies ✧ Abstract # 93 – 113

Geoinformatics is an integration of science and technology that deals with acquisition and manipulation of geographic data, transferring it into useful information using analytical and visualisation techniques, for making better decisions. With innovations in the field of remote sensing, the application of geoinformatics in geomorphology gained a wider spectrum. For understanding the spatiotemporal characteristics of the landscape, mathematical algorithms are now being increasingly used for the retrieval, analysis, reasoning and modelling of geomorphological patterns and processes.

6. Focus Area: Urban Geomorphology ✧ Abstract # 114 – 124

The changes caused by urbanisation results in feedback mechanisms that produce a variety of distortions and maladjustments in the land-water ecosystem, whereby man changes the environment in creating a totally new anthropogene 'cityscape'. Geomorphologists can contribute to the evaluation of resource potential and landuse planning of urban areas and can also monitor geomorphological process-response systems and their changes following urban development.

7. Focus Area: Sustainable Resource Management, Planning and Geomorphology ✧ Abstract # 125 – 148

The role of geomorphological service in the sustainable management of natural resources has been less clearly elaborated as a focus area for Geomorphology. Services generally relate to the geomorphological interventions to assist in the development plans for agriculture and landuse planning, urban development, habitat protection, soil conservation, watershed restoration, and coastal management. Process-based intervention requires the planners to have a better understanding of the dynamics and sensitivity of the geomorphic systems in maintaining the balance between and within the natural and human habitats.

8. Focus Area: Geomorphosites and Geotourism ✧ Abstract # 149 – 157

Geologic or geomorphologic elements of nature can qualify as geomorphosites, if they are worthy of being conserved as a natural heritage. Many of these sites are already modified, damaged or partially destroyed by human impacts. The new interest of the scientific community for these geomorphological heritage sites call for a need to popularise these by assessing their scientific, cultural, aesthetic, social, and economic values. This can be achieved through geotourism, which promotes tourism to geomorphosites, conservation of geodiversity and an understanding of earth sciences through appreciation and learning.

✧ THE HOSTS ✧

The Host City

Kolkata is located in the eastern part of India at 22°82′N & 88°20′E. It spreads linearly along the left bank levees of the tidal Hugli River (spring tide range: 4.2 m) — the westernmost distributary of the Ganga Delta. Its elevation varies from 9 m along the western riverfront areas to 3 m towards the East Kolkata Wetlands, a Ramsar Site renowned for its traditional, wastewater-recycling fisheries. The Bay of Bengal coastline is located 100 km south of Kolkata. The World Heritage Site of the Sundarban mangroves is 60 km away.

Established in 1690 as a colonial outpost, Kolkata is the second largest city of India and is the capital of West Bengal (2011 population: 4.5 million). A city of love, grandeur, and glory, Kolkata gained a popular name, 'City of Joy', for its happy amalgamation of different cultures, styles, and moods, along with many forms of faiths, politics, and economies. A kaleidoscope of contrasting ideas, Kolkata is full of life and bustle, sometimes verging on

the chaotic, but orderly on the larger perspective. Its imperial monuments and its strong cultural and religious flavour leave an indelible impression on the visitor.

The Host University

The University of Calcutta (www.caluniv.ac.in) was established in 1857 as the first institution in Asia conceptualised as a multidisciplinary and secular Western-style university. One of the premier Universities of India at present, it now runs 61 academic departments and 23 research centres under 8 faculties. It is recognised as a *Five-Star University* and a *Centre with Potential for Excellence* by the NAAC and the UGC.

The University has 14 campuses in Kolkata and its suburbs. Among these, the oldest campus is located at College Street (Ashutosh Shiksha Prangan), which is also the main administrative centre. The other principal campuses include the Rashbehari Shiksha Prangan at Rajabazar, Taraknath Palit Shiksha Prangan at Ballygunj and Shahid Kshudiram Shiksha Prangan at Alipur. Besides this, 168 undergraduate colleges are affiliated to the University, out of which 62 teach Geomorphology as a core module of Geography and/or Geology in Honours Courses.

A seat of learning is known by the students it produces. A number of renowned writers, scientists, engineers, industrialists and world leaders graduated from the University of Calcutta. Nobel Laureates who either studied or worked here include Rabindranath Tagore, Ronald Ross, Chandrasekhara Venkata Raman, and Amartya Sen. Multifaceted personalities like Bankim Chandra Chattopadhyay, Sir Asutosh Mukherjee, Babu Rajendra Prasad, Sheikh Mujibur Rahman, Satyajit Ray, Ganesh Pyne, Sir Rajen Mookerjee, and Rama Prasad Goenka were alumni of this university. Notable scientists associated with the University include Jagadish Chandra Bose, Prafulla Chandra Ray, Meghnad Saha, Prasanta Chandra Mahalanobis, and Satyendra Nath Bose.

The Host Department

The Department of Geography of the University of Calcutta was founded in 1941 at its College Street Campus by the doyen of Indian Geography, *Padmabhushan* Prof. Sivaprasad Chatterjee. In 1963 it was shifted to the Science College at the Taraknath Palit Shiksha Prangan. This year the Department is celebrating its 75th year of foundation.

Widely-known teachers like Prof. Nirmal Kumar Bose (National Professor), Prof. Kanan Gopal Bagchi, and Prof. Bireswar Banerjee contributed significantly to the development of the Department in its early years. Three former Presidents of the IGI, Prof. Manotosh Kumar Bandyopadhyay, Prof. Subhas Chandra Mukhopadhyay, and Prof. Subhashranjan Basu adorned its faculty positions. Three other former Presidents, Prof. Nikhil Krishna De, Dr. Amal Kar, and Prof. Guruprasad Chattopadhyay were its alumni.

Today, the Department accommodates 15 faculty positions and admits 120 students in the Masters course. It also employs nine non-teaching staff in its office, library and laboratories.

The specialisations of the Department include • Geomorphology and Hazard Studies, • Tropical Climatology, • Pedology and Landuse, • Environmental Geography, • Industrial Geography, • Urban Geography • Tourism Geography, • Regional Planning, and •

Cartography. Its spatial thrust areas have traditionally been West Bengal, Sikkim and Jharkhand, although studies on other areas of the country are also encouraged.

The Department has so far produced three DLitts, two DScs and close to two hundred PhD recipients. The members of the faculty published more than 1,000 scientific papers in reputed journals at the national and international levels and completed or continuing fifteen major projects sponsored by the UGC, DST, World Bank and other funding agencies.

In 2011-12, the Department successfully completed the UGC DRS Phase-I and DST FIST programmes. In 2013-15 it received support from the DST PURSE scheme. At present it is conducting Phase-II of the UGC DRS programme.

The main facilities of the Department include:

- A Seminar Library containing 11,659 books and 3,325 volumes of journals.
- A Map Library holding a rich collection of rare maps, satellite images and aerial photo pairs.
- An RS/GIS Laboratory housing 30 workstations with state-of-art facilities.
- A Pedology & Sedimentology Laboratory.
- A Museum that exhibits specimens of geographical and ethno-cultural interest.
- Cartographic Survey Facilities of the Department include advanced survey equipment like echo-sounders, total stations and differential GNSS systems.

In its premises it also houses two Learned Societies of eminence: the 1933-established Geographical Society of India (www.geographicalsocietyofindia.org.in), established in 1933) and the 1976-established Himalaya Samiksha Parishad (www.himparishad.org).

The Department generally organises two to three national-level workshops and symposia every year on various themes of geography. Two of the major events that were arranged in recent times include the International Conference on Dimensions of Development and Resource Conservation (2012) and the International Conference on Urbanisation and Regional Sustainability (2016). Two previous IGI conferences were hosted by the Department: the 5th Conference in 1993 and the 12th Conference in 2001.

PRESIDENTIAL ADDRESS

Current Scenario of Research in Indian Geomorphology and its Future

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I am pleased and honoured to meet you here on a theme of exceptional relevance at 29th Indian Institute of Geomorphologists (IGI) Annual Conference on 'Geomorphology and Natural Hazards'. I would like to express special thanks to the Organisers for the time and effort they have invested in organising this event. As a President, I warmly welcome all the participants who have come from all over the Country.

In this talk, I would like to comment on the '*Current Scenario of Research in Geomorphology and its Future*'. First, I will take up some matters of research practices and reflect upon the question of how it copes with undertaking research with implications for the future.

Geomorphology is an important branch of geography and is sub-field of the discipline in general and geomorphology in particular. In most of the universities of India, physical geography is being taught at undergraduate level and geomorphology at post graduation. Geomorphology has many fields like *fluvial, environmental, regional, coastal, glacial, arid, karst* and so on and so forth. These subjects are been taught at post graduation in many universities either as general paper or as specialisations. Research has been carried out on geomorphology and its allied fields by geographers as well as geologists in both India and abroad.

In this connection, first of all, I want to highlight on some of the works undertaken at M.Phill and Ph.D level in different national universities.

In *Punjab University* research on geomorphology started in the decade of 1981-1990 where work on cycles and erosion were carried out. Joshi (1984) worked on 'Geomorphology of the Ghaggar river in the Dun and Water Gap Locale'. The research topic of Kaur (1985) was 'The Himalayan Main Boundary Fault Zone: A Geomorphologic Reconnaissance'. Mann, in the same year (1985) worked on 'Geomorphic Landscape on Pinjaur, Nalagarh Dun'. A piedmont bench was the focus of study of Dulat (1986). In the same year, Sekhon worked on the 'Geomorphology of the Markanda Terraces'. The thesis of Raina (1986) was on 'Morphology of the Markanda Terraces' while Bhel (1990) penned the 'Water Gap Depositional System of the Ghaggar River'. In Punjab University, the focus of research is on various aspects of human geography while geomorphology as a sub branch of physical geography continues to contribute to <10% of the total research.

In the *University of Delhi*, one-third of the research is in the field of physical geography, of which geomorphology has been a major component. 'Geomorphic Study of Sahibi River Basin' was undertaken by Kumar (1978). 'Drainage Basin of Khudia' by Basu (1979) and Kosi Basin by Ansari (1982). Singh (1989) worked on the Quantitative Geomorphology on

the Third Order Drainage Basin of Kumaon Himalaya and Nilgiri Hills. Gautam (1989) worked on the 'Geomorphology of Laterites in Chota Nagpur Plateau'. The main streams of research which developed in Delhi University are regional and fluvial geomorphology.

Regional geomorphology and geo-hydrology have been the focus of research in *Jawaharlal Nehru University, New Delhi*. Gurjar (1975) studied about the 'Regional Structure of Longitudinal Valleys of Aravalli region'. Mohammad (1982) worked on Mewat river. Khan (1983) focused on 'Drainage Densities of the River Basins of Northern India'. In the same year (1983) Kumar worked on 'Fluvial Geomorphology of Dhauli Ganga'. Chand's (1986) research was related to the 'Geomorphology of Lahul (Central Himalayas)'. Ganjoo (1987) focused on the landslides. Research of Yadav (1981) was on 'Channel Morphology of the Upper Catchment of Narmada'. Srivastava (1988) undertook 'Morphometry under varying Lithological Condition of Basins of Indravati River'. In the same year, Meera worked on Narmada by applying remote sensing techniques and identified the structurally controlled landforms. In 1989, Sreekesh (1990) worked on the 'Hydrological Characteristics of Periyar Basin' and Mathur in 1990 studied about the slopes in the few selected topographies. Prasad (1992) did 'Morphometric Analysis of Kanchi River Basin, Ranchi Plateau'. Kumar in 1987 evaluated 'Geomorphological Evaluation of Environmental Degradation and Management in Dhavliganga Basin, Central Himalayas'. Mathur in 1995 reviewed the 'Effect of Rockmass Strength on Hillslope Form and Development in Bundelkhand Physiographic Region'.

Human aspects of geography have been dominating in *Aligarh Muslim University*. Physical aspects contributed to < 18% of the research. 'Fluvial Morphology of Gangetic basin' was done by Role in 1989. Roh (1991) focused on 'Fluvial Morphology of Gangetic Delta'.

The Department of Geography of *University of Allahabad* is one of the pioneer departments of the Country where the research focus on geomorphology has been developed. $^{1}/_{5}$ of the total work is related to this aspect of geography. Verma as early as in 1958 studied about the 'Geomorphology of Ranchi Plateau'. Srivastava (1977) focussed on the 'Drainage Basin Characteristics of the Bengal River'. Upadhaya (1981) undertook 'Morphometric Study of Small Drainage Basin of Southeast Chotanagpur Plateau'. Similar sort of study was undertaken by Ojha (1981) for small basins of Palamau Upland. Rangani (1985) work was on Rohtas Plateau, while in the same year Prasad focused on the 'Geomorphology of Chhindwara' and Pal on 'Upper Damodar'. Dube in 1986 studied the Environmental Geomorphology of Trans-Yamuna Region of Allahabad District. Agnihotri (1987) worked on the geomorphology of area adjoining Rewa. Bhat (1990) worked on surface hydrology of Jamthara drainage basin while Singh's (1991) focus was on morphogenesis of Rohtas Plateau. In 1992, Rastogi surveyed Belan-Son Inter stream region of Eastern Rewa Plateau. Dube in the same year worked on 'Seoti Basin'. In Allahabad University a new focus of research which developed is '*Urban Geomorphology*' and this work has been carried out in the cities of Calcutta, Agra, Delhi etc.

Considerable amount (around 15%) of the research in *Banaras Hindu University* is related to geographical studies which integrated both physical and human dimension. Singh in 1966 worked on the 'Changes in Courses of Rivers and Effects on Urban Settlements in the

Middle Ganga Valley'. On similar lines, Asthana (1968) reviewed the Landforms and Settlements in Almora. Singh (1974) worked on Palamou upland of Chotanagpur Plateau. Gupta in 1977 studied landforms and settlements of Champawat. Jha in 1982 focused on Himalayan Ramganga Basin. Kodali (1987) worked was on geomorphology of Konar basin. A study of Bagnas-Tal-Rupa-Tal Watershed was undertaken in 1992 by Krishna.

Amongst the Indian Universities, the research on physical geography and its sub-discipline 'geomorphology' is very well developed in *Calcutta University* where it accounts for 40% of the total research in geography. In physical geography, regional geomorphology and fluvial geomorphology dominated the research area. As early as in 1956, Sen worked on lower Damodar basin. Nakata 1972 research was on piedmont topography of North Bengal. Basu in 1974 investigated River Dynamics of Bhagirathi Valley, West Bengal. Geomorphologies of Subarnarekha basin was studied by Mukhopadhyay in 1974 and River Terraces along Alaknanda Valley, Garhwal Himalayas was studied by Pal in the same year are worth mentioning. South Koel basin was the area of study by Desai (1981). Dutta (1982) studied Taraphini Basin of West Bengal. Chatterjee (1984) worked on the influence of Geomorphic Characteristics in Darjeeling District. Begum (1985) focused on Nature and Evolution of Landforms in a small area South of Giridih town while Panchdayyi in the same year focused on Fluvial Geomorphology and Flood Characteristics of Subarnarekha Basin. Chaudhuri (1986) analysed the Basin Characteristics of Garra River of Subarnarekha Basin and in the same year, Roy analysed the terrain of Kangsavati Basin. Pal 1988 worked on the Morphology of Coastal Track of West Bengal. In 1989, Agarwal worked on the North Koel Basin, West Bengal. Biswas (1990) carried out Landform Analysis in Rangit valley, West Bengal. Maiti in 1991 also studied the landform development of middle Mahanadi Basin, Orissa. The same sort of work was done by Maiti in the same year but on the Tarai area located in the eastern Himalayas in West Bengal. Evolution of Terrain Character of Upper Subarnarekha Basin was undertaken by Roy in 1992. Chakrabaorty in (1992) focused on the Geomorphology of the Sanjai Basin. Mukhopadhyay in 1993 focused on Fluvial Geomorphology of Tista basin.

The field of physical geography at large and geomorphology in particular is not developed in *Osmania University, Hyderabad* with < 5% of the research focusing on this stream of geography. G. Sounsravatti worked on 'Geomorphology of Chittor Basin, Tirunelvelli District'. M.R. Saxena focused on the 'Geomorphic Study of Dindi Basin'.

The focus of research on geomorphology in *University of Madras* comprised of around 10% of the total work in the Department of Geography of this university. However, the direct work on geomorphology and its sub-branches is almost absent.

At *University of Rajasthan,* physical geography in general and geomorphology in particular is well developed. $^{1}/_{5}$ of the research in this university is in this broad group. Regional geomorphology has been the foremost sub-discipline which is well developed in the university. Rao in 1976 worked on Geomorphology of Mej Basin, Rajasthan. D. Sinha (1992) focus was on Environmental Geomorphology of Bandi River Basin. In 1993 Gautam put forth some Aspects of Geomorphology of Upper Banganga Basin, Rajasthan. In the following year (1994) Agarwal focused on Prabati Basin.

The focus on geomorphology was low in *Jai Narayan Vyas University, Jodhpur*. Amal Kar in 1997 worked on 'Morphology and Evolution of Aeolian Bed Formation in the Hot Desert'.

Human geography is the pivot around which the research themes revolved at *Mohanlal Sukhadia University, Udaipur*. The first research work on geomorphology or its allied areas was done in 1996.

At *Dr. H.S. Gaur University, Sagar* (now Central University) a few works are undertaken in this sub branch of geography. In 1970, R.K. Rai worked on Geomorphology of Sonar-Beawas Basin, M.P. In 1980, P. Soni, focused on Rewa plateau while two years later in 1982 L.P. Baghel studied lower Ken Basin. Later, in 1989 Goil focused on Maikal Plateau.

The number of researches on physical geography in *University of Bombay, Mumbai* is less than $^{1}/_{5}$ but the focus on geomorphology is low. Damle's work was only one which focused upon the 'Environmental Geomorphology of Salcette, Goa'.

At *University of Pune* research pertaining to physical geography and geomorphology per -se is very much developed. 33% of the research in the Department of Geography is focused on this branch. The early works of Kale in 1980 focused on Slope Morphology of Shiv Ganga Basin. Changtham (1985) focused on Laterites and the work was on Mahabaleswar Plateau. In the same year, Avhad studied the characteristics of Valley Side Slope on Katraj range. The focus of study of Vidya (1986) was on Panchganga Basin. Borse in 1987 worked on scarpland of Warandha Ghat area. Morphometric analysis of Barana basin has been done by Salvi in 1987. Coastal landscape had been the focus of study by Telele (1988). In the same year, Ugle worked on Koyna basin. Galande in 1988 also did Morphometric Analysis of Padal Basin which is a typical Karst topography. In the same year, Patil studied the characteristics of valley forms. The following year (1989), Ghodke work was on channel bed. Awasthi in 1990 worked on Morphology of Revdanda Beach, Raigad district and in the same year Bidwe worked on weathering characteristics of Amboli Ghat area. Singh (1990) focused on fluvial geomorphology while in the same year, Belgali studied Dudh River Estuary, Palghar. In 1993, Saxsena focused on Channel Morphology of Kudki river. Pimpale (1995) used TDCN analysis in drainage development. In the 1995, Patil focus was on bad land along Tapi Channel. Keskar did the 'Geomorphic Study in Ban Ganga Estuary, Maharashtra' in 1996, while Gole (1997) focused on 'Koyna River'. Mohan (1997) worked on the Geomorphological, Sedimentological and Geochemical aspects of Mayem Lake located in Bicholim Taluk of Goa, India. The study focused on several aspects of the lake. Kodagali (1992) worked on the Geomorphology of the Central Indian Basin and the influence of topography on the distribution of Polymetalline Nodules. The major objective was to study the morphometry and geomorphology of the central Indian basin and to understand the relationship between the topography of the sea floor and the distribution of the polymetallic nodules. Prakash (2012) worked on the Sedimentological and Geotechnical studies of Coastal Sediments of Central Kerala. The major objectives of the study were mainly concerned with the establishing probable relationship between organic matter, textural, physical and geotechnical properties of the coastal sediments of Kerala; to

understand the depositional environment of coastal and marine sediments and to study the paleo-environmental condition of central Kerala coast.

Other than the above said works, some of the other studies can be cited in this regard which mostly concentrates on the north eastern states of India. Thesis of Thingo V. (1994) was on the Terrain Evaluation of Kohima District, Nagaland with special reference to geomorphology. Researchers like Mazumder (1984) worked on the Geomorphology of Tripura. The major objectives of the study was related to the geomorphic characteristics of the state in relation to the lithology and structural characteristics. It examined the evolution of the drainage system and the related features and regionalised the entire study area on the basis of physiographic facies.

These were some citations of M.Phil and Ph.D. which have been carried out in a few Indian Universities. Besides them, a number of research articles have been published by Indian Geomorphologists. A few of them are as follows- contribution of Indian geomorphologists in the regime of *Fluvial Geomorphology* has attained considerable attention both in-terms of conceptual and applied field of knowledge. One of the primary focuses of the fluvial geomorphologists is on geomorphic aspects of Himalayan and Peninsular rivers. Goswami (1985), Kale *et al.* (1997a) discussed about the seasonal characteristics of Indian rivers. These studies stated that irrespective of size and shape of the sediments, the characteristics of Indian rivers is mainly controlled by the seasonal pattern. Kale 1998 has also found significant differences in the fluvial systems in-terms of channel morphology, hydraulic geometry and flooding characteristics. Scholars like Singh 1996 and Shukla *et al.* 1999 focused on channel morphology and revealed in their study that in spite of a gentle slope with fine sandy bed loads some of the world's largest river like Indus, Ganga and Brahmaputra show graded channel pattern. In the last few decades, number of attempts has been made by hydraulic engineers to establish probable relation between the channel morphology and various channel parameters. Various scholars like Agarwal (1984), Bhargav *et al.* (1985) too based their works on similar lines of thinking. Some of the studies conducted by Goswami (1985), Sarma and Basumallik (1984), Kale (1990) focused on the aspects like channel morphology, meander geomorphology and hydraulic dynamics while some focus was on the measurement of the rivers in terms of their width. Singh (1996), studied 221 Indian rivers and it was found that a majority of them had width ranging between 30-50 m while some large rivers had width ranging between 800-2300 m. Studies by Bajpai and Gokhale (1986) examined the probable existence of major drainage systems in between the present day Ganga-Yamuna by using satellite images. Abandoned channels, meander scars were also mapped along different rivers of Ganga plain. Number of studies focused on the channel avulsion which is an important process prevalent in Ganga plains. The above said process is well documented by Singh (1996) in the Ganga plain. Research conducted by Majumdar (1941) and Wadia (1975) primarily focussed on the impact of earthquake in influencing the characteristics of Himalayan rivers. The available records and the results obtained from the studies indicated that there is a significant impact on channel morphology and channel bed load and its association with the earthquake. Goswami (1999) reported, that 1950 Assam earthquake was responsible for the rise of water level (of about 3m) in Brahmaputra. Sarma and Basumallick (1984) in their studies depicted the immediate

effects of such phenomena like neck cut off while formation of lakes and waterfall in the rivers. Chindrang river in Assam was well documented by Wadia (1975). Works of Deodhar and Kale (1999) and Gupta *et al.* (1999) discussed about the incised alluvial channel of the peninsular rivers which are unlike the rivers of IGB plains where large magnitude of floods increase the width and width-depth ratio [Singh (1996)]. Apart from the channel morphology dynamics, several studies focus on the channel bars and riverine sand dunes. The work of Singh and Kumar (1974) focused on the mega ripples in the rivers like Ganga, Yamuna and Son and also attempted to focus upon process and sedimentary structures and Palaeo current pattern in the braid bars and point bars of river Ganga. Results showed that evidences of direction of bed-forms obliquely move into the channel in marginal parts rather movement of bed forms obliquely on the bed in the bar margins which was suggested in the earlier studies. Similar type of study was also done by Rajaguru *et al.* (1995) in an alluvial reach of Narmada river. Results of which showed similar type of pattern in the point bars of Narmada river as the study undertaken by Singh and Kumar (1974). The number of studies related to the fluvial forms and processes in the bed rock channel are fewer than the alluvial channels. Rajaguru *et al.* (1995) and Kale *et al.* (1994) made significant effort in estimating the hydraulic parameters of large floods in the bed rock reaches of Narmada and Tapi. The study of Kale and Shingade (1987) revealed that the pot holes existed in Indrayani river of the Deccan trap region and it was concluded that multiple channel pattern of bed rock is formed due to merging of grooves and pot holes in the joints of basaltic rock. Sediment load and its storage is also considered to be a subfield of fluvial geomorphology which is also young. Suspended load related study was done be Garde and Kothyari (1986) and they estimated the sediment deposition rate in reservoirs ranging from small, medium and large sizes. In this study, they have incorporated landuse, drainage density and rainfall. In the recent years, the sediment load in mountain region is studied by different scholars like Rawat *et al.* (1992), Rawat and Rawat (1994). The results showed that the regions associated with anthropogenic stress and tectonically disturbed lands many a times had higher sediment load than other regions. Rawat *et al.* (1992) depicted that considerably large part of the total load (61%) comprised of bed load while a small portion (31%) was related to the suspended load in the small mountainous streams. Flood morphology and impact of floods from the point of view of geomorphology was studied by different scholars. Ramaswamy (1987) focussed on the large floods in different rivers and it was found that a direct relationship existed between floods and intense cyclonic storms and depressions. Other than natural causes of flood, non-meteorological factors were also reported in a number of research papers by geomorphologists (Wadia 1975). In these studies, it was noted that the major factors affecting floods were landslides caused by heavy rains, earth quakes etc. In comparison to the Himalayan rivers, Peninsular rivers are more stable in terms of bankline and channel position in response to the flood and it is well documented by number of scholars like Rajaguru *et al.* (1995). Long time flood related studies were also done by number of scholars. Parthasarathy *et al.* (1991) studied the features of monsoon during 1901-1940 and it was found that the characteristics of the monsoon as 'zonal monsoon' while time period of 1871-1940 was found to be dominated by less stable 'meridoinal monsoon'. Goswami (1988) examined the sediment load and its relationship with the flood event in one of the large river of India, ie, Brahmaputra. In the paper, it was revealed that,

during flood that occurs once in at least two years, carry 95% of the annual load. On the other hand flood that occurs at an interval of 10 years carry about 3% of the annual load. In several studies, it was also found that even after flood events, in the rivers like Godavari for example the banks were largely unaffected (Majumdar 1970). In the case of river Narmada also Rajaguru *et al.* (1995) hardly observed any significant changes in bank line after August 1991 severe flood.

India has long coast line of about 5700 km with a number of landforms and processes that carved them. But at the same time, the studies regarding the *coastal geomorphology* is relatively less than the other subfields of geomorphology. In the recent past, some the researchers have seriously focused on the field and made some significant contributions. Chattopadhaya (2002) focused on the geomorphology of the coastal plains of Kerala in terms of its emergence. Karlekar (2001) focused on the coastal configuration of Kolamb creek of Malvan, Maharashtra. In this study, he incorporated remote sensing techniques and analysed on the basis of Satellite images like IRS-1C, LISS-III PAN images. Dey (2002) studied the configuration of Digha coastline of West Bengal which is considered to be one of the erosion affected beach of West Bengal. In this work, he incorporated the landform development along the coast and risk assessment. In India, few studies are also conducted on the sea level changes. Studies undertaken by Mathur (2002) mainly concentrated on the chronology of Harappan port towns. Dwarka in Gujarat and one more site Hazira (Surat district) has come into light in this study. Kerlekar (2002) focused on the landslides and slopes failure on the Vengunla coast of Maharashtra where cases of Vevaliwadi and Khandapiwadi were taken into considerations on the basis of observations and evidences. Some of the recent studies regarding the coastal geomorphology can be cited in this regard. Kumar *et al.* 2012 focus on the variations in the near shore currents in the coastal regions of Karnataka and tidal variations in the estuarine system of Sundarbans. Besides depositional features there are some studies that focused upon the rocky features like sea cliff and wave cut platforms. Mahapatra *et al.* 2014 focused on the shore line changes in the south Gujarat by using multi temporal satellite images.

Mehta *et al.* (2012), Negi *et al.* (2012), Raj *et al.* (2013) and Bajpai *et al.* (2015) discussed and focused upon the Karakoram Himalaya mountains by using remote sensing techniques along with ground observations where fluctuations in the snout positions, glacier feature and glacial lake were observed. In terms of glacial retreat the work of Kulkarni and Karyakarte (2014) is an important contribution. In this work, they have mapped 11000 km^2 area which is extended in all major climatic zones of Himalayas and it was noted that the Himalayan glaciers are retreating at a rate of few meters to 61 m/year. The study also showed that in the last 4-5 decades there is about 13% loss of glaciated areas. Bajpai *et al.* 2015 worked on glacial inventory for Tista river basin by using Remote Sensing and GIS techniques. A number of parameters like glaciers distribution, orientation, altitude, mean slope and aspects etc have been incorporated. In the paper the result depicted that the entire region is associated with number of glaciers ranging from very small (0.1328 km^2) to large glaciers (1557 km^2) area. Bahuguna *et al.* (2007) investigated Gangotri glacier from 1962. They have concluded that the contribution of high rate of retreat of small glaciers, climate change and glacial fragmentation are considerably influencing the sustainability of Himalayan

glaciers. In terms of geomorphic evidences Mehta *et al.* (2012) worked on the post LGM glacial advancement in Himalayas, a study focused on Chorabari glacier located in Garwal Himalaya. In this study, remote sensing data along with field geomorphology was substantiated with OSL dating. Bhattachaya *et al.* (2007) worked in the regime of outburst floods in the Sagarmatha region and incorporated hydrodynamic modelling. The study not only gave the primary information about the GLOF but also focused on the cost effectiveness of the preliminary information on the extent and impact of possible GLOF events.

In the recent years, there has been a significant progress in the field of geomorphology where major emphasis was on conventional indices like basin *morphometry, gradient index* as well as using *structural characteristics* by on field identification. Studies by Joshi *et al.* (2013), Dar *et al.* (2013), Sahu and Saha (2014), Alam *et al.* (2015) and Kale *et al.* (2014) worked on the similar lines of thought. Scholars like Maurya *et al.* (2008) discussed about the geomorphic evolution of coastal zones of Kachchh in late Quaternary period. At the same time, Patidar *et al.* (2007) focused on the fluvial geomorphology and neotectonic activity by using GPR data in Katrol hill range, Kachchh. The tectonic evolution of central Gujarat plain can be traced in the work of Maurya *et al.* (1995). Juyal *et al.* (2000) discussed on the environmental changes in the lower Mahi basin of western India in the late Pleistocene period. By using infrared stimulated luminescence they have concluded that there was evidence of two major fluvial aggradation phases. Goswami *et al.* (2013) worked on the foothill zones of eastern Himalayas. In this work, the inter-fluvial zone of Mal and Murti was taken into consideration and effect of neotectonic activities was analysed. Results depicted, the formation of downcutting of the rivers. The works of Devrani and Singh (2014) in the Garhwal Himalaya is an important contribution in the tectonic geomorphology. The major objective of the study was to depict the significance of local factors and places in the process of sedimentation in the active belt of Garhwal Himalaya along Alakananda river and it was concluded that the importance of local forces is as important as to discuss about the valley fill deposits along the Himalayan valley in particular stretches. The work of Kothyari *et al.* (2012) is another study which focused upon the neotectonic activity in the Main Boundary Thrust (MBT) zone of Kumaon Himalaya. It was concluded that the region is neotectonically active and there are several indicators like structurally controlled drainage pattern. Malik *et al.* (2014) worked on the Kaladungi fault and evidence of forward and lateral propagation of fault and fault related fold was observed. Ranitoli fault fold of Kumaon Himalaya was studied by Joshi *et al.* (2016). In the research paper, reconstruction of the fault along with oblique slip was found by using number of geomorphic indicators. Kar *et al.* (2014) focused on the Matiali fan located in Darjeeling Himalaya. The authors incorporated geomorphic and sedimentological characteristics. It was concluded that there are two aggradational terraces in the river valley which are incised on the fan. In Arunachal Himalaya, the work of De Sarkat *et al.* (2014) can be cited. The study stated that a number of levels of terraces existed both in terms of paired and unpaired terraces along the river Kemeng.

There are several other fields of studies where geomorphic hazards and processes related to formation of soil and weathering are taken into considerations. In the recent years, the major

focus of Indian scholar are on geomorphic hazards like flood and drought. Sharma *et al.* 2012 tried to correlate slope failure and heavy rainfall in Uttarakhand. Other scholars like Rao *et al.* (2014), Rana *et al.* (2013), worked in the flood on the occurrences of Himalayan region from different point of view. Kale (2012) worked in the frequent flood issues in south Asia. Pandey *et al.* (2012) discussed about the drought condition in the Chotanagpur plateau by using geoinformatics. The results indicated that, the entire region is classified into number of indices and 8.9% area comes under the low vulnerable zone while 17.3% of the area is designated as 'very high' in terms of drought condition. Arjunan and Achyuthan (2015) worked on the weathering process in the eastern coastal region of India. The study revealed the fact that the weathering processesis not only associated with the tropical weathering processes but also with saltwater spray and microbial activity.

In this discussion, a very minute portion of geomorphology as a discipline, has been projected and it can be inferred that there is a significant growth of the field in the last few decades from different perspectives that includes both logical and practical aspects of knowledge. I personally feel that there is a need to integrate geomorphology with sub disciplines of human and physical geography like urban geomorphology, bio, zoo and coastal geomorphology, orology, potamology and lithology and geomorphology, rural, urban and regional studies and geomorphology.

Another point which I personally strongly feel is that, use of modern techniques like GIS and Remote Sensing are still relatively restricted than the emphasis on field investigations whereas, this has been the strength of the subject. Hence, as a request I would end up saying that use these modern techniques but continue with the field investigations to the utmost.

In the end, I would say 'Landscape, which looks so constant, is on the move. Let us ALL explore and study it.'

Thank you.

References

Agarwal, V.C., Garde, R.J. and Ranga Raju, K.G. (1984) Planform Criteria and Geometry of Meandering Streams. *Irrigation and Power Journal*, 41: 393–401.

Bajpai V., Kanchan R. and Sharma A.K. (2015) Study of Glacier Inventory for Tista River Basin Using Remote Sensing and GIS Techniques. *The Deccan Geographers*, 53(1): 29–37.

Bajpai, V.N. and Gokhale, K.V.G.K. (1986) Hydrogeomorphic Classification of the Marginal Gangetic Alluvial Plain in Uttar Pradesh, India, Using Satellite Imageries. *Journal Geological Society of India*, 28: 9–20.

Bhargava, D.N., Agarwal, B.L., Bhargava, A.N. and Pal, M. (1985) A Study of Meander Loops in Alluvial Rivers Based on Field Data. *Proceedings of the 52nd Research and Development Session, New Delhi, October*. New Delhi: Central Board of Irrigation and Power: 39–51.

Deodhar, L.A. And Kale, V.S. (1999) Downstream Adjustments in Allochthonous Rivers: Western Deccan Trap Upland Region, India. In Miller, A.J. and Gupta, A., (Ed), *Varieties of Fluvial Form*. New York: John Wiley and Sons: 295–315.

Garde, R.J. and Kothyari, U.C. (1986) Erosion in Indian Catchments. *Proceedings of the Third Internal Symposium on River Sedimentation*. The University of Mississippi, 31 March–4 April 1986: 1249–1258.

Gohain, K. and Prakash, B. (1990) Morphology of the Kosi Megafan. In Rachocki, A.H. and Clunchi, M. (Ed) *Alluvial Fan: A Field Approach*. New York: John Wiley and Sons: 151–77.

Goswami, D.C. (1985) Brahmaputra River, Assam, India: Physiography, Basin Denudation and Channel Aggradation, *Water Resources Research*, 21: 959–78.

Goswami, U., Sarma, J.N. and Patgiri, A.D. (1999) River Channel Changes of the Subansiri in Assam, India. *Geomorphology*, 30: 227–44.

Gupta, A., Kale, V.S. and Rajaguru, S.N. (1999) The Narmada River, India, Through Space and Time. In Miller, A.J. and Gupta, A., (Ed), *Varieties of Fluvial Form*. New York: John Wiley and Sons: 113–43.

Kale, V.S. and Shingade, B.S. (1987) A Morpho- Logical Study of Potholes of Indrayani Knickpoint, Maharashtra. In Datye, V.S., Diddee, J.N., Jog, S.R. and Patil, C.J., (Ed) *Explorations in Tropics. Pune: Prof. K. R. Dikshit Felicitation Volume*, Pune: 206–214.

Kale, V.S. (1990) Morphological and Hydrological Characteristics of Some Allochthonous River Channels, Western Deccan Trap Upland Region, India. *Geomorphology*, 3: 31–43.

Kale, V.S. (eds.) (1998) Fluvial Regime and Flood Hydrology of the Brahmaputra River, Assam. *Flood studies in India*. Bangalore: Geological Society of India, Memoir, 41: 53–76.

Kale, V.S., Ely, L.L., Enzel, Y. and Baker, V.R. (1994) Geomorphic and Hydrologic Aspects of Monsoon Floods on the Narmada and Tapi Rivers in Central India. *Geomorphology*, 10, 157–168.

Kale, V.S., Hire, P. and Baker, V.R. (1997a) Flood Hydrology and Geomorphology of Monsoon-Dominated Rivers: *The Indian Peninsula. Water International*, 22: 259–65.

Karlekar S. (2002) Slope Failure and Landslides on Vengurla Coast, Maharashtra, *Indian Journal of Geomorphology*, 7(1 & 2): 135–140.

Majumdar, J.C. 1941: Ganges Flood and its Lessons. Journal of Institution of Engineers, India.

Mujumdar G.G., Rajaguru S.N. and Papu R.S. (1970) The Recent Godavari Flood (September 1969) and its Relevance to Prehistoric Archeology. *Bulletin of the Deccan College Research Institute*, 24: 1–17.

Parthasarathy, B., Kumar, K. R., & Munot, A. A. (1991) Evidence of Secular Variations in Indian Monsoon Rainfall-Circulation Relationships. *Journal of Climate*, 4(9): 927-938.

Rajaguru, S.N., Gupta, A., Kale, V.S., Mishra, S., Ganjoo, R.K., Ely L.L., Enzel, Y. and Baker, V.R. (1995): Channel Form and Processes of the Flood-Dominated Narmada River, India. *Earth Surface Processes and Landforms*, 20, 407–21.

Ramaswamy, C. (1987): Meteorological Aspects of Severe Floods in India 1923–1979. *MMH* No. 10. New Delhi: India Meteorological Department.

Rawat, J.S. and Rawat, M.S. (1994): Accelerated Erosion and Denudation in the Nana Kosi Watershed, Central Himalaya, India. Part I: Sediment Load. *Mountain Research and Development*, 14: 25–38.

Rawat, J.S., Haigh, M.M. and Rawat, M.S. (1992) Hydrological Response of a Himalayan Pine Forest Micro-Watershed, Preliminary Results. *Proceedings of the International Symposium on Hydrology of Mountainous Areas*, Simla, 28–30 May: 235–58.

Shukla, U.K., Singh, I.B., Srivastava, P. and Singh, D.S. (1999) Paleocurrent Patterns in Braid-bar and Point-bar deposits: Examples from the Ganga River, India. *Journal of Sedimentary Research*, 69: 992–1002.

Singh, I.B. (1996) Geological Evolution of Ganga Plain: An Overview. *Journal of the Palaeontological Society of India*, 41: 99–137.

Singh, I.B. and Kumar, A. (1974) Mega and Giant Ripples in the Ganga, Yamuna and Son rivers, U.P. (India). *Sedimentary Geology*, 12: 53–66.

Singh, M. (1996) *The Ganga River: Fluvial Geo- Morphology, Sedimentation, Processes and Geo-Chemical Studies*. Heidelberg: Ruprecht-Karls- Universitat.

Wadia, D.N. (1975) *Geology of India*. New Delhi: Tata McGraw-Hill.

NOTE: All the references which are not mentioned in the above list are of unpublished doctoral theses and can be found in the reference section of the respective Universities where they were submitted.

ANNUAL REPORT FROM THE SECRETARY GENERAL, IGI

The Indian Institute of Geomorphologists (IGI) aims to promote researches on methodological advancement in the field of geomorphology in India. The idea of forming an association was conceived by Prof. Savindra Singh, Geography Department, University of Allahabad during an International Conference on Geomorphology and Environment held from Jan 17 to 21, 1987 under his convenership in the Department of Geography, University of Allahabad wherein more than 200 delegates from European Countries and India participated and presented their research papers. After long discussion for two days regarding the name and logo of the association, its goals and objectives, mode of formation, constitution etc. were finally decided to call a general house meeting of all the delegates on January 19,1987 to finalise the modalities. Ultimately the general house agreed that the name and logo should be Indian Institute of Geomorphologists, and IGI respectively. The following objectives were formulated.

- To bring the entire earth scientist dealing with geomorphology and allied disciplines on a common platform under the banner of IGI.
- To hold annual conferences in different places of the country,
- To publish a research journal entitled Indian journal of Geomorphology now it is Journal of Indian Geomorphology,
- To coordinate researches being carried out on geomorphology and allied disciplines in different universities and laboratories in the country,
- To encourage young research scholars doing researches in geomorphology by giving awards and certificates,
- To give more emphasis on researches related to human society and its welfare such as environmental geomorphology, urban geomorphology, environmental hazards and disasters and their management on different spatial and temporal scales etc.

Most of the above mentioned goals and objectives of the IGI have been fulfilled. Till now 28th annual conferences of IGI with different focal themes have been organised at different places important being Andhra University, Waltare (first, 1988) Rajasthan University, Jaipur (twice), Poona University (twice), Calcutta University (twice), North Eastern Hill University Shillong (twice), North Bengal University, Siliguri and Darjeeling, Vishva Bharati University, Santiniketan, Tamil University Thanjavur, Annamalai University, Chidambaram, M.S. University, Tirunelveli (Tamil Nadu), University of Allahabad (twice), Kurukshestra University, Kurukshetra, Jammu University, Jammu, Delhi University, Banaras Hindu University, Varanasi, Tripura University, Agartala, Anna University of Chennai (2011), University of Allahabad (2012), M.S. University, Baroda (2013), Vidyasagar University Medinipur (2014), North Eastern Hill University (NEHU) Shillong (2015) and this year Calcutta University, Kolkata. The Calcutta University is going to hold the Conference thrice, i.e., a hat-trick!

The publication of Journal of Indian Geomorphology is smooth and updated. New volume is going to be released in 29th IGI conference. The family of IGI has grown rapidly with its life members exceeded to 557 It has been observed that young geomorphologists are coming very fast and they are doing quality researches in the field of geomorphology..All the life members have contributed much in the growth and progress of this organization. It is a matter of pride that we are going to organise 9th International Association of Geomorphologists (IAG) in 2017 at Vigyan Bhavan in New Delhi.

I wish the 29th IGI conference a grand success under the dynamic leadership of Professor Sunando Bandyopadhyay convener of this conference and all the faculties and students of this department. I take this opportunity to extend a very warm welcome to all the delegates coming from various parts of the country.

I wish the conference a grand success.

Prof. Savindra Singh

Secretary General - IGI

Geography Department
University of Allahabad

℘ 6TH PROFESSOR S.R. BASU MEMORIAL LECTURE ℘

Drass Valley Glaciers (Ladakh Himalaya) Currently In Stable Phase – A 'Climate Change Effect': An Overview of Morphology and Dynamics of Machoi Glacier

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It is a great honour and privilege to deliver the Prof. S.R. Basu Memorial lecture at the IGI conference in Kolkata. I am extremely grateful to the family members of Professor S.R. Basu and the IGI for having provided an opportunity to share my experience on Cold Geomorphological sciences with young scientists. My association with Prof. S.R. Basu dates back to 1988, when I had an opportunity of meeting Prof. Basu while I was presenting the research findings on Kashmir Himalaya at IGI Conference held at the Department of Geography, Rajasthan University, Jaipur. Since then I have had privilege of knowing Prof. Basu intimately as a dynamic researcher, and above all as great human being. Prof. Basu was one of the top ten geomorphologists of the country with one of the sharpest minds and most prodigious output of his generation, a great researcher and above all a renowned scholar of international repute in the field of fluvial geomorphology, particularly channel morphology, during last five decades. He envisaged the importance of empiricism and modeling techniques in field of physical geography. His research contributions in physical geography had a global acceptance. I have great admiration on his commitment to the society and the discipline of geography more so his humanity with youngsters. Therefore, I have accepted to deliver and share data on impact of recent climate changes on the stability of Ladakh glaciers particularly Drass basin glaciers for the benefit of young researchers.

Glaciers are the visible indicator of climate change. Glacier mass balance, length, area and snowmelt runoff are some of the parameters that are directly related to the climate. Glacier area change in response to climate change with a time delay and leads to fluctuation of its extent .The climate and glaciers are interrelated. Thereby, the glacier length change, through advance or retreat, is indirect, delayed, filtered but also enhanced signal to a change in climate, whereas the glacier mass balance, or change in thickness or volume, is the direct and underplayed response to annual atmospheric conditions. It is the climate that is driving force controlling the mass balance in glacier in space and time and resulting the recession and advancement of a glacier. Climate ice fluctuation causes variation in the amount of snow and ice lost by melting. Such changes in mass balance initiate complex series of changes in the dynamics and the flow of glacier that ultimately result in change of position of terminus.

The Kargil region forms a vast mountainous region between the Great Himalaya Range in the South-Southwest and Indus Valley in the northeast and occupies southern part of

Ladakh. It has nearly 1,796 glaciers, confined in Upper Indus basin, housed in Zaskar, Suru and Drass sub basins. Drass sub basin has 150 glaciers encompassing in an area of 152.68 km^2 with ice volume of 62.02 km^3. Drass sub basin is the fifth order basin of fourth order Indus and it extends between the Gumri (close to Zoji-La) in the west to Kargil in the east. Zoji-La is gateway to Drass, situated on National Highway 1-A connecting Srinagar with Kargil and Leh (Ladakh). The Srinagar–Kargil road remains closed to vehicular traffic during winter season due to closure of Zoj-La pass as a result of heavy snowfall. The Drass valley is encircled by precipitous ridges with high peaks (5,200 – 6,100 m) of Himalaya. The magnitude of high relief and overall steepness of slopes provide an overwhelming impression that region has a distinct climate between that of the Central Asia and the monsoonal South Asia. The study region has cold sub arid type of climate. The winters are long and chilly (minimum temperature: –15 °C to –35 °C), lasting from November to May. Summers are short (June to September) and mild (temperature varies between –8 °C to 25 °C) .Nearly 72% of its annual precipitation is received by western disturbances .and is confined between November and May which sometimes prolongs to summers as well; otherwise summers get scanty rains. During last one decade, the region is getting some precipitation during summers as well through westerlies thus showing sign of climatic shift.

The recent publication by Intergovernmental Panel on Climate Change in Fourth and Fifth Assessment reports generated lot of debate about the status of the Himalayan Glaciers. The present study is meant to understand how high relative relief is a cause of perturbation in ambient temperature in generating katabolic winds in glacier valleys; and how the winds affect the extent and terminus of glaciers. We assess regional differences in extent of glaciers in Drass valley through Remote Sensing techniques. The IRS LISS III (October, 2001 and 2013) data was provided for Drass basin by the Space Application Centre at pixel resolution of 23.5 m for detailed study. The base map of the area was prepared from Survey of India 1964 topographic maps of the scale 1:50,000. Only seven topographic sheets of the Drass basin were available that covered 115 glaciers. Out of these, 81 glaciers (>0.1 km^2) were selected for detail study. All the satellite images were geo-referenced using topographic maps. Images co-registered with each other resembled similar resolution. The glacier boundaries were delineated using GIS from FCCs to map various glacial features such as glacier boundary, accumulation area, ablation area, equilibrium line, moraines, etc.

The location and sources of meteorological data used in this study were chosen considering their proximity to glaciers and length of their records. The meteorological data of Drass is monitored by th India Meteorological Department and Snow and Avalanche Establishment (Government of India), adopting standard meteorological practices. The data for a period of 28 years (1987–2013) were used to assess seasonal changes, if any, in monthly mean maximum, mean minimum temperature and precipitation as tool to glacier stratigraphic system. Hence, under this system length of season and duration of 'mass balance year of glacier year' varies. The mass balance year is divided into winter (Nov–Mar), late winter (Mar–May), summer (Jun–Aug), and late summer (Sep–Oct). This is used in this study to isolate the inter-seasonal signals. Under this system, the specific net ablation and net accumulation were carried out in the field through ablation stakes measurement, fixed firmly in the ablation zone of glacier by steam ice drill. Net accumulation measurements

was carried out by pit measurement of residual snow in the accumulation zone of the glaciers at the end of ablation season (generally September). Snow densities measured were for water equivalent.

Monitoring of the 150 glaciers of Drass sub basin suggest that 120 glaciers do not show any change in their area, Two glaciers show gain in area, and 28 glaciers indicated loss in glacier area. The snout of majority of large glaciers is facing northeast, northwest and east (67% of 30 glaciers). The long term monitoring of Drass glaciers shows decrease in area from 187.9 km² (1965), to 158.42 km² (2001) and further to 156.65 km² (2013). The glaciers have vacated the maximum area (28.48 km²) between 1965 and 2001 in comparison to 1.77 km² between 2001and 2013. Thus overall glacier area loss in Drass basin glaciers per year is 0.813 km² (1965–2001), and for 11 individual large glaciers in the basin, the loss is between 5,423 m² and 1,473 m². Similarly, snout of the glaciers facing N and NW do not show any change in area between 1969 and 2001. During 2001–2013, glacier vacated some 0.136 km² of area per year and 80% of the glaciers do not show any change in area and are in stable mode.

Temperature and precipitation are the two most parameters to study climate change The all India annual mean temperature has increased by 0.05 °C every ten years during 1901–2003 and the recent three decades. the all India mean annual temperature has increased by 0.22 Celsius every ten years. Over a record period of 28 years, there has been a small increase in annual mean temperature at Drass at –0.426 °C every ten years till the year 1995. However, since 1996 the rate of increase has accelerated to 0.175 °C every ten years. The time series of mean monthly temperature (maximum and minimum) trend line for 28 years indicate lack of fit of lower portion of data (1988–2000) compared to upper portion of data (2001–2013) hence it is attributed to phase transition threshold. It indicates that winter is cooler, late winter warm humid, and summer cool and wet during time series 2001–2013 in comparison to cold winters (November–March), mild late winter (March-May) and warm and dry summer of 1988–2000. Further, the decrease in mean maximum as well mean minimum temperature during 2004-2013 is associated with change with Pacific Oscillation and with increase in El Nino/southern Oscillation events that resulted lower ablation season temperature particularly during summers of 2004-2014 This is further substantiated by decreasing trend in diurnal temperature during 2004–2013. These trends in weather conditions have undoubtedly lead to favourable environment for decelerated retreat of glaciers, to the extent of no change in 80% of glacier area (120 glaciers), during the last ten years (2004–2013). Further, the remaining 30 glaciers including Machoi glacier where subjected to detailed field study (2011–2014), which revealed slow retreat of glacier snout with marginal loss in glacier area.

The permafrost area of the region also shows a loss of 17% in 50 years: from 99.66 km² (1965) to 84.24 km² (2001) and 81.76 km² (2013) as quantified by measuring the magnitude of emission level of greenhouse gases (CO_2 and CH_4) from thawing permafrost areas like ice wedges, pangolins and patterned ground. Further, permafrost degradation at lower altitudes has lowered active layer thickness (1–2 m) which thaw in summer and refreeze in winter leading to warm permafrost conditions since year 2005-06. Fragmentation of permafrost line observed between 3,217 m and 3,334 m stations along aerial distance, along 20 km of

Higher Himalayan flanks and Drass uplands. During winter season the snowfall on the bare slopes is sometimes drifted to interior areas subjected to extreme freezing due to very low temperature (–40˚C) for long duration of the winter. The freezing leads to large pressure and stress conditions on valley walls and solifluxion and navel fluxion in the inter mountain basin floor and valleys .It leads to the process of ground freezing resulting in formation of cracks and hummocks. During summer season thawing produces more water than retained and latter plantation and frequent freezing develops thermo plantain and frost thrusting along valley walls due to differential heaving. Along the valley walls there is mass wasting caused by super-saturated permafrost frozen wall that moves downslope and produces scree cones and rock glaciers, leading to slides. It covers an area of 90.63 km².

Machoi valley glacier is a benchmark glacier in Drass basin, been monitored and studied by many geologists and glaciologist for the past 130 years. A 1875 photograph of the glacier published in book, 'Valley of Kashmir' by Lawrence shows the extension of Machhoi glacier up to rock cliff closely in contact with base of lateral moraine ridge. The glacier was relatively much thicker than at present. In 1895, RD Oldham of the Geological Survey of India visited the glacier and observed its snout location at half a mile from the road head and has evidently extended almost down to where the road now runs and is shown by heaps of morainic material. His observation was also confirmed by La Touche (1910). The geomorphologic evidences (high lateral moraines, terminal moraine and recession moraine, whale backs and roche moutonnees) document that Machoi glacier in the ancient times extended up to the altitude of 3,410 m and joined the main Gumri valley glacier. The scars of Machoi glacier deposits observed on the side of the Gumri River in form of remnant moraines breached at 3,440 m, 3,665 m and 3,760 m with sediment of the kettle moraine (3,580m and 3,750 m). This give an idea about genesis of medium lateral moraines to medial moraine that were reworked by Machoi glacier during its advance to 3,440m to join Gumri.

The research team of the University of Jammu extensively monitored the Machoi glacier from the snout to the altitude of 4,800 m (accumulation zone) by GPS survey and carried continuous field mass balance measurements during 2011 to 2014. The glacier has a positive net balance with cumulative specific balance of 0.16 m w.e. $km^{-1}yr^{-1}$. This has resulted in shifting of the equilibrium line of altitude from 4,540 m in 2011-212 compared to 4,509 m in 2013-14. The glacier snout is seen to advance 4 m in the central part (3,656 m to 3,652 m), but along the sides there has been deformation squeezing and retreat (up to 1.56 m) .The glacier has lost an area of 0.62 km² during the last forty eight years (1965–2013), whereas 9.0418 km^2 during the last thirteen years (2001-2013).

ABSTRACTS OF PLENARY LECTURES

I

Geomorphosites in india: Glimpses of India's Incredible Geodiversity and Geoheritage

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The Indian subcontinent is endowed with rich geological and geomorphological diversity. It includes the Himalaya – the tallest mountains on the Earth, with some of the longest glaciers outside the polar regions, the vast interminable alluvial plains of Ganga-Brahmaputra, the Ganga–Brahmaputra Delta – the world's largest delta, the Western Ghat – one of the most spectacular great escarpments of the world, the Deccan Traps – one of the largest igneous provinces in the world, and the Lonar Crater, one of the youngest and best-preserved impact craters in the world. Much of this landscape diversity is due to India's long geological history, spanning the last ~3.5 billion years in general and the last ~200 Ma in particular.

Many of these places of natural wonders and scenic viewpoints attract millions of tourists each year. Scientifically accurate information about these geomorphological wonders in India, however, is generally unavailable or present in scientific journals and reports. The monograph on "Geomorphosites in India", to be published under the scientific patronage of the Indian Institute of Geomorphologists (IGI), is designed to provide succinct, key geographical and basic geological and geomorphological information in simple words for three dozen of the many often visited natural wonders/scenic spots in India, such as the desert landscapes of Leh and Jaisalmer, the glacial valleys of Chandra and Kedarnath, the Nohkalikai, Jog and Shivasamudram waterfalls, the speleothems of Mawsmai, Kailash and Borra Caves, the badlands of Garhbeta, Bhimunipatnam and Chambal, the Kosi megafan, the Diu and Varkala sea cliffs, the Sundarban mangrove wetlands, sandy beaches of Goa, the landslides in the Darjeeling Himalaya, the domal inselberge of Janapur, the boulder inselberges of Hampi, the mesas and tablelands of Badami and Panchgani, the Great Rann of Kachchh, the Lonar Meteor Crater, the parabolic sand dune of Dechu, the gorges of Ken and Bhedaghat, the towering rock formations of Jamsola, the Pachmadhi landscape in Gondwana rocks, the Bhimbetka rock shelters, etc. Each geomorphosite is covered by a Description Card, giving key facts about the landform/feature supported by a location map/image, colour photographs and a few key references. Information for all the 31 geomorphosites and 5 geomorphoparks is presented in a consistent format, allowing the reader to find and compare information quickly and easily. A brief description of the major geomorphic provinces of India and the geological and tectonic history of India is given in the beginning. Students and teachers of geography, geology, ecology, archeology and environmental sciences as well as geo-tourists interested in natural wonders will find the description cards informative and very easy to understand.

II

Knowledge driven predictive method of landslide susceptibility – a key to prepare medium scale landslide susceptibility map of India

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Landslides are significant hazards that can be disastrous to human life and property. Recent global disaster assessment studies reveal that the countries with the highest risk to such disasters are mostly located in the developing world such as Venezuela, Peru, Tadjikistan, Philippines, Colombia, India, China, Nepal etc., where the estimated landslide fatality rate exceeds one per 100 km^2 per year. According to the total landslide fatalities reported worldwide in the last decade, the developing countries account to about 80%, of which in India, nearly 8% of landslide fatalities are reported. Landslides frequently account for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands in the mountainous terrains of India. In India, excluding the permafrost regions in the north, about 0.42 million km^2 areas of the landmass (12.6%) is landslide-prone which are spread over 1127 Survey of India (SoI) Topographic map sheets (part or full) in 19 States/ Provinces and over 65,000 villages in hilly/ mountainous areas. In this vast terrain, landslides occur frequently in the Himalayas and in some parts of Western Ghats and intermittently to very intermittently in rest of the locations, mostly during the monsoon periods (June-October), causing huge, varied and irreparable damages.

To mitigate the effects of such type of hazards and disasters, the Government of India had already modified the disaster management policy by enacting the National Disaster Management Act in 2005. This act aims at adopting proactive and multidisciplinary approaches towards achieving disaster awareness and mitigation. The new policy emanates from the belief that investments in disaster-preparedness and mitigation are much more cost effective than expenditures on relief and rehabilitation. Therefore, to properly allocate resources, planning and implementing landslide hazard prevention and mitigation, preparation of landslide susceptibility maps and their use in implementing proper land use zoning are essential to prevent and mitigate this ominous hazard. Accordingly, a national scale project has already been launched by the nodal department – Geological Survey of India (GSI) through its National Landslide Susceptibility Mapping (NLSM) programme, which has been a right and effective operational step towards preparation of a GIS-based seamless landslide susceptibility database of India.

Published literatures demonstrate that the empirical analysis for predictive modeling of landslide susceptibility can be achieved by either bivariate or multivariate techniques. Whereas spatial associations of known landslide occurrences with factors of landslide susceptibility and the inter-relationships among the factors are complex and likely non-linear, methods of bivariate analysis typically model those relationships as linear. In contrast, multivariate analysis, especially those with non-linear functions, are more often

employed in predictive modeling of landslide susceptibility for two main reasons. One is that multivariate analysis can model complex associations of spatial variables. The other is that multivariate analysis can simultaneously and automatically select predictors based on the spatial input data. However, some of the predictors selected may not represent genetic processes of landslides being studied because of purely statistical or mathematical assumptions used in such multivariate analysis, which acts like black-box (e.g., independence among predictors with respect to target variables), whereas, the prevalent bivariate methods are more intuitive and interactive, which supports ample opportunities to introduce terrain-specific knowledge on landsliding by the experts.

Unlike multivariate methods, bivariate analysis are less often employed in predictive modeling of landslide susceptibility because i) the function *f* in bivariate analysis mainly describes spatial associations of individual factor with known landslides but not the relative importance of each factor and ii) lack of methodology to select predictors and simultaneously assign predictor weights. This problem was effectively solved in GSI's NLSM Programme by introducing a 2-stage empirical method of landslide susceptibility, developed through an intensive pilot research by the author in Darjeeling Himalayas. This 2-stage method concerns: 1) quantifying spatial associations between individual spatial factors and landslides through bivariate spatial association analysis for terrains having abundant historical landslides (e.g., the Himalayas) to determine ratings and weights of predictors, or determining the same by using the expert-driven opinions in an analytical hierarchy process (AHP) for areas where historical landslides are either absent or insufficient, and, 2) by integrating such rated and weighted geofactor maps using the weighted multi-class index overlay in a GIS to prepare the predictive maps of landslide susceptibility. This 2-stage empirical methodology is successfully being employed in GSI's largest ongoing national level operational programme in landslide studies - NLSM by suitably modeling the terrain-specific ratings and weights of spatial predictors, which yields outputs showing reasonable post-modeling validation (70-75%) in varied terrains.

The earth science community is convinced that India's geological and geomorphological diversity is truly incredible and worth protecting, and we hope that the monograph on 'Geomorphosites in India' will convince all the other stakeholders.

III

Time-Series Analysis of Land Degradation Trends and Drivers: An Experiment with Aeolian Time Series in Thar Desert

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The repetitive observation of earth's surface features by satellite sensors since 1979, and the easy availability of the data in digital form, has helped researchers to better understand the spatio-temporal trends in different land surface parameters and their drivers, both natural and human-induced. Many new and innovative GIS-based statistical modelling methods

have also come up in last two decades to take advantage of the available data. Although the trend results so far are heavily skewed towards understanding of changes in the vegetation cover since the 1980s, the techniques used have potentials for use in many other change detection studies.

In order to understand the regional trends in spatio-temporal variability of aeolian sand reactivation within Thar Desert we first calculated the pixel-level land surface brightness from the surface reflectance data of MODIS Terra (1 km resolution; 8-day summary; March to mid-June; 2000-2011), and filtered out the areas of apparent sand brightness as surrogates for aeolian sand reactivation. Since the results were found to be contaminated by some mixing with other brighter surfaces (e.g., river beds, playas, gypsiferous plains, rocky uplands), a grain-size index was also calculated that highlighted the aeolian fine sand areas vis-a-vis other areas. A product of the two indices provided a robust "aeolian sand reactivation index" (ASRI). The monthly harmonic mean of the ASRI image pixels were then extracted from the 8-day images, which showed very high sand reactivation in the years 2003, 2005 and 2006. The series was then subjected to a linear trend analysis to map the coefficient of determination (r^2) of a least square regression between the pixel values and a statistically determined perfectly linear series over the 12-year period, which suggested persistent rate of change over time in all the four months in few areas only. Mapping of the slope values of the relationship through median trend analysis reveal that very strong negative trend occurs in the north-eastern Thar, especially in March, while a moderate negative trend occurs in all the four months over much of the eastern Thar, possibly due to land stability under irrigation. Contrary to the general notion, however, a strong positive trend over the years is not noticed in the western part but in few small areas across the desert, which rules out climate as a major driver. Almost all such highly reactivated sandy areas within Indian part of the desert have been subjected to deep ploughing by tractor in the last two decades, and irrigated cropping has not yet stabilised the land. A better understanding of the strength of the annual and seasonal trends in degradation was possible when all the 8-day ASRI images for March to mid-July for 12 years were subjected to a harmonic regression analysis using the median trend method, and choosing 2 harmonics, wherein results from harmonic-1 best represented the annual cycle, and harmonic-2 highlighted the semi-annual cycle. The resultant maps of amplitude-1 (annual cycle; G), amplitude-2 (semi-annual cycle; B) and amplitude-0 (intercept, i.e., the mean annual value; R) in a FCC revealed highly interesting spatial pattern of the trends that could be better linked to land use decisions over the years, and their impacts on aeolian processes. Such geo-statistics-based quantitative mapping open up immense possibilities of understanding the nature of change in landscape over time and the responsible drivers, provided we have adequate field knowledge of the landforms and land use in the study area.

IV

Lateritisation, Geomorphology and Land Management: Case of Kerala

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Lateritisation is one of the most typical weathering products in the humid and sub-humid tropics characterised by high ambient temperature, rainfall, and a topography facilitating movement of fresh water, high rate of percolation and transfer of leachate. It is a process of desilicification resulting in progressive change in the proportion of silica and sequioxides of the weathered material. Kerala, a type locality of laterite has around 60% of its geographical area covered under laterite or laterite derived material. In fact, laterite was first reported from Angadipuram in the Malabar part of Kerala. Geomorphic evolution of Kerala, bordering passive continental margin of India's West Coast, is linked with formation of the Western Ghats, recession of the Western Ghat escarpment and successive transgression and regression.

Landform in Kerala is polycyclic in nature. Planation surfaces are noted at various levels and across Geological time scale since Early Cretaceous to Recent. At higher altitude, the most extensive plateaus formed at an altitudinal range of 700–1000 m and at lower altitude laterite plateaus spreading over 40–230 m are prominent. The most extensive phase of Lateritisation was consequent to the development of the pedimented surface, because this provided an ideal topographical condition for protracted deep weathering. Laterite occurs as a cap and spreads over high grade crystalline rocks, low grade sedimentary formations and recent sediments. At least two generations of laterite formation, pre and post Warkalli (Mio-pliocene) periods could be clearly recognised in Kerala. Relict laterites at higher altitudes indicate uplift.

Formation of indurated hard crust-frecrete as cap impacts landscape development. Parallel retreat of the sub-carapace slopes is significant. Field evidences suggest that in the midland areas where landscape is dominated by hard crust laterite formation, slope wash is active in the upper part of the basin and fluvial incision is evident in the lower part of the basin. Flat bottomed valleys with side slopes having more or less equal angle of inclination are topographic peculiarities in these areas. Major landform features associated with laterite in Kerala are lateritic mesa, residual hills above mesa surface stripped of laterites, soup plates, lateritic slopes and flat bottom valleys. Management of laterite landscape is a challenge. Physico-chemical characteristics of laterites differ as a result of fundamental differences in the underlying geology. Although various plantation crops grow in the laterite area, their productivity vary besides, the duricrusts are mostly left as barren waste lands. In places, hard laterites are cut as building blocks.

This paper intends to discuss three issues: first, to explore development of laterite across different geological terranes in Kerala, and control of lateritisation on geomorphological processes; second to investigate morphology of laterite landscape, and thirdly to outline land management practices prevailing in these areas. A prudent management plan of laterite landscape warrants detailed understanding of evolution of laterite landscape and its genesis. This study intends to partly contribute in this direction.

V

The Changing Physical Environment of Cities

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Urbanisation is a global trend which not only modifies the regional environment but also provides the best opportunity for mitigating the effects of climate change. We can observe three basic factors. Cities may start in unexpected places, creating problems as they expand. Urban development increases existing problems and creates new ones. Climate change may make these alterations difficult to predict. This is especially relevant for tropical cities where rural and natural landscapes both are being replaced inside and outside of cities at a fast pace. Cities need to deal with altered hydrological and geomorphological processes such as floods and slope failures. These geomorphic changes should be incorporated into city planning and management. That can be done, but is often difficult to achieve, because of a shortage of geomorphological knowledge, funds, resources, and trained personnel.

Geomorphology and urban management are interrelated. We require (a) acquisition of appropriate environmental data and (b) ability to interface with specialists who plan and manage cities: urban planners, engineers, city managers. The second problem persists even if the capability of data acquisition and transfer exist. We also need to identify the role of climate change in modifying geomorphic processes. It is necessary to determine the possible characteristics of future cities. Should we anticipate the cites of the future as warmer plus wetter or drier places? What would be the special problems of coastal cities? We need to determine the landforms and processes of the future and the scale of change. Already, several cities have been mapped for climate change and such information exists for both the local governments and citizens. A geomorphologist therefore can play an active role here, the expectation of which may increase with time.

VI

East Kolkata Wetlands: To be or not to be

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As far back in 2002, the system of wetlands to the east of Kolkata was included in the Ramsar list of sites for wise use criteria. This event was not celebrated in Kolkata, West Bengal or India. No one realised that this was a milestone reached in conservation activism, or a notable progress in knowledge gathering, particularly when this knowledge has evolved among the local wetland community, without any technical or scientific inputs from outside.

Till today, there is not one display board visible anywhere in the 12,500 hectare protected area, notifying the presence of a Ramsar site. The good numbers of doctoral researches carried out so far – with a few exceptions – have nothing to do with the sustainability of this glorious and graceful landscape at the edge of the city of Kolkata. This is a state of strange indifference by the citizenry and the governance at the same point of time, although the constituencies are independent of each other. This state of statelessness deserves an intellectual enquiry, if at all the wetland is to be protected, and knowledge from here can become useful elsewhere. The present paper is one of the earliest in this direction. An attempt has been made here to find the way forward to end this stalemate.

This ecosystem has a tentative future. It cannot be saved by the local people in spite of their profound knowledge in managing it. The government has no tangible plan in place. NGOs never attempted to place any sensible management plan. Perhaps it is time to think differently.

Looking positively, how about setting up a joint sector project with a green business initiative? These are eminently emerging in today's world. Right now there is at least a $10 million business in place with a prospect of growing larger. The effort will require a set of cooperation which should not be difficult to come by. This is not an impossible idea except that it has to be taken up seriously by those who matter. We should remember that we are saving an ecosystem that sequesters carbon, an ecosystem which has a positive ecological footprint and finally supports a heritage that is unique in the world.

☙ GEOMORPHOLOGY AND NATURAL HAZARDS ❧

001

Composite Vulnerability Assessment using Quantitative Techniques: A Case Study in Muriganga – Saptamukhi Estuarine Interfluve, Sundarban, West Bengal

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The coastal regions, deltas and estuaries are severely affected by the sea level rise, cyclonic activities, and climate changes. Sundarban delta is one of mysterious landscapes in the world, which has successively evolved due to sediment accumulation by the great Ganga and Brahmaputra river systems. The area is characterised by low-lying islands, flat topography, coupled with macrotidal activities, powerful surges and seasonal cyclonic events. All these conditions combine to put together this landscape defenceless to frequent flood and erosion. During the last hundred years the face of Sundarban has been changed remarkably from wild to human occupied territory by protecting this low lying flat plain from tidal inundation through artificial embankment. In this background the current study attempts to highlight the spatial extent and magnitudes of internal risk factors of the region using composite vulnerability index. Coastal vulnerability defines a system's openness to flood and erosion risk due to hydrogeomorphic exposure, socioeconomic susceptibility in conjunction with its capacity or incapacity to be resilient, to cope, to recover or to adapt. Coastal vulnerability assesses the potential risk from erosion and flooding of any low lying coastal region due to its physiographical, hydrological exposures, socio-economic, political susceptibility and resilience capacity. A natural system affects the socio economic scenario of any region. Hence multi-dimensional database can be more effective to understand the extent of exposure, susceptibility and resilience of any system. To through some light on the situation of vulnerability of western estuarine Sundarban, between Muriganga and Saptamukhi interfluves, the composite vulnerability index has been estimated to delineate the magnitude and spatial extent of vulnerability with the help of quantitative techniques and geospatial tools. The study highlights the critical situation of the population under different potential risk classes residing in the study area, with the intention of suggesting some proper course of action of planning and management to conserve coastal communities in their original habitat.

002

Assessment of Vulnerability to Flood for Murshidabad District with Special Reference to Kandi Block: A Reexamination of Approach

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Flood risk has been existed from time immemorial at the interface of the natural and human systems. But the extent of vulnerability has increased manifold in recent years, partially due

to population growth and unplanned construction of transportation network, canals, and aqueducts as well as cross channels etc. Sensitivity to flood hazard is normally expressed as a function of the variability of annual rainfall, discharge and the degree of socioeconomic tolerance. Murshidabad district is flanked by mighty Ganga on the north and checkered by braided Ganga-Padma. Moreover, a number of fast flowing rain-fed rivers of varied sizes and gradients from north-eastern Chhotanagpur plateau has aggravated the vulnerability. In addition to this excess rain, obstacled discharge lines, reduced percolation rate and degradation of local water retention reservoirs (wetlands etc.) are some of the causes that act as enhancing factors of vulnerability. The study is based on secondary sources of data and uses composite indices for calculation of risk. Block-wise (Murshidabad district) and village-wise (Kandi block) spatial pattern of flood risk has been revealed with the help of GIS. This study aims at preparing a flood risk map of Murshidabad district at block level and of Kandi block at village level combining physical, social and economic factors. Murshidabad district experiences recurring flood. Kandi block of hosts the Hijal *beel* (lake) that covers a good part of the block. It is found, in this study, that degree of flood risk is not only determined by the physical exposure to flood but also the degree of socio-economic development of the different villages. The study further shows that the overall vulnerability for the different blocks suggests that vulnerability in terms of flood and socio-economic development is relatively low in Burwan and Naoda blocks, where as the central part of Kandi block, i.e. Hijal *beel* and its surrounding villages and the villages along the river Dwarka have higher flood risk. The area likely to be flooded and the flood-prone population of the block are as high as 75.6% and 92.43% respectively. The average frequency of the occurrence of flood in the block during last decade is six. The approach to probe the vulnerability on the basis of physical exposure to flood is therefore requires to be rethinking. Population density and state of development as well as cropping intensity needed to be combined with physical exposure.

003

Changing Trends of Rainfall, Its Variability and Extreme Events: A Case Study of Jammu, Udhampur and Doda Districts, Jammu and Kashmir

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Climatically, the Himalayas present an extremely wide variation from tropical to the Alpine and even Arctic, as well as a very close juxtaposition of different types of climates. There is a great variation in temperature and precipitation from the foothills to the Alpine peaks and from the western end to the eastern end. In general, the entire western Himalayan region tends to be semi-arid or sub humid.

The present study aims to determine the changing trends of rainfall, its variability and extreme events in the long term annual mean and monthly precipitation series using non-parametric method in Jammu, Udhampur and Doda districts of J&K. The study reveals that in the study area, there is an increased rainfall pattern, which shows significant positive

trends over the whole region. Rainfall during the months of July, August and September shows significant increasing trend while October and November months show decreasing tend. The study shows that 2006 is the wettest year, while 1963 shows a year with the lowest negative rainfall deviation. The high value of the variability coefficient has been observed in Udhampur (34%), Doda (29%) and at Jammu (29%) regions. According to the inter seasonal analysis of 109years data (1901-2010) variation in the coefficient of variability was highest in post monsoon and winter seasons as compared to the summer and monsoon season.

004

Riverbank Erosion and Anomalies in Hazard Classification in India

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Situated on the River Brahmaputra in the Indian state of Assam, Majuli island is the largest river island of India, and is one of the most populated riverine islands in the world. Numerous studies have shown that before 1950, the island had an area of around 1,250 km^2. However, since the 1950 earthquake of Assam, Brahmaputra has been eroding its entire valley in Assam in general, and in Majuli in particular at an astonishing rate. Recent estimates show that more than half of the original area of the island has been lost due to erosion. The socioeconomic impact of such large scale erosion is immense as thousands of families have seen their home and their agricultural land washed away by the river. However, those affected by river bank erosion in Assam do not qualify for direct assistance by the central and state governments, because according to the guidelines of the National Disaster Response Fund (NDRF) and State Disaster Response Fund (SDRF), erosion is not considered as a natural hazard and hence no compensation under its scheme is provided to the victims of erosion. This paper examines the academic rationale for excluding erosion from the list of natural hazards, and provides a compelling case for understanding riverbank erosion not just as a natural phenomena, but also as a natural hazard.

005

An Analysis and Assessment of the Environment and Flood Conditions Experienced in the Lower Subarnarekha River Corridor, Odisha

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The area lying in the immediate vicinity of any stream or river is designated with the term corridor where the interacting river processes are at its maxima. This region exhibits the most dynamic part of the floodplain. Here the flood pulse is at its maximum and generally phenomena such as bank erosion may take place. The lower Subarnarekha river is broadly alluvial in nature as the river leaves its confined channels at the Chhotanagpur plateau and

meanders its way to the Bay of Bengal. The flood situation is a common occurrence in this region as low magnitude low intensity flooding occurs almost yearly. Since the human occupation in the river corridor is moderate to high, it turns even a low intensity flood event into a major disaster. This paper tries to analyse the vulnerability factors and the psychology of the villagers about the floods. Mapping of the river corridor, along with hydromorphological attributes help the analysis. The river dynamics is studied from maps and imageries and these have been supplemented in the field by a perception survey.

006

Role of Geomorphology in Understanding Natural Hazards and their Management with Special Reference to Uttarakhand

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Geomorphology is a significant branch of physical geography which studies the origin and development of different types of landforms on the earth's surface and the processes modifying those landforms. Human beings have over time tried to tame and modify these geomorphic/environmental processes to suit their economic needs. Applied geomorphology is concerned with human beings as geomorphic agents in terms of their planned or inadvertent effects on geomorphic processes and forms. Hazards are often associated with different agents and processes some of those include atmospheric, hydrological, geological, biological and technological. Specifically natural hazards are considered within a geological and hydro-meteorological conception where earthquakes, volcanoes, floods, landslides, storms, droughts, and tsunamis are the main types. These hazards are strongly related to geomorphology since they are important ingredients of the earth's surface dynamics. Geomorphic knowledge helps in identification, prediction and assessment of probable effects and management of natural geomorphic hazards. However, natural hazards cannot be prevented but the understanding of the processes and scientific methodologies to predict patterns of behaviour of such processes can be a powerful tool to help reduce vulnerability. Geomorphological research can provide theoretical and applied approaches to the prevention of natural hazards in terms of origin and dynamism of the physical processes. Furthermore, geomorphologists could also offer important contributions based on the understanding of the interaction between natural hazards (natural vulnerability) and the societies (human vulnerability). Geomorphological works include not only understanding but also the mapping and modelling of earth's surface processes many of which directly affect human societies. This paper is an attempt to recognise the role of geomorphology in the management of hazards at different stages which includes preparedness, mitigation, prevention (pre-disaster stage), relief, recovery, and rehabilitation (post-disaster stage) with special focus on the events of natural hazards in Uttarakhand.

007

Flood Hazard Zonation by Multi Criteria Analysis in the South Kamrup District of Assam

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Multi Criteria Analysis is an important method that can be fruitfully utilised for flood hazard zonation and risk assessment. The South Kamrup district of Assam, comprising of Nagarbera, Chamaria, Goroimari, Chhaygaon, Palasbari, and Boko revenue circles, is prone to flood hazard. The area is drained by the Brahmaputra, Kulsi, Boko, Singua and Singra rivers causing flood in every year. The present study is an attempt to determine the intensity of flood hazard in the study area based on multi-criteria assessment approach with application of remote sensing and GIS techniques. The Multi criteria analysis is done combining nine variables of the study area: rainfall distribution, soil, drainage density, landuse landcover, slope, geology, population density, roads, and embankments. Further, for performing Analytical Hierarchy Principle, a paired comparison matrix is prepared for criteria and individual classes and applied to obtain a unified weight map for all input variables. These weighted maps are once again reclassified to prepare a flood hazard zonation map of the study area.

008

Self Rehabilitation at the face of Natural Hazards and Prospects of Tourism: A Case Study of Pakhiralaya Panchayat, Gosaba Block, West Bengal

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The Indian Sundarban (21°–22°30′N, 88°–88°29′ E), comprising of 19 community development blocks (6 in North 24 Parganas and 13 in South 24 Parganas district) is Physiographically a deltaic plain, having an intricate network of creeks. The area is remote in comparison to Kolkata, the major metropolitan city of the region and houses about 4 million people engaged in monocropping and other minor occupation. Pakhiralaya, of Gosaba community development block works as a transit location for the trips to Sajnekhali, Sudhanyakhali, Dobanki and Netidhopani and has many tourist lodges and resorts. Land prices have seen a hike after the advent of tourism in the area. The rural economy is thus changing owing to the advent of tourism. The construction of resorts has deforested the area leading to loss of various birds which used to stay at Pakhiralaya and thus gave its name. While the young people opine that tourism is good because some are getting jobs based on tourism, the aged opine that cultural and social changes have come up due to tourism and often tourism influences the society badly. The approach road from Gosaba to Pakhiralaya is dilapidated and in all probability this has been a strategy to uphold the operation of boats here. Devoured by the rivers, the earthen embankments of the area have succumbed to the dashing of river water robbing the settlements. Once a forested stretch, some areas of

Pakhiralaya were reclaimed in the year 1969. Repeated embankment breaching has caused the settlement shift to interior locations. Ravaged by the tropical storm Aila, the agriculture of the area has been hit hard and people are burdened with a shift in their occupations. This paper addresses the shift in occupation and livelihood followed by that of settlement after Aila through oral history. Google Earth imagery have been considered for years 2003 and 2016 and it has been found that towards Bali, embankments have breached up to 51.8 meters and 94.4 meters while towards Dayapur this breaching is up to 81.8 meters. The concept of self rehabilitation of the people without the help of the government and NGO s has been brought out in this paper.

009

Drought Conditions and Events in India: A Review from Social Perspective

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Drought is commonly viewed as the result of unavailability of water in an area at a given time, which normally occurs in the drier season. Thus rainfall and drought are the two contrasting aspects of natural environment. Undoubtedly the pattern of association between rainfall and availability of water is markedly complex. Low per-capita availability and storage facility combined with inefficient water usage and over extraction of groundwater cause serious water stress in extensive areas of India. It is taken for granted that rainfall is not evenly distributed across the country and so does the water resource. However, the natural imbalance of water distribution does not always bring about drought. It is often caused due to sudden and excessive thrust of water to areas where the land is readily saturated. According to the existing policy of the state governments higher proportion of water is allowed to raise water-intensive crops like sugar cane and run the thermal power stations depriving the other sectors and thus causing a genuine mismatch in the water distribution services. This paper discusses how regional imbalance, inappropriate cropping pattern, unregulated ground water mining, poor government policy and political apathy jointly worsen condition of the drought prone regions. Regions of Rajasthan, Karnataka, Maharashtra and Orissa are typical examples of drought-related deprivation. Whereas droughts in states like Chhattisgarh, Punjab, Haryana, etc. appears to be the result of improper agriculture practices and poor water management. The analysis has relied on secondary data sources and used information on the severe drought of 2016, particularly the state of Maharastra. The findings reveal that various acts, policies, programmes related to irrigation, water harvesting, crop insurance, food security have not helped the people at all in coping with drought condition. Drought causes remarkable effects on primary, secondary and tertiary levels of economy, political upheavals, social conflicts and out migration. Paucity of proper jobs and severe distress in agriculture compel the people of Rajputs to Brahmin and landlords to farmers of almost every community in this part to raise voice demanding their inclusion in backward class status and reservation in education and employment. As the crisis deepens, it is suggested that in lieu of short-term relief measures, policy should be taken on proper watershed management, water resistant cropping, employment generation scheme, water recycling, regulation on water extraction and weather forecasting.

010

An Assessment of Flood Probability and its Relation with Exposure Indicator of Flood Vulnerability for Spatial Flood Potential Mapping: A Case Study of Jalpaiguri District, West Bengal

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The assessment of flood event in any particular area can be done by the probability analysis of danger level crossed by the concerned river. Danger level is the threshold level of flood event in any particular drainage system. Like assessment of a flood event, analyses of the exposure indicator of a particular area is also important to explain how a given place is physically exposed for flood hazard event. In a region, Exposure Indicator is estimated from percentage of flooded area, flood frequency, floodwater depth, floodwater stagnancy period, elevation of the flooded area and velocity of the adjacent river. Both the probability and the Exposure Indicators can be used to assess the future flood potential of the area concerned. Flood is an annual event in the Jalpaiguri district of West Bengal. Almost every year, all rivers and their adjacent areas in its jurisdiction face flood. The present paper discusses the probability of flood in the rivers in Jalpaiguri and the relationship with the Exposure Indicator of flood vulnerability of different administrative blocks to find out spatial flood potentiality.

011

Using the BANCS Approach for Determining Site-Specific Riverbank Vulnerability and Estimating Bank-Line Shifting for the Silabati River at Garbeta, Paschim Medinipur District, West Bengal

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The Bank Assessment for Non-point Consequences of Sediment (BANCS) methodology provides a field-intensive method which allows a more direct and detailed analysis of the riverbank erosion situation, enabling the factoring in of site-specific parameters like bank composition and the layered nature of sediments which behave differently to the channel shear stress and furthermore, to predict near-future bank erosion rates. This augments refines and extends the usual studies of riverbank erosion which are usually performed by comparison of shifting bank-lines from multi-temporal geospatial datasets and through repeated cross-sectional surveys of the channel at the same location to showcase the changes in bank slope angles induced by erosion and planimetric plotting of previous and present bank positions. The BANCS approach is twin-pronged comprising of the BEHI and NBS sub-units. The BEHI (Bank Erosion Hazard Index) method involves a number of observed, measured and computed parameters, which are then combined to generate the BEHI Value and Status for each location surveyed along a particular bank-line. Variables include the bank profile height and angle segments, the layer-wise bank material composition and texture, the plant root depth and density along the bank and the surface protection available.

Along with the BEHI, the Near Bank Stress (NBS) experienced at these locations has also been computed to show the likely points of vulnerability associated with higher stress sites. Cross-sectional surveys across the channel have also been done to extract hydraulic parameters which have a bearing on bank erosion and historical bankline shifts for the most recent decade have been obtained from very high resolution imagery datasets. The BEHI and NBS values are combined to estimate future erosion rates. A number of locations along the Silabati River stretch at Garbeta in Paschim Medinipur district, West Bengal are surveyed using the above methodology and the relative vulnerability of each of the bank locations have been mapped and documented.

012

Flood Hazards in Rarh Bengal Plain, Eastern India

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Floods, one of the common natural hazards in the humid tropics, have been threatening humanities for long in West Bengal. Intense human activities and changing land-use patterns in recent time have increased human vulnerability to floods in this region. The intensity of flood in southern parts of Ganga river (physiographically known as *Rarh* plains) is more because geomorphic analysis suggests that the rivers of the *Rarh* plains had a very dynamic regime in the past. These rivers flow eastward, roughly parallel to each other, and debouch into the Bhagirathi–Hooghly. These include: the Mayurakshi, the Ajay, the Damodar, the Silabati–Rupanarayan and the Kangsabati–Haldi. Major parts of these rivers have now been constrained by embankments on both sides, and several dams have been constructed along their course. As a result, their floodplains undergoe great changes due to aggrading river bed, confinement of flow due to construction of embankment, inundations and sand incursion because of embankment breaching. Therefore, it is of utmost importance to identify such areas of concern and suggest mitigation measures to reduce the risks and vulnerability. Keeping in view the above, more than 25 years of existing and estimated annual peak discharge data of each river have been used for analysing the trend of flood occurrence. After identifying the best-fit model, the peak gauge height data (h_{max}) are then analysed combining with Geographic Information System for predicting flood affected area and preparing inundation map at a specific return period. In addition, the role of geomorphology is emphasised in flood analysis and management of these cratonic rivers of *Rarh* Bengal plains.

013

Flood Inundation Mapping in Belsiri River Basin using HEC-RAS and HEC-GeoRAS

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Flood is a natural phenomenon which is frequently associated with floodplain environment; it is a high magnitude episodic discharge of river which, in turn, sometime brings about significant changes in the adjacent floodplains. In this paper an attempt is made to map the flood inundation areas in HEC-GeoRAS model integrating the empirical methods of flood

frequency analysis. For the mapping of flood inundation area, the calculated design floods for 5, 10, 20, 50,100 and 200 years return periods using data for the period 1991–2011 are integrated in HEC-GeoRAS and the corresponding inundation areas are estimated, mapped and demarcated. It is estimated in the model that design floods 126, 139, 147, 158, 163, and 168 m^3s^{-1} for 5, 10, 20, 50,100 and 200 years return periods estimated following Log Pearson Type III method correspond to inundation areas of 22.704, 22.946, 23.138, 23.303, 23.394, and 23.442 km^2. Data of Belsiri basin collected from government sources reveal that during 1988–1999, 2000–2001, and 2001–2002, annual flood inundation areas were 7.31, 14.2,7 and 15.91 km^2. These data are similar to flood inundation data estimated using HEC-geoRAS. It is evident in the flood inundation map prepared in HEC-GeoRAS that the extents of flood inundation are increasing.

014

Sequential Change Mapping and Analysis of the Changing Morphology of the Rupnarayan River, West Bengal

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River shapes, course direction and its surrounding landscapes are changed by several hydrodynamics and subsequent morphodynamic processes. Rupnarayan river in West Bengal is the combined flow of the Dwarakeswar and Silai. Huge sediments are carried by these rivers into the Rupnarayan at Purba Medinipur district. On the other hand, it causes severe bank erosion at Tamluk and Mayachar islands of Purba Medinipur. Both of these are of great concern at present. In this work, the entire course of the Rupnarayan from its origin up to its confluence with the Hugli at Geonkhali is taken as the study area. The study is mainly oriented towards the morphometric measurement of the river through temporal changes during 1980, 1991, 2003, and 2014, using Landsat TM satellite data. An attempt has been made here to detect the temporal changes in the bank of the Rupnarayan in Purba Medinipur and Haora districts. Besides this, direction of shifting, changes of river width, erosion and deposition along river bank, formation of sandbars, and sinuosity index measurement, etc. have also been calculated with the help of remote sensing data and GIS techniques.

015

Mandakini Valley Disaster of 2013: Impacts and Changes

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Mandakini valley of the Uttarakhand Himalayas is geologically a sensitive area. Natural phenomena like heavy rainfall, cloudburst, rockfall, mudflow, landslides and avalanches are common here. Catastrophic rainfalls since 2013 have caused spatial geomorphological changes around Mandakini Valley and have taken thousands of lives. Man's sumptuous

living and unplanned growth not only enhanced the disaster but changed the valley's morphology. Unplanned developments and human encroachments in the river basins, rainfed canals and agricultural river terraces have imparted an inverse impact on the flora, fauna and lives of people bringing forth new challenges. The multi-dimensional losses have affected the culture, river ecology and environmental scenario to such an extent that the environment is going to have major shifts.

016

Flood Frequency Analysis of Iril River Basin

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Flood is one of the most frequently occurring natural disasters incorporating hazards and vulnerabilities and claiming lives and properties. It is often caused naturally by long term climatic changes and human induced forces such as changing trend in land use land cover pattern. Since the potential threats of flood cannot be overlooked, prior efforts are being undertaken to control and reduce its negative impacts. An important aspect is estimating the magnitude and probability of occurrence of flood in accordance to a certain time frame with the help of flood frequency analyses. Flood frequency analysis by Log Pearson Type III distribution is adopted in the present study. It is one of the most standard statistical techniques used in determining the return period of the probability of flood of a river. The present study attempts to analyse flood frequency of Iril River which is one of the largest and most important river in Manipur in terms of various socioeconomic and hydrological aspects. Covering an area of 1,317 km^2, and draining the eastern part of Imphal city, the Iril river is prone to frequent floods in its lower reaches which is an important part of the study area. In this paper 14 years (1998–2011) of annual peak discharge series of Iril river has been worked out with the above mentioned technique. The probability distribution function was applied to return periods of 2, 5, 10, 25, 50, 100, and 200 years. It is estimated that the associated discharges are 376.89, 457.42, 500.49, 546.52, 576.02, 602.19, and 625.78 cumecs respectively, most of which is above the normal flow rate. Such prior information should enable the planners and decision makers in implementing new policies and frameworks to lessen the negative impacts of floods.

017

Effect of Tropical Cyclone 'Philin': A Case Study of Ward No 7 of Gopalpur, Odisha

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The very severe cyclonic storm Philin was the second-strongest tropical cyclone ever to make landfall in India after the 1999 Odisha super-cyclone which made its landfall also in the Odisha coast on October 13, 2013. The landfall of this cyclone created havoc in coastal locations of Orissa. Gopalpur, a famous coastal resort of the state, was heavily damaged by

the resulted surge. This paper aims to study the effects of the cyclone in ward no. 7 of the town. About 65 households were surveyed in the study area by questionnaires with both open and close ended questions. It has been found that most of the houses were waterlogged on the day of landfall but then the water level gradually reduced. The day to day activities of the local people were affected mostly due to the flood. Major adverse effects of the storm included property loss, drinking water unavailability, transport and communication disruption, loss of domestic animals, and impaired economic activities.

018

Human Adaptation Technology on River Bank Erosion in the Jia Dhansiri River, Assam: A Case Study of Five Villages

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This study is an attempt to examine the human adaptation technology to river bank erosion in the Jia Dhansiri river at five villages during a period of 15 years between 2000 and 2015. The study adopted the method of superimposition of bank lines of variously dated maps and satellite imageries for examination of the bank erosion hazard. Personal interview method was followed using a questionnaire for examination of human adaption technology on bank erosion. It is found that more than 59% and 79% land area of the villages under study are engulfed by the river during 2000-06 and 2000-15 respectively. Thus, river bank erosion is found to be an extremely dominant fluvial hazard in the Jia Dhansiri river at five villages under study. This study reveals that bank erosion affected families living mostly based on crops grown in own agricultural lands has been decreased from 89% to 45% during 2000-15. Families living through earnings from paid agricultural labour has been increased from 3% to 22% during 2000-15. Percentage of families opting for secondary occupation has been increased from 7% to 32% during 2000-15 after losing their land to bank erosion. It is also found that there were no families dependent on tertiary occupation in the year 2000, which has been increased to 1% in 2015. It is found that people of the five villages under study has responded to bank erosion hazard mostly by changing their occupation.

019

Identification and Classification of Landslides in a Geomorphologically Complex Terrain of Jammu Lesser Himalayas: A Morphometric and Geotectonic Approach

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The Jammu Lesser Himalayan region is mainly drained by the Chenab river, one of the major western Himalayan rivers of Indus flow system, and is most susceptible to the mass movement activities. The primary remote sensing and ancillary data is showing that the study area has unstable slopes in narrow valley region to foothills all along the river basin, but the distribution of the same is not linear. The Chenab river crosses a number of

lithologies which promote or resist slope failures depending on its properties; therefore, the area shows a pattern of landforms. These landforms or the geomorphologic features and their processes help in identifying the potential zones of slope failure. This research is an attempt to study the implication of these morphometric parameters on geological and hydrological parameters to identify the areas with high erosion rate or/and high sediment load up to sub-basin level. The spatially delineated geomorphological units are recognised and the geomorphometric indices are calculated for each catchment or sub-basin of Chenab river basin. The parameters are calculated for the trunk river (7th order) of Chenab basin and two major sub-basins of tributaries Chandra and Bhaga rivers (6th order). The analysis shows that the east-west elongated basin has impermeable surface in northern and eastern parts of the area and lack of discernible trend of erosional characteristics all over the basin. High asymmetry factor (Af >50) and low valley floor to width ratio (Vf <0.01) values of the basin indicates that the basin is tectonically active. This geo-tectonically controlled drainage pattern is also depicted by related morphometric parameters, like high drainage density (Dd) values, anomalous stream length index (SL) values, and low bifurcation ratio (Rb) values. On the basis of geomorphologic data, coupled with geological information and morphometric analysis, the units which are most susceptible to the mass movement activities are identified. The erosion rates (observed and calculated using RUSLE) and the sediment load data at specific locations suggested that the weathering is accentuated in the talus and fluvial glacial deposits at the angle of repose. The sediment load data serves as a marker and point towards the fact that the geomorphic units prone to failure contribute anomalous amount of sediments to the downstream reaches, increasing the likelihood of floods/flash-floods and make dams like Dul-Husti and Baglihar prone to failure posing a threat to the inhabitants and the environmental balance.

020

Channel Shifting and Avulsion of the Ganga River in Haridwar district, Uttarakhand

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Channel shifting and avulsion are inherent characteristics of drainages in the Himalayan foothill region. However, the mode and magnitude of shifting and avulsion depend on a number of geomorphic, hydrologic, and geological factors, including tectonics. The present researcher has investigated the Ganga river flowing through Haridwar, in the Himalayan foothill region. Several evidences, including satellite data (LISS-III and LISS-IV images), topographic data, GPS data, sedimentological data, subsurface structural information and hydrological data have helped in understanding the mechanism of channel shifting and avulsion of the Ganga river. Depending on the previous satellite data and detailed field survey, several complete and partial abandoned channels have been identified by the researcher. Avulsion is the rapid abandonment of a river channel and the formation of a new river channel. Shifting and avulsion of channel is a type of hydrogeomorphic hazard of the study area which is constituted on a vast fan alluvium situated at the base of the Siwalik

Himalaya. The study revealed that the course of the Ganga has shifted towards east and west in the last 34 years. As a result of shifting, settlement and agricultural area situated along the riverbank are being badly damaged. Many village areas have been shifted. Some villages have been abandoned. The fundamental cause of avulsion is the relative loss of carrying capacity of a channel to such as extent that the existing path becomes unfavourable for sustaining the flow, and the channel then finds a new course along a more favourable gradient. The loss of capacity of a channel may take place in different ways.

021

Causes of Saltwater Intrusion and its Effects on Boatkhali Area of Sagar Island, West Bengal

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In recent times increasing salt content in surface and ground water is becoming a serious concern in the coastal area of West Bengal. The Boatkhali area of Sagar island is facing the similar problem of severe coastal erosion and salt water intrusion. The main objective of this paper is to study the causes of salt water intrusion and how it is affecting the life and livelihood of the people of this region. The amount of surface salinity was measured from the soil samples collected from various locations of Boatkhali with salinometer. The sampling positions were carefully located by taking GNSS points. The groundwater salinity was measured by collecting water samples from tube-wells and subsequently the chloride concentration was determined by volumetric titration. A questionnaire survey was also carried out to find out the problems related to saline water intrusion. The salinity is high near the coastal area and less in the interior part. The main causes behind the salt water intrusion is breaching of embankments along with coastal erosion. The salt water intrusion increases the amount of salinity in agricultural field and most of the people of this area are changing livelihood practices from agriculture to fishing. Increasing salinity in drinking water is also becoming hazardous for the people living in this region.

022

From Landscape to Disasterscape: A Study of Disaster Creation in Eastern Uttar Pradesh

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This paper analyses the dynamics of conversion of landscape into disasterscape created by human activities in eastern Uttar Pradesh. In eastern Uttar Pradesh there are great vulnerabilities due to human occupancy of flood-prone areas. Because of human activities (agriculture and grazing) vegetation has been destroyed in riparian zone of rivers. So, bank zone has been eroded and flood inundation occurred in overbank zone; on the other hand, due to overuse of tube-wells in irrigation of crops, groundwater level is falling rapidly. So,

there is a huge problem of drinking water. This condition has been changed into disaster. Because of excess vulnerabilities which are growing day by day, ecosystem is badly affected and it is reflected in human culture and economy. In this paper an attempt has been made to find out an approach to check and control conversion of landscape into disasterscape with the innovative and classic ideas that included qualitative and quantitative parameters.

023

Human Intervention on Fluvial Hazards: A Case Study of the Nagavali River along the Rayagada District, Odisha

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The Hathipahar near Rayagada town, Odisha, is a rocky waterfall and is famous for its scenic beauty. It is located in the upper catchment of the Nagavali river. A canal was digged unscientifically from the river to construct a dam as well as a hydel power project. On 3rd July, 2006, Hathipahar and its surrounding areas experienced a devastating flash flood due to heavy downpour. This flash flood created another opening of the Nagavali river through that canal in soft alluvium, leading to a sudden shifting of its course and huge loss of land of about 0.54 km^2. High resolution satellite data from Google Earth, Bhuvan image and SRTM DEM are used to demarcate the location and to detect the spatio-temporal changes of the river and its surrounding areas. Climatic and hydrological data have been collected from different sources and field survey has been carried out in order to record the present scenario of the area. The length of the Nagavali river in the Hathipahar area is increased from 2.67 km to 2.87 km due to this hazard and the river is shifted 557.17 m westward during 2006–2011. The newly formed course is also possessing seasonally high stream energy and is very active in headward and valley bottom erosion. Bank erosion is still continuing along the Nagavali river during every monsoon season and it is extended up to 9.84 km upstream from the study area.

024

Impact of Anthropogenic Activities on River: A Case Study of Lower Ajay River Basin

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Rivers shape the majority of the surface landforms of the Earth. They also have great importance in developing and sustaining human civilisation. Rivers not only provide water to the human society, but also work as source of irrigation, means of transportation and fertiliser of farmlands. However, unscientific utilisation by the humans affect river health and creates a number of problems affecting their natural settings and increasing the intensity and magnitude of river-related hazards. The Ajay River flows through the states of

Jharkhand and West Bengal and falls into the Bhagirathi near Katwa (88°08'E & 23°39'N) in Burdwan District. The present study focuses on the human induced changes in the Lower Ajay Basin. Landuse land cover changes like coal mining, deforestation, decaying of rivers etc. within the Lower Ajoy Basin initiated the problems of soil erosion and channel siltation. Development of mining, especially, caused degeneration of its tributaries and affected discharge. Due to the rapid rate of siltation, water holding capacity of the river reduced and the intensity and magnitude of flood within the lower reach of the Ajay increases with time. Using digital image processing techniques, images from Landsat series (1970-2016), and declassified photos (1960-1980), available from the United States Geological Survey websites were analysed to identify the nature and extent of land use land cover changes in the area. The non-spatial data, collected from different secondary sources, were also analysed to understand the impact of these changes on the riverine environment. Finally, the work also tried to understand the impacts of various anthropogenic activities on the Ajay to suggest measures for eco-friendly management of its river basin.

025

Natural Disaster & Agriculture

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In every year natural disasters, such as hurricanes, floods, fires, earthquakes and tornadoes destroy agricultural production. Because agriculture relies on weather, climate and water availability to live, it is easily impacted by natural events and disasters. Natural disaster contaminates water bodies, causes loss of harvest or livestock, increase susceptibility to disease and destruction of irrigation systems and other agricultural infrastructure. It affects agricultural production including crops, forest growth and arable lands which require time to mature. FAO reviewed 78 post-disaster need assessments in 48 countries of Africa, Asia, Latin America (2003–2013). According the study, the agriculture sector including crops, livestock, fisheries and forestry absorbs approximately 22% of the economic impact caused by medium and large scale natural hazards in the developing countries. For climate related disasters such as floods, droughts and tropical storms, 25% of all damage and losses is in agricultural sector. To reduce, prevent and mitigate the impact of natural hazards, strong emphasis on sector-specific and sustainable reductions measure, technologies, and management policies are required.

026

Impact of Landslide Produced Sediments on the Morphology of the Lachung River, North Sikkim

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Landslide is a very common hazard in the Lachung river basin located at the extreme northeast corner of Sikkim. Sediments produced through these landslides are carried down the river and thereby changes the morphological characters of the river. The present study is centred mainly on the spatial distribution of landslide, estimation of the sediments produced

by them and their impact on the morphology of the river bed. Location of individual landslides is spotted with the help of GPS. Each landslide has been chosen according to its accessibility, nearest distance from the river and geological formation for their detail study. The amounts of sediments produced by individual landslides have been estimated from the map prepared with the help of GIS. Sediments from riverbed at various sites, close to the toe of the landslides have been tested in laboratory. Cross profiles across the Lachung River have been taken in different reaches in order to understand the nature of changes related to the depth of the river. From the study it is found that in most of the sections in the lower reach of the river is decreased drastically.

027

Prediction of Different Magnitudes of Landslide Zones in the Kurseong Hill Subdivision, West Bengal

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Kurseong hill Subdivision, one of the three subdivisions of the Darjeeling district, West Bengal, is seen to be affected by landslides in the rainy season almost every year which disrupts communication system, destabilise the economic and cultural setup and sometimes claiming life and property bring trail of sorrow and distress in the life of hill people. Earlier the severity of the landslide occurrence was much less. But with rapid agglomeration of population and growth of settlements over the hills in post-independence period, following the establishment of ordered govt., proliferation of profitable hill tourism in the panoramic sites the magnitude and frequency of landslide have increased many folds.

Therefore, the present paper takes an attempt to predict the different magnitudes of landslide zones on the basis of Spatial Terrain Parameter Evaluation (STPE) and Anthropogenic Criteria Identification (ACI) methods in the Kurseong hill subdivision. Selected terrain parameters like Hard rock geology, Elevation, Slope (both degree and length), Aspect with flow vector convergence, Relief, Density and Frequency of drainage, Dissection, Ruggedness, Topographic wetness along with some important anthropogenic criteria like landuse and farming system, removal or change of terrain cover; settlement density, constructions on vulnerable slope and rock strata, improper sewer and outlet system have been taken into consideration for this study.

It has been evident from the study that human interferences have changed the magnitude pattern of landslide zones which are resulted from the terrain parameters in the study region. A considerable portion of lower magnitudes of physically susceptible landslide zones has been predicted as high and very high zones of slope failure due to human activities on slope.

028

Beach Dynamics of Mandarmani Coastal Tract, East Medinipur, West Bengal

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Mandarmani coastal tract, extending from the Jaldah inlet mouth in the west to the mouth of Pichaboni inlet in the east, is one of the longest beaches (about 12 km) of east Medinipur district. Here the beach morphology is influenced by natural processes like wave, tide and wind as well as by human activities. During field survey, it is observed that in the eastern section from Dadanpatrabar to Pichaboni estuary the anthropogenic activities are less prominent than the western segment where most of the hotels and resorts have come up. Consequently, the beach morphology also varies from east to west. In the eastern section lowdunes can be observed, bounded by dune binding vegetation. On the western sector most natural dunes are displaced for hotel construction with boulder walls. As a result beach lowering in this part of the beach is a common phenomenon. The violent waves dissipate their energy directly on the beach protection walls. Some of the hotels are already damaged. The presence of mud balls in the western part is a significant indicator of beach lowering. To understand beach dynamism 23 profiles were surveyed. The beach gradient and width also show variations from east to west. Beach width varies from 100 m or so to more than 200 m. The beach gradient varies from 0.01 to 0.04.Variations in energy condition can also be indirectly inferred from ripple structures.

029

Spatial Distribution of Different Types of Hazards of West Bengal Related to Geomorphology

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A hazard is a set of circumstances which creates a level of threat to life, health, wealth, or environment. Every year India faced different types of hazards, includes Physical, Chemical, Biological, Psychological and Ergonomic hazards. These types of hazardous incident create risks to human life and increase environmental vulnerability of that particular place. In India, West Bengal is only state which comprises ice capped mountains, plateaus and coastal plains. Furthermore this particular state contains a huge number of rural and urban populations. Annually West Bengal faces numerous types of natural and anthropogenic hazards for its physical diversity and human encroachment on nature. The type and nature of hazards varies spatially according to relief and its association with local people.

030

Assessment of Nature and Occurrences of Tropical Cyclones Landfalling in Sundarban during the Last Hundred Years

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The Sundarban receives mostly all tropical cyclones formed in the Bay of Bengal for its coastal location. The climatic data available from Regional Meteorological Centre, Chennai, shows that during the period from 1891 to 2007, the North Indian Ocean experienced 1471 tropical disturbances of which 1148 disturbances were formed in Bay of Bengal accounting 78% of total disturbances of Indian Ocean. 77% Depressions, 83% Cyclonic Storms and 75% of total Super Cyclonic Storms of North Indian Ocean were occurred in Bay of Bengal. Maximum number (>50%) of Severe Cyclonic Storms of North Indian Ocean as well as Bay of Bengal occurs in November and May. That is why these two months are very much prone to formation of Severe Cyclonic Storm (SCS) which can be correlated with river embankment breaching. On the other hand the winter season is fairly free from Severe Cyclonic Storm (SCS) hence, safe for river embankment breaching. The effect of the storm surge is likely to be more devastating in areas which were not earlier vulnerable and found a significant extent of coastal flooding, erosion and saline water intrusion. The overtopping breaching of embankment is striking phenomenon occurred during May, 2009 due to the storm surge of Aila. The Gregorian Lunar Calendar Conversion tables are used to identify the lunar day of occurrences of severe cyclonic storms in lunar month. It is revealed that Aila was too much severe for destruction of embankment and flood because of the fact that it was travelled over the region on 25th May, 2009 i.e 2nd day of lunar month when all the rivers of the region attained its highest tidal level and tidal amplitude and additional wind surge pushed water towards interior portion. The tidal wave surges were also abruptly raised due to huge influx of water through funnel shaped estuary of the river and closer and constricted channels in the interior portion had turned the tidal surges into bores. The total length of river embankment of Indian Sundarban is 3,500 km of which 767 km was entirely washed out by Aila. The huge loss of human lives, livestock, properties and infrastructures were accounted both in India and Bangladesh.

031

Identification of Landslide Susceptibility Zones in Gish River Basin, West Bengal

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Darjeeling Himalaya is one of the several mountainous areas of India which is often affected by landslide hazards. Proper identification of landslide susceptible areas is very much necessary in order to take mitigation measures against landslide hazard. In this paper a multi criteria evaluation is applied using some selected indicators to identify the areas vulnerable for landslide hazards. A series of techniques is used in ArcGIS 9.3 and Erdas 9.2 for preparing the individual data layers as well as composite model. Thirteen parameters are

selected to prepare the landslide susceptible zone for this basin. To find out the weightage value of each indicator Analytic Hierarchy Approach has been taken into consideration. All the layers are again divided into some classes and weightage value of each class is calculated based on Analytic Hierarchy Approach. The obtained results show that near about 7 km^2 (Approximately 4%) area within the basin is highly susceptible for landslides. In this zone, drainage density is high (5 km/km^2), relief is greater than 600 m and slope is greater than 21°. This landslide model is validated by frequency of landslide occurrences already taken place in the study area. The result shows that very high landslide susceptible zone is associated with very high frequency of landslide occurrence. So, the proposed method can be applied for predicting landslide susceptible zones.

032

Study of Seismic Hazards Potential of South 24 Parganas and the Sundarbans of West Bengal

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Earthquakes result from tectonic activities deep inside the earth. The resultant geological features lead to fault-rupture in any direction away from the epicenter and soil stratification. Seismic hazards, outcome of earthquakes, result in slope instability, ground collapse or subsidence, liquefaction of soil base, structural destruction, tsunami etc. in the near-field, as well as, far-fields along the line of faults or the line of propagation of seismic waves. For studying the seismic hazards potential of any region, the study of historical data and geological conditions are of prime importance. The Indian landmass is divided into three tectonic provinces — the Himalayan, Indo-Gangetic and Peninsular India. The varied landmass generates intra-plate quakes. Seismic hazard map of BIS shows the South 24 Parganas district under Zone IV, while city of Kolkata lies in Zone III. The entire Bengal Basin suffers high risk of soil liquefaction owing to ground shaking. Study of the Indo-Gangetic region shows settlement of thick sedimentary alluvial deposits in Bengal Basin mainly in three zones; viz. the Western Shelf, Central Hinge, called Eocene Hinge Zone (EHZ) and Deep basin part in the east and southeast opening into Bay of Bengal. Of these, the most prominent tectonic feature is the NE–SW trending EHZ. The EHZ can become hyperactive and trigger an earthquake of magnitude 6 or more in the Richter scale. The other major fault systems viz. Garhmoyna–Khandaghosh Fault, Pingla Fault, Jangipur–Gaibandha Fault and Debagram–Bogra Fault extend through the margins of Bengal Basin. In the consequence of any seismic impulse, EHZ may channelise the impacts into major quake, that can cascade through these faults. Inversely, these faults may also extend seismic impacts to the EHZ. These apart, the Great Sumatran Fault, that converge the Indo-Australian and Eurasian plates, meet on the ocean floor and accommodate most of the strike-slip motion. The fault terminates in the north, below Banda Aceh, which was devastated during the earthquake of December, 2004. The resultant waves were translated into the southern coastal region of India as Tsunami causing major devastation. The present study analyses the seismic vulnerabilities and concludes that any major quake translated

from the EHZ or Sumatran Fault Zone towards the southern coastal region of Bengal would spell greater devastations, even bigger than 1964 Sagar Island quake to the Sundarbans, South 24 Parganas district and Kolkata.

33

Coastal Geomorphological Vulnerability Assessment and Mapping in the South West Coast of Kanyakumari District, South India, using Remote sensing and GIS technology

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The coastal area of Kanyakumari in southern Tamil Nadu is highly prone to geomorphological vulnerability due to waves, currents, storm surges and anthropogenic activities. The Indian Ocean tsunami on December 26, 2004 had devastating effect along this coastal stretch deforming the coastal landforms and killing many people. Coastal geomorphological vulnerability assessment is an approach to analyse various physical and environmental factors for adaptation of future strategies and to plan appropriate mitigation measures along the coast. Mapping of integrated coastal geomorphic vulnerability has been performed using three conceptual frameworks such as (i) sea level rise vulnerability using CVI model, (ii) environmental vulnerability using EVI model and (iii) habitat vulnerability using HVI model Demarcation of site specific vulnerable zones has been executed utilising integrated functionalities of remote sensing and GIS collating numerous spatial and non-spatial data sources. Certain index based algorithms were applied digesting multiple parameters suitably assigning ranks and weightage to assess degree of potential magnitude to vulnerability using geo-processing tools in ArcGIS 10.2 software. Results of CVI reveals that 52 percentile of area in Kanyakumari sector and 42 percentile of Thengapattinam sector belongs to the very high vulnerability category since the landforms are susceptible to subsidence. Similarly, EVI computations render 13 percentile of area within the extreme vulnerability type prone to damages of coastal environment due to both natural and anthropogenic activities. Wherein, the Manakudi, Thengapattinam, Manavalakurichi and Mandaikadu coastal zones are seriously impaired in terms of environmental quality threatening the sustenance of marine and coastal ecosystems. Besides, the result of HVI model shows that the 09 % percentile of landforms is experiencing very high vulnerability owing to the degradation of coastal habitats. The coastal zones, namely, Thengapattinam, Inayamputhenthurai, Manavalakurichi and Kovalam have been undergoing insurmountable damages to marine and coastal habitats due to flooding and seawater inundation during storm surge, cyclone and other extreme events. The change of morphological configuration in the salt marshes, tidal flats, creeks and estuaries has been on the increase depicting the magnitude of vulnerability to the habitats since the nutrients are being carried away during flooding and surface runoff. Human habitation in the low-lying areas (elevation range less than 10 m) of Inayamputhenthurai, Mandaikadu, Pallam and Puthenthurai are under the threat to get damaged due to erosion and land subsidence. The

study discerns that the coastal vulnerability to the marine and coastal ecosystems is directly proportional to the sensitivity of multiple environmental factors and inversely proportional to degree of resilience to impacts of those factors. The resultant maps and the derived geo-database of coastal vulnerability assessment come handy as primary information source for sustainable coastal vulnerability management.

034

Flood Hydrometeorology of Monsoon Dominated Mahi Basin, Western India

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The analysis of flood-generating meteorological conditions is one of the prime aspects of flood studies in flood geomorphology. Therefore, the rainfall data of Mahi Basin have been obtained for seven rain gauge stations from India Meteorological Department (IMD) from 1901-2011. The peculiarity of spatio-temporal distribution of rainfall and associated floods in the Mahi Basin have been derived on the basis of statistical analyses such as mean, standard deviation, skweness, coffficient of variation and time series plots. The mean annual rainfall of the selected stations in the Mahi Basin ranges from 649 mm at Sagwara to 1013 mm at Banswara. The value of Cv ranges between 0.32 and 0.38 which shows that there is no substantial variability in the distribution of the rainfall in the Mahi Basin. The values of the coefficent of skewness (Cs) of annual rainfall are positive for all the sites, ranging between 0.32 at Sailana and 1.16 at Banswara. The positive Cs values suggest the occurrence of a few very wet years during the gauged period. The time series plots of annual rainfall have been derived for all selected stations, which shows inter annual and intra annual variability in the distribution of rainfall with some high episodic floods. The analysis reveals that the southwest monsoon accounts for 93% to 95% rainfall. July is the rainiest month throughout the basin. The highest 24-hr rainfall of selected stations ranges from 221 mm at Kherwara to 559 mm at Banswara. The return periods of highest 24-hr rainfall have been calculated by applying Weibull Method. It ranges between 110 and 113 years. The highest 24-hr rainfall have resulted events such as 1913, 1927 and 1973 floods in the Mahi Basin which are mostly associated with the Low Pressure Systems (LPS).

035

Assessment of Major Driving Forces in Coastal Erosion and its Impact on Environment in and around Digha Coastal Area, West Bengal

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The meso-tidal Talsari-Digha-Junput (59.81 km) coastal plain (a part of Balasore-Contai coastal plain) to the west of Hooghly estuary with successive rows of dunes with intervening clayey tidal flats, through this linearity, four creeks have found their way into the sea: Jatranala, Digha, Jalda and Pichhabani. During monsoon strong wind action and storm surge change the dune morphology with blowout gaps, slip faces, hanging dune cliff, exposure of

paleo-mud and older coastal plain. Due to strong long shore currents seasonal variation of alongshore and offshore sediment drift determine the erosion and accretion nature of the coast. Present study deals with: (1) Rip currents generation and its impact on coastal morphodyanamics, (2) Impact of Longshore current drift on shoreline erosion, (3) Change of coastal dune morphology to the respect of coastal geomorphology, (4) Magnitude of coastal erosion and accretion. The presence of rip embayments creates vulnerability within the natural beach defence system.

TECTONIC AND STRUCTURAL GEOMORPHOLOGY

036

Identification of Tectonic Activity from Morphological Signatures in Agartala Region, Tripura

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Agartala, the capital of Tripura, is one of the most important cities of northeastern India. From geomorphological point of view, the whole area is characterised by high lands (*tilla*) and low lands (*lunga*), but the main city is situated over rolling plain between the River Haora and its tributary Katakhal. Morphological signatures are very important for identification of tectonic activity. The present work is aimed at identifying the presence of tectonic activity from morphological signatures in and around Agartala city. Landsat images (bands 7, 6 and 5) and secondary databases have been used in this study. On the basis of these evidences and structural characteristics, fault mechanism of Agartala and the nearby Baramura hills has been studied. Based on the feature representation from the satellite images, morphological signatures and their characteristics, presence of some lineaments and sag ponds has been identified. A North–South strike-slip fault movement has been identified in the Baramura hils. From this study it has been found that, the strike slip fault movement results into formation of southwest–northeast trending lineaments in this region.

037

Tectonic Control on the Channel Pattern of the Alaknanda River in Srinagar Valley, Garhwal Himalaya

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River morphology is the field of science dealing with changes of river form and cross-section shape mainly due to sedimentation and erosion processes. This paper describes the results of a continuing investigation of tectonic control on channel pattern and morphology of Alaknanda river in Lesser Garhwal Himalaya. An investigation of the tectonic controls of the channel pattern and meandering of the Alaknanda in Srinagar valley is conducted using

remote sensing data and conventional method. The style of active tectonic on the deformation and characterization of fluvial landscape has been investigated on typical strike-slip transverse faults near the zone of North Almora Thrust. The structural and lithological controls on the Alaknanda river system in Srinagar valley are reflected by distinct drainage patterns, abrupt change in flow direction, incised meandering, offset river channels, straight river courses, palaeochannels, multi levels of terraces, knick points and pools in longitudinal profile. A litho-tectonic map of the Srinagar valley has been prepared by the use of morphotectonic features and field investigation. The results of the study show that the sinuosity index of the river is 1.35 which shows sinuous to meandering trend. All eight sets of meanders are controls by tectonic features. Six levels of terraces at Chauras are the results of tectonics. The meandering course is correlated with tectonic features. Hence it is concluded that the river channel is closely controlled by structural features in the study area.

038

Study on Porosity of Intra-formational Weiloi and Tyrsad Conglomerates of East Khasi Hills, Meghalaya, India

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The study on porosity is to quantify the storage capacity of the rock. Porosity varies in conglomerates and is dependent on the size, shape, and arrangement of the cement and clasts. The study area is in topographic sheet number 78 O/11 and the conglomerates are exposed along Umnongrim-Weiloi-Mawspong-Umlangmar-Kyrphei-Rampana-Tyrsad-Nongmadan- Um Mar-ia and Umkaber-Lyniong profile in East Khasi Hills, Meghalaya and around 100 samples of conglomerate were collected for the study. The conglomerates are composed of large to small, well rounded to rounded clasts at times greater than two centimeters in diameter. The size, roundness and sorting of clasts indicates the fluvial nature and immature river system. The porosity is measured using the standard technique i.e by determining the bulk volume of the porous sample, and then determining the volume of the skeletal material with no pores where pore volume is equal to total volume substrate by its material volume. The highest porosity percentage of conglomerate is 74.4 % found in Rampana site located near Tyrsad and the lowest porosity of 4.2% is located at Maria site also near Tyrsad area, the average porosity is 26.15 %. The study further highlights the significance of such a high porosity or pore spaces in the conglomerates and hence can be the host rock for water and other mineral resources.

039

Dwarakeshwar River of West Bengal and its Underlying Conditions

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A surface runoff is the reflection of exogenetic forces and endogenetic forces as well as tectonic activities. River course is nothing but the spatio-temporal combination of gradient,

underlying geology and climatic input. The surface runoff is the living relict of evolutionary history of its catchment area. The Dwarakeshwar is a sub basin of Ganga river system and it lies in intermittent position of Damodar rift system of Gondwana Group of formations in its northern part and Singhbhum shear zone in the southern part. The metamorphosed form of per-aluminous sedimentary rock of Proterozoic and existence of mafic and ultra mafic composition indicate its palaeo-association. The river emanated from the Purulia-Bankura shear zone and has become a dominant water course during the Silurian. The basic objective of the present study is to get an idea on the geological association of upper catchment of Dwarakeshwar basin with special emphasis on the Purulia–Bankura shear zone which is ductile to brittle in nature. The Horton's concept; 'present is the key of past' has been taken as the basic method of study. This river has gone through a long phase of Pleistocene climate change. The river terrain; relicts of tertiary erosional surface have also been identified. At present, this river is a combination of three scenarios: flash flood in its upper catchment, monsoonal flood in the middle reach and tidal inundation in the lower section. This is mainly a reflection of the underlying structure and landforms.

040

Stream Network and Changing Valley Forms of the Paro Chu Basin, Bhutan Himalaya

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The Paro Chu is a right-bank tributary of the Wong Chu. It has its origin in the southern face of the slope of the Jomolhari, the Himalayan peak. It is a NNW–SSE flowing fifth order perennial channel which drains into the Wong Chu at Chhuzom. The width of the basin varies depending on the nature of underlying rock characteristics. Moreover, one would certainly be struck to observe that the upper course of the channel drains through a flat floodplain at Paro town where the channel is shallow and full of boulders and, in its lower course, the river passes through a narrow and deep gorge right up to the confluence. The objective of this study is to substantiate the impact of litho-characteristics and impact of tectonics on stream network and changing valley-form. This paper is divided into two segments, the earlier being the study of network characteristics; the latter stressing on the changing valley form of the river at the face of tectonic uplift of the Bhutan Himalaya. The geotectonic studies done by earlier workers confirm it. The study of stream network followed Horton's method of stream ordering and the laws of stream number and stream length have been used to determine the relationships between stream order and number of streams and between stream order and order-wise mean stream length. The randomness of network has been checked by binary notation method of Shreve. The valley form has been checked on the basis of valley cross profiles and one longitudinal profile with changing gradient and dynamicity of channel pattern. Finally, it is concludeded that the impact of variable litho-characteristics of the basin is responsible for the discrepancies in the network which signifies the deviation from Horton's laws and the influence of tectonics justifies the changing valley form. The incision of the Paro Chu at the face of uplift of the Bhutan

Himalaya obviously intensifies the process of erosion. As a result, the production of sediment also increases. The extra load of sediments, confronting the stronger flow of the Wong Chu creates a right-bank channel bar at the confluence. The bar grows larger with time.

℘ LANDFORMS AND EARTH SYSTEM PROCESSES ℘

041

Beach Mapping on the Coastal Stretch between Jaldah Estuary and Pichhaboni River Mouth, Kanthi Coastal Plain, West Bengal.

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In order to gain a better understanding of rapid changes in coastal morphometry, various monitoring methods are considered, which is a combination of Total Station Survey, GPS survey, observational survey and photographic documentation. Ultimatelyall the data are brought under the GIS environment. Improved spatial interpolation techniques are now implemented to produce detailed topographic surfaces from Google Earth Map, Total Station Data and GPS data. The present study was carried out on the 17 km coastal stretch of Mandarmani, beach, in Ramnagar II block of PurbaMedinipurdistrict. The present study reveals the identification of varying micro-terrain features of the beach face under different energy settings like – ridge and runnels, rip channels, beach bars, ripples, sand waves and others. The micro features are monitored by quadrate method and physico-chemical parameters of sediments wereanalysed in the laboratory. Volumes of sediments lifted by crabs on the upper beach face were also estimated in the field. Finally a beach map was prepared on the basis of available micro features, beach slope and beach elevation to identify the different energy regimes of the beach environment.

042

Variations in Suspended Sediment Concentration During Spring Tidal Condition at Some Selected Brick Kilns on the Left Bank of River Hugli, South 24 Parganas, West Bengal

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Brick making is an old industry of West Bengal. Among the various areas where this activity is practiced South 24 Parganas is an important one. Brick kilns here are located mostly along the banks of major rivers. In this district 189 brick kilns are found on the bank of Hugli river. From north to south some zones of concentration are identified for the present study viz — Akra, Chittirgunj, Acchipur, Raichak, Diamond Harbour and Kulpi. Ten to fifteen kilns are located in each zone. In these zones different procedures of brick

making are followed. Some kilns use the sediment deposited from suspension within sedimentation tanks, some excavate the sediment deposited on the banks and some buy sediments excavated from riverine bars and agricultural fields. The variation in brick making mechanism is partially dependent on the amount and textural character of suspended sediment available at different areas. Questionnaire survey was done to have a preliminary view about the nature and rate of sedimentation. For determining the spatial pattern and diurnal variation of sedimentation water samples were collected at equal time interval through a tidal cycle at some of the brick kiln locations mentioned above. Tidal monitoring for about ten hours, during spring tidal condition helped to establish the relation between tide and suspended sediment concentration. It is observed that there is fluctuation in the amount of suspended sediment concentration in the above mentioned stations, among them Kulpi has the highest amount and Chittirganj has the lowest suspended sediment concentration. The current induced by tide, passage of ships and position of riverine bar in the vicinity may be some of the causal factors behind such varied sedimentation pattern.

043

Spatio-temporal Variations in Coastal Morphology of Gangasagar and Digha Coasts, West Bengal

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The entire Bengal Basin was formed under the influence of marine environment with the help of tectonic and glacial cycle. West Bengal coast is morphologically classified into eastern and western sections which are parts of the macro tidal mangrove-dominated Ganga-Brahmaputra delta (Sundarban) and the meso tidal chenier Subarnarekha delta (Medinipur) respectively. Total length of the coastal area is 180 km. The study is about spatio-temporal variation between coastal morphology of Gangasagar coast and Digha coast. The main objectives of the study are to identify the dynamic character of the beach by studying beach profiles, to identify the relationship between present conditions of beach by sediment analysis, to identify the probable causes of the erosion. The area conjures up the entire spectrum of interactions between the coastal sediments and the three most important variables that govern coastal morphodynamics sediment input by rivers, sediment reworking by waves and sediment reworking by tides. Among these, the first variable is accretional and the other two, primarily erosional. To understand the coastal change i.e. migration of coastline and dynamic of beach form, comparative cartographic techniques have been used. Here, I have tried to bring out some dynamic characteristics of Gangasagar and Digha beach by surveying and sediment analysis and tried to identify the present status and relationship among sediment characteristics, its movements, changing perspective with elevation, geomorphic units, groups etc. The most deadly natural environmental hazard faced by the inhabitants of Gangasagar coast is the fearsome coastal erosion and most affected by this southern part. Tide is the main cause of erosion of embankments. It is observed that coastal erosion has been increased by specific cyclonic storms in Gangasagar. During such storms the raised high tide line goes right up to the dune cliff and waves broken barriers of eastern

embankments and flooded human habitation and agricultural field. The sandy Digha coast and estuarine banks are mostly erosive and the erosion is enhanced by human activities at present. I measured 13 beach profiles, which is separated by new Digha sector, old Digha sector and Gangadharpur sector. . The causes of erosion of this area are mainly affected by some reasons i.e. depletion of sediments by long shore drift. Fluvial discharge from the eastward opening of Subarnarekha delta-estuary gets recurred northward and hits the eastern section of the Digha coast. This interruption is one of the main causes of beach lowering.

044

Application of Schmidt Hammer Rebound Values for Estimating Rock Resistivity of the Par River, Gujarat

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The morphology of bed-rock channels is largely controlled by the compromise between the applied fluvial forces and resistance offered by the bedrock. The rock resistance to flow dynamics noticeably varies with respect to lithological considerations. In order to study the control of lithology on the channel, 371 Schmidt hammer rebound values (N) for 14 cross-sectional sites were obtained and rock mass strength (RMS) of the Par River have been estimated. Besides, 44 N values of dykes have been obtained to compute RMS and to find out differences in rock erodibility. The N values were converted into standard averages of RMS (N/mm2) by calculating a statistical power-law relationship. Statistical parameters of RMS were derived. For semi-quantitative assessment of rock erodibility between basalt and dyke material, 167 and 22 N values of respective substratum have been analysed and comparison has been shown by using box-whisker plots. The minimum RMS is 42.18 N/mm^2 and maximum RMS is 111.36 N/mm^2. The mean RMS ranges between 63.18 and 91.35 N/mm^2. The CV (15%) proposes that there is less variation in the RMS of rocks of the Par River. In order to find out control of dykes on the river, RMS values of dykes were derived. Minimum RMS of dykes is 66.77 N/mm^2 and maximum RMS is 111.36 N/mm^2. The average RMS of dykes is 92.72 N/mm^2. It is greater than basalt rocks in the river due to hardness of dykes. The value of CV (10.75 %) suggests that there is very less variation in RMS of dykes. The RMS values can be surpassed only during infrequent large magnitude floods. It is assumed that Schmidt hammer numbers are proportional to the tensile strength, higher Schmidt hammer rebound values indicate less erodible bedrock. Therefore, an attempt has been made to find out differences in erodibility semi-quantitatively between basalt and basalt dykes. The analyses suggest that the basalt rock is comparatively weaker than basalt dykes. The analyses reveal that the Par river bed exhibit marked differences in rock erodibility. It is further proved that the presence of dykes do control the bed morphology of the Par river at few locations.

045

Representation of Morphogenetic Regions and the Morphogenetic Processes using GIS with Spatial Reference to Maharashtra State

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Regional study of any geographic or geomorphic phenomena is important for understanding the region, managing its resource and application of the knowledge in regional development. Understanding the physical set up is the basis of such regional assessment. Identification of morphogenetic region(s) is of interest to the geoscientists, geotechnical experts and planners.

The present study is carried out delineate the morphogenetic regions of Maharashtra and to know the characteristics of each morphogenetic region with reference to climatic conditions prevailed over a long time. In order to understand the climatic conditions, climate data of 64 years (1950 to 2013) in grid format has been opted for analysis. The elevation data is extracted on the basis of ASTER-GDEM data of 30 meters spatial resolution. Using both these data sets on a GIS platform the primary morphogenetic regions of Maharashtra State have been identified. These regions are further categorised according to the dominant physical processes operating such as weathering processes and their types, erosion processes and mass movement which operate in those morphogenetic regions. Based on the analysis carried out, four major morphogenetic regions have been identified covering entire Maharashtra as Selva-Maritime, Moderate, Savannah and Semiarid regions.

046

Overwash Impacts on the Intertidal Mud Banks: A Review of the Active Chenier Process on the Shore Face of Subarnarekha Delta

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Overwash begins when the run-up level of waves usually coinciding with an associated storm surge, exceed the local beach or dune crest height. Wave run-up limit is controlled by beach slope, wave energy, elevation of the dune crest, back barrier surface, and surge height of the storm at the crest. Overwash has transported the bulk sediments with sand size grains across the shores dominated by salt marshes, mangrove swamps, tidal mud banks and back waters of Subarnarekha delta. The present paper deals with the impact of overwash deposits over the tidal mud banks and vegetated tidal flats. Understanding of such critical process of sand–mud dynamics is essential for implementation of wetland restoration project and other development project in the coastal zone. Generally, overwash sand deposits have caused a decrease in the total organic matter within the coastal chenier plain dominated by salt marsh

platforms, mangrove terraces and barrier bar sand dunes. Additionally, salinity changes resulted from the events of marine inundation caused significant changes in assemblages of ostracods, diatoms, foraminifers, pollen grains and placer minerals content within the sedimentary depositional surface. Retreat of the mud banks by erosion and reduction of dune elevation and complete erosion associated with surface elevation changes of sand fan lobes modify the coastal wetlands through repeated storm generated overwash process in the coast. The stratigraphic samples from the sub-environments of deltaic domains also indicate occurrences of sand–mud interactions of the sedimentary facies.

047

Assessing the morphological characteristics of gully cross-sections: A case study of Garhbeta Badlands, West Bengal

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Gullying is one of the most widespread erosion processes which reduces land productivity due to high level of soil loss and land dissection. The formation of gullies implies an alteration of overland flow, a shortening of runoff lag time and an increase in runoff volume. Gully initiation is essentially a threshold-dependant process, controlled by several factors like geological, topographical, hydrological and morphological factors. Gully morphology includes the physical properties of a gully such as, gully width, depth, length, cross-section area etc. and facilitates the understanding of the relationship of gullying process, land use change and erosional features. The aim of the present research is to study the morphological characteristics of some selected gully networks and identify the changes morphology from gully head to gully mouth. The study was conducted in the Ganganir Danga of Paschim Medinipur district in West Bengal. For this purpose cross-sectional profile survey was done in three gullies at regular intervals using Total Station and GPS. To describe the morphological characteristics of the gullies a total of twenty six parameters were calculated for each of the fifty gully cross-sections. The morphological parameters were categorised into (i) Dimension parameters (gully width, depth, area) (ii) Asymmetry parameters (left wand right widths, area of left and right sides) (iii) Erosion degree (erosiveness, concavity and shape index) and (iv) Erosional pattern difference (width-depth ratio). The average gully length varied from 330-350 m. The gully width and depth increased respectively from 9-12 m and 2-3 m near gully-head to 30-35 m and 4-6 m near gully-mouth reaching a maximum of 45-50 m and 7-8 m in the middle part of the gully. The width-depth ratio varied greatly within the range of 1.73 and 9.81 with an average value of 5.47. The shape index ranged from 0.07 to 0.64 indicating most of the cross sections are V-shaped. The shape factor varied from 0.49 to 5.14 with an average value of 1.25 indicating that the gullies are mostly in the youthful stage of development. The morphology of the gullies in the study area is controlled by the weathering crusts, soil properties and vegetation cover. The gully shape is not only the result of the hydraulic processes operating within the gully channel but also mass movement on the gully side walls. The comprehensive study of

gully cross sections thus provide useful understanding of the evolution mechanism of gullies and for implementing erosion control measures.

048

Fluvio-Hydrological Study of Murti River with Special Reference to Formation of Hydraulic Drop and Jump

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River Murti (80 km length) originates from Neora Valley National Park and flows through Dooars before meeting river Jaldhakla. The river reaches the plains at Samsing, and flows through the Gorumara forest. The river is famous for several tourist destinations on its both banks. To study the river hydraulics, especially the locations of hydraulic drop and jump, Froude number (Fr) is applied. Approximately 400 meters upstream stretch is selected for the study. This paper mainly deals with the computation of channel gradient, studying the morphological character of the channel bed, locating the sites of hydraulic drop and jump and analysing the mechanism of their formation. To the study of the hydraulics of Murti river a number of field visits were conducted both in the upstream and downstream stretches of Murti. From the study it is revealed that due to high channel bed roughness index and rapid changes in the channel gradient the upstream stretches of river Murti is not suitable for river rafting and river engineering.

049

Downstream Variation in Bed Load Size and Sorting along the Dwarakeswar River, West Bengal

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Grain size is a fundamental attribute of sediment that helps to classify the sedimentary environment and explain the transport dynamics. Textural variation along with sorting process is controlled by various factors such as flow regime, boundary roughness, petrological characteristics of source material, mobility condition and rate of weathering of deposited materials on terrace and bar. The objectives of this work are — (i) to understand the distributional pattern of grain size along the upper and middle reaches of Dwarakeswar river, (ii) to derive the factors controlling the sedimentary environment of upper and middle reach of Dwarakeswar river. The work was carried out using SRTM data of 30meter resolution and the data obtained was ground checked for validation. Sediment samples were collected from within-channel bar sequences and further supplemented by Total Station survey and GPS mapping. Results indicate that both natural and anthropogenic factors (e.g. sand quarry) are significant in this river system, and are responsible for asymmetric distribution of sediment grain size mainly in the order of coarse gravel to medium sand.

Grain size distribution in the Dwarakeswar river system is also controlled by coefficient of abrasion, stream velocity, particle diameter and shape of source material. Analysis of longitudinal-profile of the main channel reveals that resistivity of the bedrock to weathering, and their mineralogical composition determined the channel morphological character as well as the sediment character. The long profile of Dwarakeswar river is best fitted to the fourth-order polynomial curve (R^2 = 0.979), which indicates that the downstream variation of slope is irregular. Such irregularity is also reflected in the sediment grain size distribution.

050

Hypersalinity as a Factor for Mangrove Degradation in the Delta Plain of Sunderban: A Case Study in a Part of Southwestern Sundarban, West Bengal

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In hot and humid climate of the coastal Sundarban a negligible input of fresh water (except the areas of Hugli River mouth, and Ichhamati–Raimangal downstream) may be offset by high evaporation at the surface. For which a large number of strong hypersaline patches are visible to develop within the basinal surface of different islands after the events of tropical cyclone and tidal waves, particularly in the abandoned portions of Sundarban delta. The dense hypersaline surface water then sinks and moves out of the tidal estuaries as a subterranean flow or a bottom current to make them more saline in conditions. The inundation patterns, tidal drainage loss, topography and rate of evaporation as well as the below-ground piping are major processes for extension of such hypersaline patches over the mature tidal flat surface of the Sundarban. The present paper attempts to highlight: (i) The types and categories of hypersaline patches, (ii) Nature of vegetation changes within the surface, (iii) Physico-chemical properties of the soil, and (iv) Stratigraphy of the hypersaline patches. Monitoring of soil and water quality, total station survey repeated field checking and application of Remote Sensing techniques for temporal assessment of the hypersaline patches with GIS mapping techniques are employed in the present study for analysis of growth and extension of hypersaline patches. The study reveals that their growth and extension have degraded a large portion of mangrove forest in the Sundarban, and that the fate of coastal wetlands will be affected by rapid rate of extension of such hypersaline banks in the near future with global environmental changes and abandonment of the parts of delta. The Forest Department has attempted to restore such degraded wetlands, but understanding of mechanisms for growth and extension of hypersaline patches is essential for proper implementation of wetland restoration process.

051

Identification of Processes Leading to Beach Dune Formation between Akshi and Revdanda Beach of Konkan Coast, Maharashtra

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The grain-size analysis of the sediment samples provides the size frequency spectrum in terms of weight or volume present in a specific size interval. Plotting of a textural analysis on probability paper helps to understand the central tendencies and distribution parameters of samples plotted. It is otherwise not very easy to obtain the various parameters like mean, median, standard deviation, skewness and kurtosis. The nature of Beach and dune samples can be easily ascertained from their probability plots. Each plot should be studied separately after identifying different process segments visible on probability curve. Identification of such segments always helps in improving the quality of interpretation of the processes dominant at the place from where the samples have been collected. Three common process segments were identified on probability plots. Two of these are tails and the other is the middle portion of the curve. These segments are designated as 'coarse tail', 'central segment', and 'fine tail'. No matter where the samples are taken from around the beach or back-beach, important hydrodynamic processes can be conveniently identified. The cumulative sand grain weight against size of the fine tail on the probability plot corresponds to the sediment load of suspension movement. The coarser tail is considered as representative of the surface creep and the central segment that of saltation. Sediment samples were collected from the back beach area on the coastal sector from Akshi to Revadanda on Konkan coast of Maharashtra. The results of textural analysis were plotted on probability papers. The process segments were identified and used to interpret the dominant processes leading to the formation of Berm, Dunes and back dunes in the study area.

052

Retreat of Gangotri Glaciar and its Geomorphic Expression

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The present paper concerns a study on the retreat of Gangotri glacier and its geomorphic expression. In the past few decades, global climate change has had a significant impact on the high mountain environment. Glaciers and permafrost area are especially sensitive to changes in atmospheric conditions because of their susceptibility to melting. Gangotri glacier is a well-known glacier in Garhwal Himalaya, situated in Uttarkashi district of Uttarakhand. Global warming is a major environmental issue, which is mainly responsible for glacial melting all over the world and it has a great impact on the Gangotri region and its surrounding environment.

The rate of retreat of the glacier was monitored with the help of GPS and LISS III Image of 1997 and 2005. The SoI topographical sheet (1962) is used as baseline data. The glacier boundary was digitised from satellite imageries and topographical sheets of 1962, 1976,

1997, and 2005 using Erdas Imagine 8.4 and the temporal change in the glacier boundary has been estimated by superimposing the vectors in the GIS environment. The glacial area was also calculated from these vectors. Between 1842 and 1935 the snout of the Gangotri glacier was receding at an average rate of 7.3 m yr.$^{-1}$. According to the study of Geological Survey of India, between 1935 and 1996 the glacier retreated by 1,147 m, which amounts to an average rate of 19 m yr.$^{-1}$. But a dramatic increase in the rate seems to have occurred in the last three decades. Trend analysis shows that the length of the glacier has reduced by about 1.42 km in 43 years, from 1962–2005. The immediate task should be to prevent any type of human activity in this area to preserve glacier and maintain its aesthetic beauty.

053

Granulometric Studies of Sediments of the Gumti River, Tripura

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Gumti is the largest river of Tripura the lower reach of which is facing the problem of sedimentation for prolonged period. In the present study granulometric analysis of bed sediment samples has been done to understand textural characteristics and depositional environment of the Gumti river sediments. For this purpose 120 km stretch of the Gumti has been selected from upstream towards downstream and 20 bed sediment samples from different locations have been collected. The location of each sample collection site has been marked by GPS. Each collected samples has been processed using standard sieving method and the result has been processed in Gradistat software to calculate different statistical parameters. It has been found that mean size of sediments ranges between medium to fine sand among which around 65% of the sediment samples fall under fine sand category. It has also been observed that mean size of sediments is highly influenced by regulation of water through the Maharani barrage, as downstream from the barrage, all the sediment samples are fine sand in nature. Most sediment samples are well sorted, which indicates less fluctuation in river energy during the deposition of sediments. Most of the samples are positively skewed with value of kurtosis varying from very leptokurtic to platykurtic. CM pattern of the sediment samples suggest that the sediments of the Gumti river are deposited by bottom suspension and rolling process which generally indicate low energy condition of river.

054

Analysing the Causes Responsible for Frequent Channel Avulsion in JiyaDhol River of Upper Brahmaputra Valley, Arunachal Pradesh and Assam

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Most of the north bank tributaries of the Brahmaputra river frequently change their course. Jiya Dhol river is a small yet very dynamic north bank tributary of the Brahmaputra, flowing east of the Subansiri river. The upper catchment of this river is within West Siang district of Arunachal Pradesh and then the river flows through Dhemaji and Lakhimpur district of

Assam. This paper aims to analyse the causes responsible for frequent channel avulsion in the JiyaDholriver. The pattern of channel avulsion in this river was monitored between 1963 and 2014 through time series satellite imageries. The change in river cross section was measured with the help of field survey during the winter of 2013 and 2015. To understand the causes responsible for changing the river course, an estimate of sediment load in the river is prepared and change in land use land cover in the upper catchment of the basin is also checked. The role of major structural disturbance in causing channel avulsion was also verified by locating major landslides in the upper catchment of the river. Significant avulsions can be observed in the JiyaDhol between 1963 and 2014. Prior to 1973, the river had a tendency to shift from west to east but between 1973 but 1993 it shifted from east to west and after 1993 it again adopted it tendency to shift from west to east. The frequent channel avulsion of the JiyaDhol River is occurring due to the fast rate of river bed siltation. During the period 2007 to 2014, 2.32 m thick layer of silt was deposited under the JiyaDhol RCC Bridge. The sediment load of the river shows an increasing trend. Little change in the land use and land cover has occurred in the upper catchment of the river from 1993 to 2013and forests still dominates the land cover of the catchment. A large volume of sediment added to the river is contributed by the landslides triggered by earth movements along major fault lines.

055

Analysis of Channel Cross Sections with Respect to Optimum Channel Cross Section in Middle Ichhamati Basin, West Bengal

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Channel cross section may be defined as the change of depth of channel with respect to the horizontal distance. The changing form of channel cross section is a wellknown parameter of a river's health. In this paper, an attempt has been made to find out the geomorphic condition of the Ichamati river with regard to the character of channel crosssection, such as, symmetry assessment, channel bed configuration, bank profile and width-depth ratio. The paper also estimated the optimum channel cross section based on channel width and depth, and have attempted to compare the crosssections with the proposed Optimum Cross Section Index(OCI). The proposed OCI represents the ratio of optimum channel cross sectional area andpresent channel cross sectional area. When the OCI equals to 1, the cross section is said to be optimum. In this study the values of OCI decreases with increasing distance from upstream.The OCI values in Kalanchi (2.1), Sarfarajpur (1.7), Bibipur (1.5) and Harispur (1.3) indicate thatthe cross-sectional areas in the upstream zone are not able to maintain their optimum area in respect of their widths. These characters basically reveal that the present river is decaying from upstream downward.

056

Analysis of Micro-fluvial Features: A Case Study of the Silai River Near Gangani Badlands at Garhbeta Block, West Medinipur District, West Bengal

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The study area encompasses the Silai river and its flood plains which overlooks Gangani badland and characteristically exhibits different patterns of sedimentation as well as stream behaviour. This part of the Silai is singular with respect to the sources of sediment supply and sediment budget indicates that the normal river-born sediments are accompanied by a lateral supply of duricrust sediments from the right bank of the channel. Accordingly this part of the Silai river also reflects a temporal variation in sediment supply and in turn a shifting and changing course of the channel. Here the ground truth verification is compared and authenticated through satellite imageries and other spatial data. The impact of badland on Silai river is also examined through some hypothesis testing by appropriate test statistics. This paper is an attempt to critically examine and analyse the micro-fluvial features of Silai near Gangani Badland i.e., the confluence of the rills and gullies with the Silai river. The study area is unique in the development of number micro-fluvial features. Another interesting point of observation is that the morphological characteristics of the Silai river in the selected bends display different types of bars and, unlike typical meander bend, the selected Silai meander bends are unique in the deposition of sediments and formation of bars in close proximity to the concave bank. In addition, even the river bed configuration has been subjected to changes when the coarser weathered, disintegrated, and loose fragments of duricrust are accumulated within the river bed. That the process of duricrust is still continuing is well documented by the formation of sand bars underlain by the coarser fragmented debris of duricrust. Detailed field observation are made with the help of Total Station, GPS, Abney Level, Clinometer and Prismatic Compass in order to generate some primary data as well as some ground truth verification with respect to already existing and available secondary data and information (topographical map, geological map, Google Earth image, satellite images, and preparation of thematic maps using RS and GIS software). Some statistical inferences are drawn to examine the nature and evolution of micro-fluvial features. Finally, hazard zonation mapping is done to account for the spatial variation of geomorphological problems in the study area.

057

Role of Geo-Hydrological Components in Classification of River Bed Boulders: A Case of River Chel, West Bengal

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The present research is focused on boulder size and shape classification on the basis of longest diameter and Cailleux Index value in a fluvial environment. The objectives of the

study are to analysis of size and shape of boulders, to determine the hydrological component of their transportation and the inter relationship between the two for defining the boulder classification. In this research work, various key factors like the longest and smallest diameter of boulders, length of the longest axis, the radius of curvature of the sharpest angle, river bed slope and roughness of the river bed have been included. Many of the recent scholars have concentrated their study on river bed boulders on the basis of engineering hydrology and according to Wentworth's grain size scale; there is no proper classification of boulders. The hydraulic parameters like, mean velocity, mean width, wetted perimeter, hydraulic radius, cross sectional area, discharge, stream power and slope, are the dominating factors for uneven size and shape of boulders in different parts of Chel river basin. The cross sectional data was obtained through field survey in 2015. The results ensure a new perspective of boulder classifications as well as the hydrological and morphological interrelationship.

058

Dynamic Lateral Migration, Aggradation and Incision of the Ganga River at the Mountain Exit point: A Geomorphological and Chronological Investigation

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The Ganga river debouches into the wide alluvial plains at the mountain exit near Haridwar, where it forms exceptionally wide spindle shaped valley. This valley is constricted at Haridwar and in the downstream of Hazipur. The valley is widest (~30 km) in the middle segment of the study area. The proximal part of the western margin is eroded by a number of tributaries originating from the Siwaliks and the adjoining plains. The geomorphological, sedimentological and geochronological investigations are carried out to understand the morphological evolution of the area. The sedimentology of the outcrops on both the margins suggest that the sediments are deposited by the Ganga as indicated by the direction of the cross beds which is parallel to sub-parallel to the flow of the river and nearly perpendicular to the flow of its tributaries. The results also suggest that the river has aggraded in response to the strengthening of the monsoon. The Ganga shows aggradation between 31 to 26 ka in the proximal partafter which the river incised at the proximal part and the depocentre migrated downstream, where aggradation occurred till ~ 17 ka. Thus, the river incised in the distal part at ~ 17 ka and at ~ 7 ka along its entire length in the study area. We observed that the incision occurred towards the end of LGM; probably because of increased river discharge at the onset of wetter period. It has also been estimated that the total volume and mass of sediment removed from the Ganga valley (in the study area) is of the order of 28.8 km^3.The study reveals that the whole sequence of events i.e. aggradation and incision took place during the Late Pleistocene to Holocene. The Ganga flaunted between the eastern and western margin due to the tectonic and climatic perturbations and occupied its present position at around 14 ka.

059

Evolution of the Paltar Bil and Associated Problems, Nadia District, West Bengal

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Dynamicity of channel is a natural phenomenon. Channel oscillation, a common characteristic on the alluvial tract of the river, is influenced by the variability of water discharge, alluvial stratigraphy, river load, channel gradient, human intervention and tectonic control. The western part of Ganga Brahmaputra Delta (GBD) has experienced frequent channel avulsion. The history of *bil* formation in this area is directly related to migration of the Bhagirathi-Hugli river. Here we have concentrated on the study of the evolution of Paltar *bil* which was actually an old course of Bhagirathi-Hugli (*Mara Ganga)*. Major objective of the study is to throw light on the evolution of the *bil* and to discuss about its present decaying condition and associated problems. The whole work is based on a number of research articles, multi-dated maps, images and field survey. Both natural and human interference are responsible for the changing pattern of *Mara Ganga*. At present the course of *Mara Ganga* is transformed into a chain of elongated water bodies and agricultural fields. Segmentation, stagnation, unauthorised land capturing, encroachment, eutrophication and filling up of the channel bed are some common problems which directly invite flood hazard. During monsoon period water inundation is a common problem to the adjacent mouza which partially paralyse the economy during flood inundation. After realising the importance of the Paltar *bil* local people have taken initiative and finally *Mara Ganga* reclamation project been started under 'Jal Dharo Jal Bharo' programme of the West Bengal Govenment.

060

Regional Evaluation and Mapping Planation Surfaces of Peninsular India by Surface Index

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The polycyclic landscape of Peninsular India as inferred from planation surfaces at various elevation levels is widely investigated. The derivation of the planation surfaces, presenting multistoried bench-land scenery – is ascribed to factors ranging from diagenetic–tectonic movements, variations in base level due to sea-level changes, long term variation in monsoonal precipitation pattern etc. These studies mostly dealt on understanding and mapping the planation surfaces at micro scale rather than understanding the macro scale evaluation covering Peninsular India. These planation surfaces were mostly recognised on the basis of field investigation and interpretation of topographic maps, which probably could have affected areal extent of these studies. Gunnel (1998) had comprehensively interpreted the planation surfaces for south Indian shield leaving Deccan basalt and adjacent ranges of Vindhyans and Eastern ghats. The planation surfaces or palaeosurfaces can be seen as erosional anomaly. Andreani *el al.* has proposed an algorithm for mapping these anomalies

by combining hypsometric integral and surface roughness to compute surface Index (SI). In order to investigate erosional discontinuity vis-à-vis planation levels, surface index (SI) was calculated as per the algorithm for peninsular India. Resampled SRTM DEM was used to compute SI. Due to coarser resolution of DEM input, the surface index was calculated by moving window of 25×25 pixels instead of 101×101 pixels. The range of SI for peninsula was found to be –0.86 to 0.86. The regions with positive SI values represent erosional discontinuity or local uplift while negative values indicate subsidence or prolonged denudation. The SI values of the planation surfaces S0 to S3 as referred by Gunnel for south Indian peninsular shield around Palani, Annamalaia and Nilgiri Hills were in the range of 0.3 – 0.6, while the reported planation surfaces of western Maharashtra around Kas, Khanapur, Bhimashankar and Parner were also associated with same range. Planation surfaces along Vindhya, Satpuda, Ajanta and Balaghat ranges were then demarcated on the same criteria.

061

Coarse-Grained Depositional Processes and Sediment Supply in Resistant-Boundary Channels of the Par River

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Coarse-grained deposits produced by high magnitude rare floods such as 1968, 1976 and 2004 floods in the Par river in eastern India illustrate depositional patterns, processes, and mechanics along resistant-boundary channels. Depositional features have been measured and mapped from source to mouth. Abrupt expansions immediately downstream of constricted reaches have been calculated by Er/Cr ratio of channel which ranges from 1.56 to 6.59. It leads to rapid reduction in flood energy and competence which in turn results in extensive depositions in the form of expanding bars. The length to width ratio of longitudinal bars of the Par river ranges between four and ten. Flood flows were likely to be considerably slower along the channel margins as compared to main concentration of flow and possibly recirculating. Point bars have been formed by accumulation of deposited material along the inner margins of channel bends. An attempt has been made to find out hydraulic parameters such as shear stress, stream power and mean velocity of high-magnitude rare floods in the constricted reaches upstream of depositional features of the Par River. Using the empirical relationships developed by Williams (1983), the threshold values of bed shear stress, unit stream power, and mean velocity necessary to transport the boulders were calculated. These values reveal unusually high ability of the river to erode and transport sediments and make it available in downstream reaches for deposition. For instance, estimated values of flood hydraulics with respect to theoretical values of the giant boulders with 6200 mm and 3350 mm i-axes show that these boulders were eroded, transported and deposited downstream of Mendhagorge. The results of the analysis indicate that only high-magnitude rare floods on the Par river could erode, transport, and deposit huge quantities of boulders and cobbles as depositional macro-forms. It is concluded that

erosional process takes place in the constricted reaches of resistant-boundary channels of the Par river and coarse-grained sediments are deposited immediately downstream these reaches.

062

Classification of River Systems of Purna Alluvial Plain in Western Vidarbha, Maharashtra

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Drainage basin is a primary natural unit to study in geomorphology, which is created under fluvial processes. Every drainage basin has its own characteristics due to variation in the geomorphological and hydro-climatological conditions. Present work attempts to classify the river systems draining the southern slopes of Satpura mountain range, on the basis of variation in their catchment characteristics. The river systems may be classified as — i) mountain-fed, ii) foothill-fed and, iii) plain-fed rivers. The mountain-fed rivers are characterised by high discharge, and large basin area above the mountain front. Whereas, the foothill-fed and plain-fed rivers have moderate to low discharge though these rivers have large basin area below mountain front. This variation can be attributed to differences in lithology on which these rivers are draining.

063

Granulometry of the Holocene Sediments in the Eastern Subarnarekha Coastal Region

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Soft sediment granulometry study was carried out along shore-normal transects in the eastern Subarnarekha coastal region extending between the Subarnarekha and the Rasulpur river mouths covering parts of East Midnapore district of West Bengal and Baleshwar district of Odisha. Frequency distribution of grain size plot shows that most of the upper samples are bimodal. The samples apparently show random variation in mean, sorting, skewness and kurtosis with increasing distance from the coast. However, the mean and sorting of samples, averaged over distinct shore-parallel ridges (cheniers), show significant correlation with distance from the coast. Landward mean grain size increases along with gradually poorer sorting. Within each profile section mean grain size shows a fining up sequence. CM plots (Passega, 1964) for all samples suggest graded suspension as primary mode of deposition. This fining up and coarsening landward grain size distribution suggests a transgressive depositional milieu in this studied part of Subarnarekha Coast.

064

At-a-Station Hydraulic Geometry of the Mahi River: Western India

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Hydraulic geometry is of fundamental importance in flood hydrology and geomorphology. It refers to the rate of change of hydraulic variables, viz. width, mean depth, and mean velocity with increasing discharge. An attempt has been made to find out at-a-station hydraulic geometry of the Mahi river of western India. Data regarding hydraulic variables associated with annual peak discharges are available for two sites on the river, viz. Padardibadi in the middle reaches and Khanpur in the lower reaches. These data have been used to derive the at-a-station hydraulic geometry equations. The b/f ratio, m/f ratio and total variance have been computed. The hydraulic geometry exponents (b, f, and m) were plotted on Rhodes' ternary diagram. The results of the analysis clearly show that the rate of change in mean velocity (m) is greater with discharge for the Padardibadi site whereas rate of change in mean depth (f) is higher with discharge for the Khanpur site. However, the rate of change in width (b) with discharge is much slower for both the sites which are attributed to box-shaped nature of channels. The b/f ratios indicate that the rate of change in width is always lower than the rate of change in mean depth which has important implications for efficiency of the channel since the flood power is directly related to the flow depth. The total variance values are not closer to the theoretical value (0.33). The variance is relatively higher for both the sites. This suggests that the effects of changes in discharge are not absorbed equally by all the three variables, but by one or two hydraulic geometry variables, in this case by depth and velocity. This fact therefore, suggests that the alluvial river channel of the Mahi river is not a true alluvial channel, which is self-formed through the independent adjustment of the morphological variables. The higher values of m/f ratio suggest that the rate of increase of velocity with discharge is close to the rate of increase of depth with discharge. This fact implies that high flows are associated with an increase in the transportation capacity of the channels. The ternary diagram indicates that one site falls in sector 2 and other in sector 6. Such channel types are characterised by decrease in width-depth ratio, higher sediment transport capacity, an increase in Froude number, and decrease in velocity area ratio.

065

Changes in Channel Geometry and its Relation with Channel Hydraulics: A study in Indian Sundarbans

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The present study attempts to assess the efficiency of natural channels in relation to its geometric properties. The selected channel in the Sundarbans is guarded by embankments

which has reduced the channel area and restricted the path for water to move. Water accumulates in the main river as it is disconnected from the distributaries due to embankment construction. This increases the rate of vertical expansion during rising tide. Channel separation and compartmentalisation was studied through time series analysis of the channel network from pre-reclaimed stage to 2015 using the Google earth image and topographical maps. Geometric modification of the channel during various phases of reclamation was studied through the cross sectional analysis and its influence on channel hydraulics was determined through the stage-discharge relation.

The result shows that after reclamation, a well-connected dense network of channels had been transformed into a sparse and isolated network in contrast to the channel networks in non-reclaimed adjoining areas. Geometrically the 'V' shaped channel was transform into a rectangular one by construction of embankment along both the sides. With increasing volume of water during rising tide, the depth of water increases but the width remains more or less constant.

066

Impact of Reclamation on Estuarine Processes in Indian Sundarbans

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Hourly day-time tidal data were collected for eighteen months from two temporary gauge stations at Bhanderkhali and Sandeshkhali, located at Hingalganj and Sandeshkhali Blocks of North 24 Parganas districts, respectively. It was observed that tidal range increased towards inland and tide takes 5 hours 30 minutes to attenuate and 7 hours 10 minute to fall indicating an asymmetrical tidal curve leading to flood domination. An ebb dominated system is transformed to flood dominated one in the process of reclamation through exclusion of inter-tidal area. Higher velocity during this short period of attenuation indicates energy concentration for potential erosion and transportation of huge sediment landward. Weaker ebb tide, being incapacitated, leads to deposition of sediment inside the channel leading to drainage decay. Local people took the advantage of such sedimentation for occupying the channel bed by constructing series of long and cross embankments. Estimate shows that drainage lines of more than 2,500 km have been completely disconnected from the drainage system causing a loss of 235.6 million m^3 of water holding capacity considering a constant depth of 1.69 m. This, in turn, contribute to an additional volume of water along the main stream leading to potential overtopping and embankment breaching.

067

Assessment of the Geomorphic Response to Recorded Catastrophic Floods: Case Study of Damodar River, India since Twentieth Century

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Considerable geomorphic research over the past several decades has addressed the role of rare, large-magnitude floods as geomorphic agents and the attention increases towards the impacts, relationships, and importance of both large and small floods. The catastrophic channel response to large floods (with a recurrence interval of over 50 yr) probably occurs when peak velocities and depths exceed the threshold values needed for the development of macroturbulence. Lessons from the above, attempts are also made to construct and locate environments in lower reaches of Damodar river basin (area ≈ 24,235 km^2) in eastern India where the effect of large floods are too pronounced to explain the channel. Annual hydrographs available for some gauging sites on the downstream of the Damodar river display a simple hydrologic regime with only one pronounced maximum as common for most Indian rivers. This seasonality (high largest discharge on record, Q_{max} /mean annual peak discharge, Q_m) and the consequent imbalance in the flow had resulted in frequent flash floods, which gave the Damodar its epithet-river of sorrow. Studies carried out in the past has indicated that the flash flood magnitude index (FFMI) is higher than world average in case of Damodar river due to major rainstorm location which further implying year-to-year differences in peak flood magnitudes are large. So, large-magnitude floods form an integral part of the hydrologic regime of the Damodar River, where the southwest monsoon (June-September) contributes the 80% of annual discharge. Some of the largest floods since 20th century were recorded in 1913, 1935, 1941, 1958, 1959, 1978, 1995, 2000, 2006 and 2007. The September 1978 flood, with a combined inflow at Maithon and Panchet was recorded as 21,070 m^3s^{-1}, is significantly disastrous in recent century and this huge inflow was moderated by the dams to a discharge of 10,919 $m^3 s^{-1}$ at Rhondia (gauging site on lower reach). These storm floods caused differential geomorphic changes particularly in the twentieth century on lower Damodar valley due to flow regulation. The present study shows that the rare floods of catastrophic magnitude also influence channel form, move large volumes of sediment, and leave strong imprints on channel morphology. The basic purpose is to quantify the potential of all effective monsoon flows in terms of specific stream power (ω), duration and energy expenditure as well as to assess the different channel response in terms of width-depth ratio in pre-dam and post-dam period for the Damodar river.

068

Delineating the Past and Present Course of Rangpo Khola in terms of Field Evidences

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The uplift of the Himalayan mountain system has affected the geomorphic processes going on in many of its structural and physiographic units. This paper examines the occurrence of the past and present course of the Rangpo Khola in terms of field evidences. Under the impact of tectonic uplift, streams and rivers incise their courses abandoning their previously matured valley floor as river terraces. The Rangpo Khola of east Sikkim has incised its course along with its left bank tributary, the Rishi Khola. In both the valleys river terraces flank the channels on both sides. Moreover, in the Rangpo valley, old and dry alluvial fans have been marked at the edge of the river terraces about 5 to 10 m above the present valley floor. As the channels responsible for the formation of the alluvial fans have also incised their courses through the fans in order to meet the Rangpo, the fan deposits are now dry. These old landforms, forming relict evidences of the past processes, have been used substantially by the local inhabitants. The present incised channel is very active and fast flowing indicating that the impact of uplift has not ceased to energise the hydraulics of the channel and the channel is yet to attain a state of equilibrium. The hydraulic drops and hydraulic jumps inside the course of the present Rangpo Khola indicate the continuity of the tectonic impact still today. The exposure of the Lingtse gneiss of the Darjeeling group along the upper valley wall of the Rangpo Khola above the Garubathan phyllites, phyllite schists and quartzites of the Daling group present in the lower valley wall indicating that the valley has been formed at the thrust contact between two groups of rock strata. The rock beds, dip towards upstream direction indicating the lack of structural control for the initiation of the channel. Apart from the presence of the thrust contact in the valley wall, some other fault evidences justify the straight course of the present river at some stretches.

069

Hydrodynamic Response of a Tidal Inlet: A Case Study of Jaldah, Purba Medinipur, West Bengal

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Inlets are linkages between open sea and inland water systems. The complex hydrodynamic characteristic of an inlet is determined by the cross sectional stability of its throat. An inlet cross-section is stable if the maximum flow velocity in the inlet is equal to a certain equilibrium velocity. Other factors such as wave and tide induced sediment transport is also important, which determines the pushing-in and flushing-out of sediment by wind, waves

and tidal currents respectively. The coastal tract of Purba Medinipur district of West Bengal is characterised by severe coastal erosion and narrow beach segments. This coastal tract includes four main inlet systems, viz. Pichaboni, Jaldah, Sankarpur and Talsari which divides the coastline into Chandpur, Tajpur and Digha sectors respectively. In this study we have considered only Jaldah inlet to examine its present condition of hydrodynamic stability. To measure the tidal characteristics three monitoring stations were set up along the inlet. Tide monitoring was done for around 10 hrs. in spring tidal condition and water samples were collected at every 30 minutes for measuring suspended sediment concentration. Four cross sections were surveyed by theodolite and total station and the longitudinal profile was measured by echo-sounder. These cross sections were used to calculate the hydraulic parameters and the stability criteria. From remotely sensed data from 1998 it is seen that the mouth of this inlet is changing its position. According to the stability criteria calculated after Mehta (1975) it is seen that the throat cross sectional area is smaller than expected equilibrium cross sectional area which indicates that if the present trend of sedimentation continues then this inlet may become chocked or bifurcated in future.

070

Morphological Changes of Rupnarayan River between Bakshiand Deulti, Howrah District, West Bengal

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The Rupnarayan river is one of the most important tributaries of River Hughli. The river carries a large amount of sediment throughout its course, resulting in huge sediment discharge into the Hugli river when it is joined by the Rupnarayan at Gadiara on the right bank. For the present study the stretch of the Rupnarayan between the settlements of Bakshi and Deulti, in Howrah district has been considered. The Rupnarayan is joined by River Mundeswari and Damodar Khal near Bakshi village. Further downstream it is joined by the Old Kansai river on the right bank. The combined water and sediments of these rivers flows through the channel of Rupnarayan causing an increase in the rate of lateral erosion along both banks of as well as aggradation within the channel forming a number of mid-channel and point bars, some of which are still not stabilised. The river carries a lot of coarse sediment as its load which have a high settling velocity. Moreover, the nature of sediments undergoes modification under the impact of tide. The mid-channel bar formed at Dwipamalita is an important feature of the study area. The bar has not been stabilised and remains submerged during high tide. The area of the bar has undergone change since 2001, when it was 1.71 km^2. In 2010 the area decreased to 0.91 km^2, but in 2016 the area again increased to 1.04 km^2. Accordingly, the width of the river in this part has changed. While the width of the river near Deulti is much less being only 0.44 km, the width of the river near Dwipamalita, on the other hand is about 1.01 km. The bars play an important role in the morphological characteristics of the channel. The changes in the area and shape of bars, as well as the sinuosity of the channel, clearly indicate that the river is engaged in eroding the left bank. Near Panitras, the Rupnarayan has moved inwards for about 0.68 km from its

position in 2001. The change in the concavity of the bank is also indicative that the thalweg shift has taken place between 2001 and 2016. If this shift continues, a lot of land may get lost in this area. Measures are already being taken to stabilise the left bank with the help of boulders and social forestry along the levee.

071

Channel Cross-Sectional Area and Its Relation with the Textural Characteristics of Sand-Sized Bed Particle in A Selected Reach of Panchanoi River, Darjeeling District, West Bengal

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The present paper deals with the granulometry of sand-sized particles in a selected reach of the river Panchanoi near Matigara. The field survey was done in the month of February, 2016. The samples were collected from different morphological units within the channel. Mean, sorting, skewness and kurtosis are the statistical indices used to interpret the relationship between channel cross sectional area and the depositional environment. The surveyed stretch of the channel is characterised by coarse to very fine sand indicating the differential energy condition in transportation and depositional environment. 'P' and 't-stat' value of ' student's t-test' determine the statistical significance of relationship at 0.05 or 95% level of confidence with specific degree of freedom. The mean diameter of sand-sized particles increases near sections with greater widths, as an evidence of higher energy condition. The particles are poorly sorted in the narrow cross sections. Wide cross sections are characterised by coarsely skewed leptokurtic distribution probably due to fluctuations in energy condition between regular flow throughout the year and the occasional flash flood discharge in the monsoonal months. It creates irregular hydraulic dynamics in the river bed with varying tractive stress and lifting force in different regimes. Boulder mining or sand extraction from the river bed also influences the transportation process and the depositional environment. Simultaneous interaction of the natural and anthropogenic agents gives rise to a complex depositional environment which is reflected by the granulometric analysis of sand-sized particles in the studied reach.

072

The Development of Two New Islands in the Bidya River of Sundarban

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The Sundarban is crisscrossed by a number of tidal channels. The Bidya river is one such channel which has experienced the formation of two new within-channel islands, namely — the Birinchibari island and Pirkhali (Kanchan) island. This paper presents a geomorphological analysis of the stages of development of these two islands. The islands are formed by the deposition and subsequent vertical accretion of sediments which have been accumulated by the river from bank erosion and tidal action. The emergence of these

two islands has an adverse effect on one hand and on the other hand these have encouraged people in carrying out their livelihood practices. The mangrove forests on these islands provide resistance to the flood water and trees protect the riverbank residents. But there is a possibility of depletion of these mangrove forests due to recent human actions. Thus, the socio-economic characteristics and the future prospect of these two islands have also been taken up in this paper, which also confirms the need for protection of these islands.

073

Morphotectonic and Sedimentological Analysis of Alluvial Fans: A Comparative Study in Spatio-temporal Scale

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Alluvial fans are depositional fluvial landforms that are characterised by sediment inflow, complex hydrological processes and are also controlled by tectonics. This study focuses on the formation of meso-scale fans formed by the tributaries of river Tista. These tributaries have formed secondary alluvial fans at their debouching points. The dynamics of the fans are controlled by the hydrological responses to tectonic events and also the sedimentation processes. The origin of these tributaries and their respective fans are related to the last stage of Himalayan uplift. This is the region of Himalayan foreland basin which contains the main frontal thrust and makes the region tectonically very active. The region is drained by many large rivers and their numerous tributaries. Active tectonism, the configuration of the basin and also the deposition of the sediments carried by these rivers have formed alluvial fans where the channel debouches into the widened valley. In the present study, the meso-level alluvial fans formed by river Gish, river Neora and river Murti have been studied. Both these fans are present in the piedmont region of the Himalayas but they deliver different characteristics and the nature of their deposition is also different. This is mainly because of the influence of the minor faults in the region which control the channel pattern and also have a great influence in the sediment delivery to the downstream section of the channels. Thus in order to understand the influence of tectonics in the dynamics of these fans, some morphotectonic parameters has been taken into consideration. These include mountain front sinuosity index, valley floor width-to depth ratio, tectonic-tilt etc. The calculated hypsometric integral also depicts that the two fans are at different stages of development. The sedimentological analysis of the fans and the association of the facies exposed along the rivers have been analysed to understand the hydrological control in the formation of the fans both in temporal and spatial scale. These sediments preserve the records of the processes and the type of environment when the fans started to deposit over the piedmont flats of North Bengal.

074

Study of River Piracy: A Case Study from Bhagirathi and Babla (Dwarka) Interfluve, Murshidabad, West Bengal

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River Dwarka (also called Babla) is a tributary of Bhagirathi. It originates from Santhal Parganas in Jharkhand and then flows through Mayureshwar and Rampurhat areas of Birbhum district. It finally joins the Bhagirathi after flowing through Murshidabad district. The off take of river Bhagirathi has shifted from Dhulian to Nayansukh, Suti-I, Suti-II, Giria and ultimately now at Mithipur (Khejurtala village) of Murshidabad. The portion of Bhagirathi, downstream of Nawadwip is called river Hugli. River Bhagirathi-Hugli migrates frequently on its floodplain since Rennell's time. Many left and right hand tributaries also joined with river Bhagirathi-Hugli at Murshidabad plain. Simultaneously few tributaries also joined with river Dwarka or Babla. On both sides of Bhagirathi-Hugli different floodplain geomorphological signatures are naturally developed. This paper examines the rate of lateral shifting of Bhagirathi, bank erosion, and changes in channel geometry near Salar (Notungram) of Murshidabad. To study river piracy of Bhagirathi and Babla various techniques and satellite images have been used. This study attempts reconstruct the spatio-temporal aspect of river capture.

075

Beach Sand Composition and Provenance in Some Sectors of South Andaman Island

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Sandy sediment samples were collected from South Andaman island beaches. These samples were subjected to textural and petrologic analysis which provided clues for understanding the provenance and depositional environment of different sediments. A detailed study was done on 10 samples collected from five beaches viz. Corbyn's cove, Chiriyatapu, Wandoor, Radhanagar beach of Havelock Island, and Lakshmanpur and Sitapur Beach of Neil Island. It can be visualised after detailed study that the sediments are mainly fine to coarse grained, angular to sub angular in shape and poorly sorted in nature. Interpreting the provenance of the sands in terms of grain size and petrology was the main aim of the analysis. Composition of beach sediments of South Andaman coast can be segregated into three types: siliciclastic, carbonate and fossil fragments. The inferences derived after detailed analysis of these samples indicate that the sediments are of two distinct provenances: (i) siliciclastic sediments, which are mainly terrigenous in origin and are secondary weathering products; and (ii) carbonate shelf sediments, which are deposited by the direct precipitation of inorganic chemical components from water.

076

Interdependence of Geomorphic, Biogenic and Sedimentation Processes in Bakkhali, South 24- Parganas District: A Case Study

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Parts of South Bakkhali coast, South 24 Pgs. are studied to envision sedimentation dynamics and interdependence of geomorphological, ichnological, and sedimentological parameters. Organism-environment interaction has been studied based on spatially differentiated crab burrows, their ichnofabric and characteristics distribution along a number of land-shore transects. Correlation and regression were calculated for competing factors – geomorphic (relief, distance from strandline and slope of terrain) and sedimentary (sediment mean size and hydrodynamic structures used as proxies for energy of deposition) vis-à-vis response of benthic crab populations as reflected in their burrow diameter, frequency and long axes orientations. Dispersal of crab burrows appear to reveal a significant control of cumulative distance from strandline and lesser controls of relief and slope. But nature of sediment substrates, mean grain size in particular, appears to have a subtle control on size distribution of burrows. However, it does not directly relate to energy of deposition, since crab populations indulge into their surface activities, making varied ichnofabrics, including burrows, scratch or scrape marks, tracks etc. only during the ebb time. Overall distribution of benthic crab burrows reflects singular dominance of nutrient control. Larger burrows prefer to cling to HTL for easy access of nutrient zone and also to escape prolonged inundation. Smaller burrows are less responsive to inundation. A marginal seaward increase in smaller burrow frequency is perhaps related to least competition from co-existing taxa near strandline.

077

Shoreline Changes along Purba Medinipur Coast: With Special Reference to Gangadharpur Beach, West Bengal

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A Shoreline changes spatially and temporally in response to different factors such as wind, wave, tide, storm surge, sea level rise and land subsidence. Accurate demarcation and monitoring of shoreline changes are necessary for understanding and deciphering the coastal processes, to take up coastal zone management, for hazard zonation, for erosion-accretion studies, for estimation of regional sediment budgets and modelling coastal morphodynamics. The conventional techniques for determining the rate of change in the shoreline position include: field measurement of present mean high water level, shoreline tracing from aerial photographs, topographic sheets and remote sensing through the GIS platform. The study area chosen for the present work is a 60 km long coastal stretch on the eastern coast of India, covering parts of Balasore and Medinipur littoral tracts of Orissa and

West Bengal respectively. This coastal tract extends from Subarnarekha river mouth in Orissa to Rasulpur river mouth in West Bengal. This stretch is known for straight coastline along with flatness and compactness of the beach. Shoreline displacement over the Pleistocene and Holocene epochs of the Quaternary period is studied to explain the sequence of development of the coastal plain under transgressive and regressive phases of the sea. Different satellite images (1972, 1990, 2009 and 2015) were used to study the shoreline configuration along the Purba Medinipur coast. Many places of this coastal tract experienced phases of accretion and erosion due to shifting of costal dunes, long-shore current, anthropogenic activity etc.It is observed that the coast extending between Shankarpur-Mandarmoni and Dadanpatrabar is under severe threat of erosion, whilethe western segment experiences accretion. this beach has become erosion-prone in the last few decades. From the beach profiles, it is found that western part of the beach is more susceptible to erosion, while the eastern end of the beach is likely to experience accretion due to the presence of a dyke at the Jaldah inlet mouth, which was constructed in 2000. Changing shoreline and dune colonies indicate dynamic nature of this coastline.

078

Application of Remote Sensing and GIS for Assessment of Morphological Characteristics of Lower Torsa River, West Bengal

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River morphology deals with the river planform, channel morphological attributes and ongoing processes within the channel in terms of sedimentation and erosion. Both natural as well as anthropogenic factors control the morphological behaviour of any river while varied physiography has been seen as one of the major factors that governs fluvial dynamics over the terrain of northern West Bengal. An attempt has been made to assess the morphological behaviour of Torsa river within a selected part of its lower course in Coochbehar district, West Bengal. This study has been done through the application of certain quantitative and qualitative techniques including Remote Sensing and GIS. This study has been done over a time span of 40 years where analysis of morphological characters like channel widening, channel shifting, bank erosion and other planform properties are the major thrust areas. The shifting of the main flow of Torsa river has been capricious. The left bank of Torsa has been experiencing severe bank erosion as the river is shifting towards the east. Flow concentration within the active floodplain is not at all stable as it changes its path as well as direction frequently by capturing spill channels and palaeochannels. Channel width is found to increase with time while sinuosity value of the reach under study gets decreased. Positive trend of channel widening, frequent channel shifting, and bank erosion mostly along the left bank has been a threat to anthropogenic installations along the river and does not indicate any sign of future stability.

079

Morphological Adjustments of Ichhamati River at Hugle-Mathpara, North 24 Parganas, West Bengal

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Ichhamati is a transboundary river that flows through India and Bangladesh. It branched off from Mathabhanga river (a distributary of Ganga) near Majhdia in Nadia district. A major part of the river traverses through North 24 Parganas district in West Bengal. Considerable stretch of the river comes under the tidal regime. In due course of time, the non-tidal Ichhamati course has shrunk considerably due to degeneration. However, the lower course of the river remains active throughout the year due to tidal activity. The study area is located at Hugle-Mathpara area in Baduria and Swarupnagar blocks. This area is characterised by a meandering bend of Ichhamati that has changed through the time. Development of agricultural lands and brick kilns—located on both banks of the river—have major influence on the shifting course of Ichhamati. In this particular segment of Ichhamati, tidal influence reduces significantly from downstream to upstream due to the increase in bed elevation of the channel. To show the morphological adjustments in this area, satellite images (Landsat and Quick-bird) and SoI topographical maps have been used. The map database is complemented by cross sectional surveys and GPS surveys in the field. In order to find out the asymmetry in sediment concentration between flood tide and ebb tide, water samples were also collected. It was found that the inflow of water during high tide is 8 times higher than the outflow during low tide. The bankful discharge of the channel is approximately 200 cumecs. Due to the flow velocity asymmetry between ebb and flood tide—the deposited sediment gets piled up on the Ichhamati bed. The average suspended sediment load during flood tide is 636.9 g m^3 and during ebb it is 355.6 g m^3. Due to gradual decrease of tidal inflow, the alignment of the meander near Hugle village has changed from a curved one to a sharp angular bend in the last 100 years. Simultaneously, the channel width has also decreased 3.5 times due to sedimentation. Alongside the geomorphic changes, the land use around the river course has also altered in recent times.

GEOMORPHOLOGY IN ECOLOGY AND ENVIRONMENT MANAGEMENT

080

Functions and Bio Functions of Soil and its Restoration

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Pedosphere, the outer most layer of the Earth's crust is composed of non-renewable natural body of soil which is influenced by the prevailing soil forming environment. Soil having multiple roles in maintenance of stability in nature through biotic and abiotic activities, is under constant threat of erosion, degradation and associated fertility loss from mainly quasi-

natural factors. Over-use of pesticides and fertilizers not only spoil the soil in terms of physical character but also affect the microbial population.

Measurement of soil erosion is not easy. Techniques of scaling of sediment depth at the break of slope, monitoring the bare root zone of trees in the upper slopes or measuring amount of biomass production may be helpful in this respect. Overgrazing, improper means and methods of land use practices, unscientific afforestation programme, monoculture plantation of acid inducing and fire prone crops, deforestation, toxic release of industrial effluent and excessive uptake of ground water, induce soil erosion in greater magnitude. Salinisation, bogging, decline of soil organic matter, soil sealing, compaction, contamination, deflation and landslides lead to soil degradation which erode not only the soil cover but also affect soil productivity.

Soil organism, the agents of bio function plays a beneficial role in breaking of organic matter, recycling of nutrients, creation of humus, formation of soil structure, fixation of nitrogen, promotion of plant growth and maintenance of food quality and security. So, there is a need for advocating sustainable use of soil bio-function through different types of policies and strategies at local, regional, national and global level. Initiation of green belts on slopes, mulching, green manuring, introduction of heterogeneous species, scientific farming practices, rational use of water resource, use of bio-pesticides, promotion of soil stabilising vegetation cover may help to save the soil resources and dependent floral and faunal communities.

081

Evaluating the Environmental Impacts of Opencast Coal Mining: The Case of the Khottadih and Sonepur Bajari Areas in Burdwan, West Bengal

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Opencast mining is more effective than almost all types of mining because of more ore can be extracted within a short time. The working conditions are comparatively safer for the miners because there is no risk of cave-in or toxic gas. Low production cost and high labor efficiency is also seen. Therefore opencast mining is gaining popularity day by day. However, it degrades the environment much more than the other mining processes. The environmental costs associated with opencast mining are generally excluded from financial appreciation of opencast projects. Spatial and temporal variation of SPM, RPM, SO2, NOX and noise concentration have examined to indicate the air quality of the study area. The researcher examines two opencast projects in Raniganj coalfield of Burdwan to explore the environmental degradation due to opencast coal mining and estimates its costs. Impact on local house prices and environmental costs of these projects could be sufficient to reduce its economic viability. The main objective of this study is to estimate the costs of these environmental impacts and compare them to the benefits of coal extraction.

082

Monitoring Species Diversity in Coastal Landscape using Shannon-Wiener Diversity Index and Sorenson's Coefficient: A Case Study of Ramnagar-I and II Blocks, Kanthi, Coastal Plain, West Bengal

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Biodiversity monitoring is mainly focused on the species level. However, researchers are using complementary assessment tools that address higher levels of biological organisation, i.e. communities, habitats and ecosystems.

Coastal habitats are extremely fragile, unique and vulnerable to human activities. Vegetation ecology studies are preferred to predict responses of vegetation to landform changes. This study has been carried out on distribution of plant species in Ramnagar-I and II Blocks with the aim at defining the relationship between vegetation and landform types and highlighting the main morphological characteristics within examined land cover classes. Recently, various frameworks have been adopted for assessing the conservation status of communities or ecosystems. So the sample survey has been done on 75 grids (500 m × 500 m) in three transects. Each transect has 25 grids which extends from south to north of the study area. The transects are chosen at three sites — near Jaldah *mohana* (estuarine mouth), Tajpur tract and New Digha belt where the vegetation diversity is well marked. This survey identifies 106 species of plant on 75 grids. Then the Shannon-Wiener Diversity Index is calculated for evaluating the richness and evenness of the sampled plants which characterises the species diversity in a community. The Sorenson's Coefficient is computed for considering community similarities in the study area. Finally, the spatial distributions of different plant diversity zones are integrated with the micro unit of coastal landscape.

083

Loss of Biodiversity: A Case Study of Ramkishore Panchayat, Kulpi Block, South 24 Parganas, West Bengal

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Loss of biodiversity is becoming one of the major issues for environmental concern in rural West Bengal. Water and air pollution, soil degradation, deforestation, construction of roads and houses, unscientific agricultural and aqua-cultural practices and change in landuse and landcover induce an increasing trend in the loss of biodiversity. Seventeen mouzas (Barbaria, Bishnurampur, Chak Ruplaskar, Dari Ratneshwarpur, Deria, Hanra, Hari Narayanpur, Jabbaria, Kalitala, Manika, Monoharpur, Radhanagar, Ramrampur, Raytala, Uttar Mukundapur, Uttar Ramkishorpur, and Uttar Ramkrishnapur) under Ramkishore panchayat of Kulpi Block of South 24 Parganas, located along the Hugli river have been selected for detailed study. Primary data are collected through questionnaire survey in field,

and secondary data have been collected from various published works and government records. Illiteracy, lack of awareness, poverty and superstitions prevailing among the local people are also responsible for the loss of biodiversity in the study area. Different types of birds, fishes, poisonous snakes, frogs, rats, earthworms, insects etc. have disappeared in greater number from the study area in the last few decades. The excessive use of chemical fertilizers and pesticides in agricultural fields lead to water pollution and eutrophication which affect aquatic biodiversity. Most of the villagers are unaware about the importance of the endangered species which in turn cause loss of biodiversity and related environmental problems. Urgent steps are necessary to save the biodiversity by increasing awareness among the villagers and formulating participatory programmes including the villagers and also the government and non-governmental agencies to save the endangered biodiversity of the study area.

084

Perception and Practice of Waste Management among Hostel Students of North-Eastern Hill University, Shillong, Meghalaya

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To effectively deal with environmental and health problems associated with unhealthy treatment of wastes, the attitude of young people like university students appears to be crucial. Their point of view ultimately plays an important role in providing solution to environmental problems and for the promoting environmental awareness. The present study was conducted among 200 hostellers of North-Eastern Hill University using self-structured questionnaire applying stratified random sampling to assess the relationship between the students' level of understanding and practices regarding waste management. Reliability of the questionnaire was tested by Cronbach's coefficient alpha and the values were 0.86 and 0.82 for attitude and practices respectively. Statistically significant and positive relationships were found between the level of attitudes and practices regarding waste management.

085

Geo-Environmental Problem around Sidhi Dam Reservoir, Madhya Pradesh

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The general awareness about ecological imbalance has led the scientists' world over to closely scrutinise developmental activities and their impact on geo-environment.

The hydroelectric project on Sidhi dam reservoir in Goriara village of Sidhi district is an important developmental scheme in Mathava Pahar of Madhya Pradesh. The lake is a natural base level for tributary streams like Sukha, descending from the surrounding hills and form centripetal drainage system towards Sidhi lake. It covers an area of about 12.52

km^2. The Sidhi lake is confined in a graben. The absolute and relative relief increases from north to south. The slope varies from $<20^0$ to $>50^0$. The drainage network of the area shows strong structural adaptation in conformity to the lineaments of the Khainjua massif.

Indiscriminate land resource exploitation during the last forty years has resulted into serious ecological imbalance in the area. A major part of the area is affected by deforestation, prolonged *Jhum* cultivation and rapid urbanisation on steep slopes. After formation of the Sidhi dam reservoir a large segment of cultivable land has been submerged under water. Besides, environmental degradation, the area also experience a number of geomorphic hazards like landslides, formation of deep rills and gullies and sheet erosion. Keeping in view of the problem, the present work aims to suggest a strategy for environmental management for the Sidhi dam command area.

086

Hydro-geomorphic Characteristics and Spatio-temporal Evolution of Wetlands:A Micro Level Study in Labpur Block, Birbhum District, West Bengal

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Wetlands have definite hydromorphic characteristics which help to regulate movement of water and maintaining the hydrological cycle. So, any modifications in hydrological process bring significant changes in the wetland behaviour. Floodplain wetlands are mainly controlled by drainage regime. At present human intervention is altering the hydro-morphological conditions of both the drainage lines and wetlands. The present work is based on micro level analysis of hydrological characteristics of both permanent and seasonal wetlands and also their spatio-temporal variation in Labpur block of Birbhum district. The result of the study reveals the fact that all the wetlands are well connected with both perennial and non-perennial channels which act as feeding sources of lentic hydrological behaviour. Moreover water level fluctuation in the wetland (*beels)* depends on the seasonal fluctuation of river discharge level. Equipotential flow of ground water also depicts its close link to the wetlands. The morphological character and areas of wetlands have changed over the last nine decades due to extension of agricultural land and settlement. The average rate of sediment deposition in the wetlands is about 3.08 mm yr^{-1}, which results in reduction in water retention capacities. Consequently it accelerates the flood phenomena during monsoon season. Wetlands are now considered as an important water resource of rural Bengal so this type of intensive study can provide data base for optimum planning of this resource.

087

Soil Characteristics and Erosion with Particular Reference to Organic Content in Tons Basin, Uttar Pradesh

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Soil organic matter plays an important role in the erosion process, together with rainfall characteristics and land use. This article establishes the importance of organic matter in the erosion process, in conjunction with other factors, under different temporal and spatial scales.

In order to carry out the study a field survey was undertaken in Tons alluvial plain in an area 2 km × 4 km in size, where soil erosion was mapped and quantified for three consecutive seasons. Soil erosion was monitored for 12 months in an experimental station set up at the field centre where automated techniques recorded runoff during each storm. The total amount of eroded soil was also collected after each rainfall event and soil properties were determined. Finally, soil samples were collected from eroded and non-eroded fields and were exposed to simulated rainfall inside a flume of 0.20 m × 1.00 m dimension. Total runoff, wash load, percolation and time to crust were also determined. Soil properties such as organic matter content, water stable aggregates, bulk density and texture were considered along with slope characteristics and land use.

Empirical models were established and data was correlated for the samples collected from eroded and non-eroded fields. After the study it could be concluded that with other soil properties together with rainfall characteristics and land use, organic matter plays an important role in the erosion processes over the alluvial environment of Tons basin.

088

Life and Livelihood in the Teesta Chars: A Case study of the Takimari Char in Jalpaiguri, West Bengal

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The river Teesta, originating from the Pauhunri and Zemu Glaciers in Sikkim, runs its entire upper course in this North Eastern State of India before entering into West Bengal. The dynamicity of this river in its 309 km stretch in Sikkim and West Bengal before meeting Jamuna (Brahmaputra in India) in Bangladesh has produced numerous documents for analysis and discussion. The Teesta encounters a break of slope as it enters into West Bengal, and it initiates the process of alluvial fan formation over a huge area. However, the river in its further southward journey, over Jalpaiguri district of West Bengal, exhibits its senility characterised by deposition on its bed and along its banks. Several 'chars' or 'river islands', are the outcome of the process. These riverine areas are being steadily encroached by human beings since a long depending upon the chronology of their formation. This paper fits in this domain attempting to exemplify the uniqueness of the chars and their inhabitants

in etching a relation together. Hence a case study of the Takimari char, situated on the left flank of the Teesta in Jalpaiguri, tries to establish the major objective of exploring the *status quo* life of the char dwellers and conversely the impact of human invasion on these char lands; since, man's forceful dominance over nature has been a major cause of alteration of the physical earth. The present work is based on both primary and secondary information for analysing and developing the presentation. It tries to throw light on the overall physical and socio-economic environment of the Takimari char, suggesting possible means of sustaining the man- nature union in this vulnerable land.

089

Assessment of Water Quality of Ranikhola River and Adjacent *Jhoras*, Sikkim

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Ranikhola river, rising in the Sikkim Himalaya is one of the multitudes of southwest flowing rain fed Himalayan rivers. The prime objective of the present study is to find out the pollution load in terms of metals and chemicals into the main rivers through *Jhoras*. For the study, six sample sites have been chosen from the downstream portion of Ranikhola river basin viz. — i) Adampool, ii) under Ranipool bridge, iii) Namli, iv) Martam khola, v) Marchak near dumping yard and vi) Singtham near the confluence of river Tista and Ranikhola. The organic and microbial status of the river water has also been studied along with the *jhoras* meeting the river. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values are also important parameters for determining the quality of river water. The ratio of BOD and COD is an indicator of biodegradability. Natural water bodies usually have an ability to purify water and acts as a sink for pollutants. But the ratio of BOD and COD in the above mentioned sample sites are less than 0.2, which is not capable for biodegradation. The highest Most Probable Number (MPN) is found in the water of Martam khola (6/100 ml), moderate MPN is found in Namli and Adampool area (2/100 ml) and the lowest MPN is found in Singtham, Marchak and Ranipool area (<2/100 ml). Therefore the results clearly show that the water of Martam khola, Adampool and Namli area is much more pathogenically contaminated than the other sites and government should be aware about the quality of water in the river and the *jhora's* and adopt management plans accordingly.

090

Methane Emission from Rice Fields: A Crucial Criterion for Climate Change

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Climate change in terms of temperature increase has become the greatest threat to the agriculture. Even slight moderation in climate is expected to affect the developing countries by large through decline in agricultural yield and consequent rise in poverty. Nevertheless,

agriculture plays a vital role in the increase in global temperature through considerable emission of greenhouse gases. Southeast Asian countries including China and India are the chief paddy growing regions of the world, which release huge amount of methane each year. India being a subtropical country is likely to be affected more by climate change and the agricultural sector has to pay the cost. The present paper deals with the estimation of methane emission and its potential to cause global warming from Indian paddy growing ecosystems. The methodology adopted in this study is according to the IPCC directives. The study shows a constant increase in methane emission up to 2014. The average emission is found to be 2.675 Tg in 1950–51 and 3.628 Tg in 2013–14 with annual growth rate of 0.005 $Tgyr^{-1}$. Both the net and per hectare methane emission from India has been found to be higher than many other major rice growing countries of the world. The study suggests proper planning to restrict methane emission from rice fields and maintain the sustainability of agrarian ecosystems.

091

Impact of Sand Mining on Channel Morphology in Some Selected Parts of Mahananda River, West Bengal

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Due to sharp changes in slope near the foothill region of Darjeeling Himalaya, the Mahananda river deposits huge amount of sediments of different size. There is a dearth of research studies on the resource extraction from channel bed and its impact on river morphology. This is a major setback in proper planning and development. The present study has been carried out to detect the nature of geomorphic changes resulting from the extraction of building and filling materials from the Mahananda river bed, located very close to the Siliguri town, Darjiling. The location of some selected sand quarrying sites along the Mahananda River has been detected and marked with the help of GPS and its impact on channel morphology has been investigated through field investigation. The field survey mainly comprised of cross sectional measurement and collection of soil samples, which were subsequently analyses for their textural properties. Due to sand and gravel extraction in the river bed the intensity of bank erosion, channel widening, river bed deepening and active channel migration has been calculated and the correlation has been established between these different parameters.

092

Salt Water Intrusion in Reclaimed area under *Khar* land Scheme in Muchkundi Estuary of Maharashtra

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Estuaries are one of the most sensitive coastal systems. The estuaries in Konkan are narrow and non-braided. But they have arms of salt water along the banks where the topography is low. These arms are called as kharlands. They are mostly shallow and are fringed by hill

slopes landward. The fringe region of these kharlands falls within intertidal zone with water level fluctuations, whereas the central region of the kharland is perennial. They have major role in flood control and fish breeding. In Konkan the land under such Kharlands are privately owned. As there is scarcity of land for cultivation the Government introduced a scheme for reclamation of this land. Earthen bunds with gates were constructed to restrict the tidal water from entering into the kharland. The land thus freed from tidal water influx was to be slowly converted into cultivated area. The settlements along the estuary banks were actually located along the fringes of these kharlands as there is more ground water available along with some flat land for cultivation. These villages were known for their groves and orchards due to ample water supply. With construction of kharland bunds the well water became brackish at the end of monsoon. The brackish water enters the wells right up to foot of the hill slopes which was never observed before. This study is based on determination of salinity for water samples collected from wells along with water level data of those wells. The data was collected from two such kharland schemes for two consecutive years. Continuous observation has led to the conclusion that there is loss of salt wedge or water front that existed before the bund was constructed and thus there is fast draining of spring water allowing the salt water to encroach easily.

℘ APPLICATION OF MODELLING AND GEOINFORMATICS TO GEOMORPHOLOGICAL STUDIES ℘

093

Potential Interaction between Transport and Stream Networks: A Case Study of Kunur River Basin, West Bengal

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Extension of transport networks supports good accessibility and is associated with the development of a region. However, transport lines have fragmented the regional landscape and disturbed the natural interplay between rivers and their floodplains. Spatial analysis using multiple buffers provides information about the potential interaction between road and stream networks and their impact on hydro-geomorphic processes of a small watershed in the lower Gangetic plain. The present study attempts to understand the lateral and longitudinal disconnection in headwater stream by rural roads with the help of GIS and field survey. Significant ($p = 0.001$) growth of total road length (overall 153%; paved 69%, unpaved 366%) and number of road-stream crossing (395%) in the last five decades (1970s to 2010s) are contributing to make longitudinal and lateral disconnection in the fluvial system of the Kunur river basin (KRB). Channel geometry from ten road-stream crossings shows significant ($p = 0.01$) differences upstream and downstream of the structure and created problems like downstream scouring, increased drop height at outlet, formation of stable bars and bank erosion. The study has also inferred tremendous growth (1922%) of

unpaved road, especially prepared by murrum or quarry laterite, within the 30 metres buffer of streamlines that might induce adverse effects on hydro-geomorphic processes.

094

Detection of Shoreline Change Employing Remote Sensing Data: A case study of the Coastal Tract from Shrivardhan Tahsil, Maharashtra

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The present paper attempts at extracting the shoreline and detecting the temporal changes in the shoreline from remotely sensed data. A small patch of the Konkan coast covering the headland-bay environment from Adgaon to Shrivardhan was selected. Landsat TM and ETM+ images from 1993 to 2015 were processed by employing four different raster band combinations. These band combinations were PCA, Water index, NDVI-TC, and NDMI-TC. Simple ISODATA binary classification technique is useful for delineation of shoreline. Based on the DSAS an extension of ArcView, 22-year shoreline changes were quantitatively re-analysed. The results obtained includes—a series of 1233 transects, which is quite time consuming in standard manual methods, as compared to automatically generated ones using DSAS. But some difficulties like establishing the baseline and transect corrections were encountered. The shoreline evolution percentage was described quantitatively by the rates of changes through the end point rate (EPR) method. Out of the four methods of raster band combination NDMI-TC was found suitable and employed for shoreline extraction. The Net Shore Migration for 1993-2000 was noted to be 4.73m while the EPR was 0.22m/yr and LRR was -0.87m/yr. From the present study, it was observed that the entire shoreline extending between Diveagar headland to Shrivardhan bay is under threat of rapid erosion on the headlands (Adgaon, Bharadkhol, Kondvil and Jeevana headlands) whereas, depositional environments with high deposition are observed all along the beaches. The magnitude of erosion is higher along the headlands and tidal inlets or bars/spits.

095

Hyper-Spectral Remote Sensing and Its Application in Lateritic Characterisation and Mapping

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Soil variability mapping is an important step in environmental and agricultural applications. For the suitable management of agriculture, better understanding of environmental processes and landscape phenomena are needed. Soil of the area should be analysed in detail. This study has been conducted with this objective using hyper-spectral remote sensing data. The data is highly rich in spectral detailing that provides a powerful diagnostic tool for mapping and monitoring of earth's surface materials. Here, the EO-Hyperion data has been used which is having 220 spectral bands. Numerous very fine width spectral bands have been used to get the reflectance pattern for individual pixel. The main aim is to identify the pixels with lateritic

characteristics. For the purpose, the mineral constituents of lateritic soil should be known because the behavior of the absorption band will vary with the behavior of mineral content of the surface materials. Laterite is rich in iron oxides and aluminum which is developed by leaching of lime and silica downward under the condition of high temperature and heavy rainfall with alternate wet and dry periods. Remaining oxides of iron and aluminum compounds make this soil red in color. This type of soil is found in Rajmahal traps in West Bengal. In this work, one strip of Hyperion data covering Garhbeta town and its surroundings in West Medinipur district has been analysed to show the methodology by which the pixel can be well-demarcated with iron-oxide and aluminum. The demarcation is achieved by the matching of each pixel's reflectance with the reflectance curve of target material content collected from the available spectral library. This classification will extract the pixels with lateritic content. Concentration of the iron oxide-aluminum composite may vary with the age, weathering status of the soil and prevailing environmental conditions. For such concentration mapping, the purest pixel or end member first needed to be identified by principle component analysis. This is followed by the pixel purity index for each lateritic pixel. All these processes should be preceded by the necessary processing of input Hyperion image like the atmospheric correction, which converts the radiance data to reflectance data. This study maps the iron-oxide and aluminum concentration that provides an adverse effect on plant growth. Thus, fertility management for agriculture and land degradation management can be taken care of with a better opportunity.

096

Extraction of Water Bodies in Hilly and Densely Forested Area Using Geoinformatics: A Case Study of Buxa Tiger Reserve, West Bengal

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Surface water is one of the important natural resources for survival of man and animals and also improvement of the forest ecosystem. The Buxa Tiger Reserve is one of the protected forests of West Bengal, which is drained by a number of rivers and dotted with water bodies. However, during dry season, majority of the rivers become dry and the small water bodies in and outside the forest become the main source of water. In this study, various methods has been used for extraction of water bodies like Normalised Difference Water Index (NDWI), Modified Normalised Difference Vegetation Index (MNDWI), Water Ration Index (WRI), Normalised Difference Vegetation Index (NDVI) and Automated Water Extraction Index (AWEI). Landsat images of different time periods have been used as an input. The study has found out that a substantial number of water bodies in this region have disappeared mainly in forest fringe areas due to anthropogenic activities. The study reveals marked changes in the land use pattern of this region, especially expansion of tea garden, agricultural land, and human settlement towards the forest. The AWEI proved to be a good method for water body extraction in this hilly terrain and dense forest area which includes shadows and dark surfaces which other methods fail to classify correctly. A map has been prepared to prediction the future situation so that a better water management method can be developed here. A water body map has also been prepared which will help in

water planning in this thickly forested region, especially in dry season. This will also help the forest authority to handle man-animal conflict in a better way and help the farmers through proper water management.

097

Sub-watershed Prioritisation Based on Morphometric Parameters using Remote sensing and GIS in Konar Catchment, Jharkhand

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Watershed prioritisation has become more important in terms of natural resource management. Morphometric analysis is found to be more effective in sub-watershed prioritisation. The present study is an attempt to prioritise sub-watersheds based on morphometric parameters using remote sensing and GIS techniques in Konar Catchment of Jharkhand. The Konar catchment is located at the upper Damodar Valley covering Hazaribagh and Bokaro districts of Jharkhand. The catchment is drained by the Konar and Siwaneriver which runs through a greater portion of Hazaribagh plateau. Various morphometric parameters such as linear, aerial and shape aspects have been computed for each sub-watershed and rank have been assigned on the basis of their relationship with erodibility. The ranking values for all the linear and shape parameters were added up to arriveat a compound value (Cp). An index of High, Medium and Low priority was established based on their Cp values in terms of management and conservation of natural resources. Out of 32 sub-watersheds, 6 sub-watersheds (viz., SWK17, SWK18, SWK19, SWK20, SWK21, SWK28) qualify for high priority, whereas 7 sub-watersheds (viz., SWK1, SWK2, SWK4, SWK6, SWK10, SWK13, SWK23) has been categorised as low priority and rest of the sub-watersheds are categorised as medium priority based on the integration of morphometric analysis.

098

Application of Frequency Ratio Model for Landslide Hazard Mapping in North Sikkim District, Sikkim

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Landslide is a common geo-hazard, which undermine the overall socio-economic set-up in the North district of Sikkim in the Eastern Himalaya. Successful landslide management plans and policy depend on in-depth knowledge about the hazard. This work intends to present an integrated approach involving uses of geospatial technologies for landslide hazard assessment at regional scale. The landslide hazard map of the North Sikkim district (4,296 km^2) of Sikkim is prepared by using Frequency Ratio method. To evaluate landslide manifestation in this region, different causative factors, viz. lithology, structure, slope,

relative relief, drainage density, rainfall, and land use / land cover are mapped for spatial analysis. These spatial layers were integrated in the GIS using overly techniques. The value of area-normalised incidence is summed up for the layers and stored as a separate attribute. Simple statistics of this additive normalised-incidence is computed and used to classify the entire study area in to five meaningful landslide hazard classes, namely, very high, high, moderate, low, and very low. The highest incidence of landslide per km^2 is recorded for Very High Hazard zone (77.52%). The second highest frequency (7.75%) of landslide is found in the High hazard zone. Very least frequency (1.55%) is found in the very low hazard zone.

099

GIS- Based Morphometric Analysis of Sabarmati River, Gujarat

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Sabarmati River is the third largest west flowing rivers of India, extending over the states of Rajasthan and Gujarat having an area of 21,674 km^2. In India where water resource is scarce the Sabarmati river drains the states which are amongst the driest states of India. Though, Gujarat is drained by the two important west flowing rivers like Tapi and Narmada but for the northern part Sabarmati is most important river. In the states of Gujarat and Rajasthan population pressure is continuously increasing, and land and water resources remain limited and their utilisation is imperative. The Drainage basins, catchments and sub catchments are the fundamental units for conserving natural resources. Detailed morphometric analysis of a basin is of great help in understanding the influence of drainage morphometry on landforms and their characteristics. One of the advantages of quantitative analysis is that many of the basin parameters derived are in the form of ratios (dimensionless), thus providing an effective comparison irrespective of the scale. The objective of the present paper is to analyse the Sabarmati river in the GIS environment for quantitative morphometric analysis which was carried for linear aspects, areal aspects and relief aspects. The analysis was carried out using ArcGIS.

100

Impact of Bridge Construction on the Hydro-Sedimentological Regime of Chel River, West Bengal

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Humans have always modified their surroundings for better adaptation which include building of urban landscapes, dams, bridges and other infrastructures. Such modifications have affected nature as well as human communities both positively and negatively. The entire north Bengal plain is dissected and drained by a number of perennial and non-perennial rivers. Among them river Chel have deposited all the carried sediments due to the normal change of gradient, but the river near the bridge crossing exhibit a bottle-neck condition as the river is forced to pass through narrow constricted section which restricted

the channel and as a consequence the velocity of the river is reduced, upstream of the bridge crossing area due to the obstruction of the bridge where sediments have started to accumulate. This paper will thus try to explain the phenomenon of channel shifting in the last 100 years and changes in sediment regime that the Chel is experiencing is due to the construction of bridges across the middle part of its course. The analysed data reveals some distinct changes in the channel planform with alteration of sediment regime and the simulation of hydraulic modelling in HEC-RAS has been done to determine the probable affected area with bridge and without bridge both in upstream and downstream areas. For these kinds of obstructions near bridges HEC-RAS serves as an effective tool in delineation of floodplain and inundation model prediction during high discharge.Thus with the help of HEC-RAS a model was prepared for showing the effects of bridge construction on channel flow. HEC-RAS will also help to understand how the original morphological condition of the stream would have evolved without the bridge construction. The study unveils the deviation of the river caused due to anthropogenic effects. The discussion concludes with the observation that the Odlabari bridge constructions have modified the normal hydrological behaviour of the river with higher probability of bank erosion in downstream and floods in upstream stretches.

101

Application of SCS Curve Number in Runoff Based Flood Risk Assessment using Remote Sensing and GIS Techniques: A Case Study on Shilabati River Basin

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Floods in the Shilabati river basin (3,019 km^2) is due to both climatological reasons and combination of other factors related to catchment. The existing flood risk forecasting system by Indian Meteorological Department is devoid of a sound flood forecasting system though the downstream catchment is frequently affected by flood every alternative year. Therefore, in this study an attempt has been made to develop a workable forecasting system, considering remotely sensed data for analysis. Both multi-criteria based weightage method and AHP based approach are considered for finding the flood risk zones of the basin. Most of the agricultural watersheds in India are ungauged, having no past records of the rainfall-runoff processes. This has led to the development of techniques for estimating surface runoff from ungauged basins. From the several methods for runoff estimation of ungauged watersheds the curve number method (SCS-CN) is used here as a distributed model whose method along with its derivatives has been widely applied to ungauged watershed systems and has proved to be a rapid and accurate estimator of surface runoff. This method was originally developed by the US Department of Agriculture, Soil Conservation Service and documented in detail in the National Engineering Handbook, Hydrology (NEH-SCS). Landsat satellite images were used to obtain land cover information through ERDAS Imagine 9.2 platform. The thematic layers like soil map, elevation map, rainfall map and land cover map were created in TNT mips platform. Curve numbers are assigned for

different land cover and soil types. In present study the runoff varies from 3.91 mm to 64.83 mm of the study area. From the above said method we create an index based vulnerability analysis which predicts the risk zones of the study area. Finally, five categories of flood risk were established (very low risk to very high flood risk zones; 0.009 to 0.088). However, it is able to give the flood risk probability in the basin very precise and cost-effective.

102

A Study on Linear Morphometric Attributes of the Jinjiram River, Assam and Meghalaya

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Detailed linear morphometric analysis of the Jinjiram river has been carried out to study the drainage pattern and morphometric analysis of the river basin based on SoI toposheet on 1:50,000 scale. The Jinjiram river basin is situated on the south bank of the Brahmaputra River. The extension of the basin is from 89°50′E to 90°30′E and from 25°20′Ntot 26°10′N. It lies between the Jinari river and the Old Brahmaputra river. Total length of the Jinjiram is 143 km. The basin spreads over the alluvial plains of Goalpara and Dhubri of Assam and hilly areas of the Garo Hills of Meghalaya Plateau. The analysis of its drainage network reveals that the basin is a 12th order basin with 2748.72 km^2 area. Based on the linear morphometric parameters, the basin is in old stage cycle of erosion with uniform slope and is less affected by structural control.

103

Terrain Analysis of Barakar River Basin, Jharkhand

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A geomorphic unit like a 7th order Barakar drainage basin which covers major part of northeastern Chhotanagpur plateau has been selected for the present study. The major objectives of this research are Terrain analysis on the basis of morphometry, drainage pattern, channel morphology and landforms using Barakar river sediments. Paleoclimatic interpretation of Gondwana sedimentary basin lying in the study region is also an important objective. To fulfill the above objectives Digital Elevation Model (DEM) has been generated with twenty two CARTOSAT Stereo pair data. Further, Ortho–Image has been produced from this DEM for landforms mapping. DEM data has been utilised in morphometric analysis. The study reveals that remotely sensed data (CARTOSAT -DEM) and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms at river basin level is more appropriate than the conventional methods.

104

Gully Erosion Susceptibility Mapping Based on Weight of Evidence Model (WoE): A Case Study of Southwestern West Bengal

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Identifying gully erosion susceptibility in cultivated region is imperative for management decisions. Present study demonstrated the application of the weights-of-evidence (WoE) model (a Bayesian probability model) to gully susceptibility mapping using GIS and RS techniques in southwestern part of West Bengal. Eight gully conditioning geo-environmental factors were considered for the susceptibility analysis, such as: lithology, geomorphology, soil type, land cover, slope, length-slope-factor (LS), stream power index, (SPI) and wetness index (WI). Tests of conditional independence were performed for the selection of gully conditioning factors, allowing eight combinations in total. Finally, gully susceptibility map was prepared using the ratings of each gully conditioning factor. The resultant susceptibility maps were validated using the area under curve (AUC) method. Gully locations were used to validate the results of the gully susceptibility map and the verification results showed 67.8% accuracy for model, which employed a combination of parameters. Therefore, the weights-of-evidence modelling is useful in gully susceptibility mapping and helps the decision makers to design improved mitigation of natural hazards.

105

Using Structure-From-Motion Photogrammetery for Generation of Digital Elevation Models and Three Dimensional Representation of Micro-Geomorphological Features

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The use of Digital Elevation Models (DEM) has become widespread in geomorphological research over the past decade. However, DEM usage is constricted by the scale of the dataset, with freely available DEMs being too coarse to represent the finer topographic attributes. Even where very high resolution DEMs (approximate resolution of ~ 2m) are procured for terrain analysis, the view obtained is essentially a top-down one. This restricts the display, measurement and analysis of morphological features which may be best captured from an initial side-on view while also obscuring geomorphological elements like slope overhangs, soil pipes or caves, from whom only their upper surfaces are captured in the vertical view of traditional DEMs. An alternative approach has been the implementation of the Structure-from-Motion (SfM) Photogrammetric techniques to capture terrain data at much lower cost using simply a standard digital camera, from a ground perspective. The photographs taken all around the target morphological feature are then aligned and meshed to allow the creation of a dense point cloud, representing the surficial characteristics of the target feature. Georeferencing of this point cloud allows extraction of accurate

measurements, with final surface rendering and textural overlays done to realistically represent the target morphological feature. This allows measurement of not only morphological attributes of elevation and slope but also the lithological and structural components, where such are desired, for example, from a rock outcrop - something which would not be possible from traditional DEMs. The SfM technique has been used for capturing morphological information from a number of micro-topographical elements in the gullied lateritic tract of Garbeta in the Paschim Medinipur district of West Bengal and also from the exposed structural elements of an extensive rock outcrop on the banks of the River Subarnarekha at Jamsola in Purbi Singhbhum district of Jharkhand. In both these cases, features which would be otherwise indiscernible from traditional DEMs, elicit valuable morphological and geological information, which are used to discern the nature of the operative processes responsible for their formation. The generated three dimensional digital models of the above terrain components may also be transformed into actual physical ones for a more interactive teaching-learning process in the classroom, to record the present state for a possible future temporal analysis and importantly, to preserve the geoheritage of important geomorphosites, which could be positioned within virtual globes at apposite locations for a greater immersive browsing experience.

106

A Study on Erosion and Accretion of Western Coast of India Using Multi-temporal Satellite Data

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Coastal zone is a very complex, dynamic and delicate area. Shoreline is one of the most rapidly changing landforms. Erosion-accretion, periodic storms, sea level changes, flooding all these geomorphic processes continuously modifies the shoreline. Accurate demarcation of shoreline is very important for planning and conservation of resources. Western coast of India is very vibrant zone and it is a store house of food, energy and minerals resources. Therefore it provides primary sources of livelihood for a large population resides near western coast. The shoreline of western part of India near Mumbai is one of the most rapidly changing landforms of the country which is influenced by various geomorphic processes. Satellite Remote Sensing technique has proved its utility in all fields of earth science studies including coastal processes. The major advantages of RS and GIS are that it allows identifying the spatial relationships between features and temporal changes within an area over time. The main objectives of the study are to identify the sites of erosion and accretion along the coast area near Mumbai; to assess the land utilization and major vegetation types of this area; and to demarcate CRZ boundary for identify the impact of Sea Level Changes in Mumbai coastal area. To fulfill the objectives of the study progressive methodology has been prepared and various satellite data has been collected and analyse the temporal variation. The results of the study show that all developmental activities are carried out in the coastal area without following any norms and anthropogenic activity plays an important role for the changing scenario of creeks near Mumbai. All ill legal constructions on the

vicinity of CRZ should be stopped immediately for the protection of natural vegetation. The results of the study are of immense utility in future planning and management of the coastal environment of Mumbai

107

Morphometric Analysis of Vincharna Watershed, Maharashtra, and Calculation of Surface Runoff using Arc CN tool of ArcGIS

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Morphometric analysis of a drainage basin possesses the quality of dynamic equilibrium that has been achieved by interaction between matter and energy. It helps to recognise the general geo-hydrological characteristics of the drainage. In this paper, an attempt of the study has been made to the detailed morphometric characteristics of Vincharna watershed, which itself is part of the Sina river basin in Ahmednagar district, Maharashtra. Morphometric analysis was done to determine the drainage characteristics of Vincharna watershed using topographic maps and SRTM DEM (30 m Resolution). The comparative analysis of two different data sets, like toposheet and remotely sensed data has been done. The drainage patterns are dendritic and parallel, the basin area covers 390 sq km. The analysis clearly indicates difference amongst the various datasets. On the other hand Arc CN tool of Arc GIS is useful to estimate surface runoff with respect to land use and land cover. SRTM, data for preparing digital elevation model (DEM), Toposheets and Geographical Information System (GIS) was used in evaluation of Linear, Areal and Relief aspects of morphometric parameters. Watershed boundary, flow accumulation, flow direction, flow length, stream ordering have been prepared using Hydrology Tool; and contour, Slope, Aspect, Hillshade have been prepared using Surface Tool in ArcGIS software. Different thematic maps i.e. Stream Network, Slope, Relief, Aspect, Hillshade have been prepared by using ArcGIS software. Based on all morphometric parameters analysis; that the development in erosive processes of the area by the river has been progressed beyond the maturity and that indicates the lithology had an influence in the drainage development. The calculation of surface runoff clearly indicates the available impervious surface, which perhaps useful in management of ground water. These studies are very useful for planning rainwater harvesting and watershed management.

108

A GIS-Based Approach in Drainage Morphometric Analysis of Nalganga River Basin, Buldhana, Maharashtra

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The analysis of morphometric parameters with the help of RS and GIS would prove a viable method of characterising the hydrological response behavior of the watershed. Satellite data

is emerging as the most effective, time saving and accurate technique for morphometric analysis of a basin. This technique is found relevant for the extraction of river basin and its stream networks through Cartosat-II (DEM). In this study, Nalganga river basin a tributary of Purna river has been selected for detailed morphometric analysis. Five sub-watersheds are delineated within this basin to calculate the selected morphometric parameters viz. stream order, stream length, bifurcation ratio, drainage density, stream frequency, form factor and circulatory ratio. The drainage area of the basin is 887.86 km^2 and shows sub-dendritic to dendritic drainage pattern. The stream order of the basin is mainly controlled by physiographic and lithological conditions of the area. The study area is designated as fifth-order basin with the drainage density value being as 0.97 km km^{-2}. The increase in stream length ratio from lower to higher order shows that the study area has reached a mature geomorphic stage.

109

Evaluating Acceptability of Predicted Topographic Wetness Index(TWI) in Mountain Catchments

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Soil moisture condition being a very important parameter in many application areas, especially in geomorphology and agriculture, has been computed through various methods to perfect the prediction. Topographic Wetness Index (TWI), that reflects the soil moisture distribution as a continuous surface, is mainly dependent on slope, slope direction and contributing area. However, cell size for computation of TWI in a raster data model has a significant bearing on the computed values. Many researchers have been made to make the predicted TWI value to relate ground soil moisture regime. As we tend to use TWI as a surrogate measure for soil moisture condition on the basis on the basis of the available function in various proprietary software or by using map-algebra to calculate it; there is a need to validate it before using it. In the resent study a small mountain catchment has been selected to correlate the TWI value with the actual soil moisture readings. DiyungKho catchment in West Kameng District of Arunachal Pradesh, with an area of 2472.26 hectares has been traversed with 49 sample points during the month of December to measure soil moisture using FieldScout TDR100 instrument with 8inch probe. TWI values have been derived using Cartosat DEM Data. For computation; TWI values at sample points have been derived using "Extract Multi Values to Points" function of ArcGIS. The same has been related with observed soil moisture data. Correlation between TWI and soil moisture for these 49 sample is negative i.e. -0.107 with a one tailed significance at 0.232. There is a high dispersal of soil moisture values around the mid values of TWI. A regression analysis run with intercept fixed at 0 seems to have a good trend: $y = 0.775x$. However, $R^2 = -0.13$ shows a poor fit. Therefore, it can be concluded that: an ideal predicted TWI surface is not fit to explain the soil moisture condition in a mountain catchment. The exercise can also be tried with soil moisture datasets generated for different rainfall or seasonal conditions.

110

Analysis of Suspended Sediment Concentration of Teesta River at High Flow using MODIS Data

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The distribution patterns of suspended sediment concentration is important to understand the morphodynamic and associated environmental conditions of a riverine area. In the case of Teestariver suspended sediment concentration is affected by the existence of dams in the upstream area. Patterns of suspended sediment concentration of Teesta river were analysed based on Moderate Resolution Imaging Spectroradiometer (MODIS) L2G (band 1) data over the Teesta river by using the advantage of its sensitivity to suspended sediment concentration. This study aims to identify patterns of suspended sediment concentration and the nature of the relationship between different ranges of suspended sediment concentration and surface reflectance. In-situ surface sediment concentration data from the Domohini gauging station were collected from 2003 to 2013(June, July, August, September and October) to calibrate 220 MODIS satellite imageries of 250m spatial resolution. Least square regression method was employed for deriving the relationship between different ranges of suspended sediment concentrations and surface reflectance. This model is then applied to generate distributed suspended sediment concentration maps of the entire river for the period of 2003 to 2013. Key achievement of this research include establishing a methodology for estimating suspended sediment concentration using freely available satellite imageries with low revisit time and developing capability for visualising spatial and temporal variation of suspended sediment concentration of the Teesta river and also indicate a sharp decrease in suspended sediment concentration after construction of Teesta Stage Dam III and IV.

111

Automated Extraction of Gully Network from Very High Resolution Geospatial Datasets for Sub-Catchment Prioritisation on the Basis of Rill Extension and Soil Loss

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The Garbeta tract, in the Paschim Medinipur district of West Bengal, is quite severely affected by soil loss and badland formation from extensive rilling and gullying on a lateritic terrain, especially at Gangani Danga. These rills and gullies are the primary pathways along which eroded sediments are borne away. Mapping of the narrow gully channels and the even finer rill network is thus of paramount importance in ascertaining the existing badland extent, its temporal growth and also in estimating the total amount of soil loss. These are made possible more accurately through using the highest resolution geospatial datasets available today. The terrain morphometry parameters for this surface were extracted and

mapped from a Very High Resolution (VHR – 2-m cell size) Digital Terrain Model (Bare Earth DTM), bereft of vegetation cover. These parameters were then combined to generate a pixel-based morpho-unit classification, following which, the gully-bed pixels were automatically extracted from the VHR-DTM. These were corroborated for a sample site through an intensive field-survey using a Total Station and for the whole area via overlaying on VHS imagery datasets from Worldview 1, 2 & 3 satellites (PAN resolutions of 0.50m, 0.46 m and 0.31 m respectively) and from the QuickBird-2 and GeoEye-1 satellites (PAN resolutions of 0.55 m and 0.41 m). Following corroboration, gully sub-basins were demarcated which were then analysed using a pixel-level 'depth-to-bed-from-shoulder' approach for each of the fine rills, to estimate the total volume eroded while the individual rill heads were plotted from each of the VHR images from 2003-2014, to showcase the extent and direction of the gully network expansion in the past decade. Basins showing the highest erodibility were thereby identified. Actual field data, obtained from the local Soil and Agriculture Office, of the rainfall induced erosion from an instrumented sample catchment was used to draw empirical relationships between the terrain parameters and the soil volume denuded, which was been used to refine the erodibility rating and prepare the final sub-basin prioritization map. The vegetation cover changes induced by this over the same time period were also ascertained from the MX datasets of the aforementioned VHR sensors (~1.2 m).

112

Evaluation of DEMs for Analysing Drainage Morphometric Parameters in a Mountainous Topography: A Case Study of Supin–Upper Tons Basin, Uttarakhand

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With numerous geospatial datasets now available for terrain information extraction and particularly streamline delineation, there arises questions regarding the scale, accuracy and sensitivity of the initial dataset from which these aspects are derived, as they influence all other parameters computed subsequently. In this study, digital elevation models (DEM) derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTERV2), Shuttle Radar Topography Mission (SRTM V4, C-Band, 3 arc-second), Cartosat–1 (CartoDEM 1.0) and topographical maps (R.F.: 1:250,000 and 1:50,000), have been used to individually extract and analyse the relief, surface, size, shape and texture properties of a mountainous drainage basin.

The Supin – Upper Tons basin is a part of the Tons River Basin in the Garhwal Region of the state of Uttarakhand in India. The Tons River is the largest tributary of the Yamuna River. The Supin – Upper Tons Basin is located between 78°06′–78°38′ E and 31°00′–31°17′N. The basin approximately covers an area about 977 km^2 with the perimeter being 180 km. The Supin River originates from the snout of the Khimloga Glacier bordering Uttarakhand and Himachal Pradesh. The Tons River emerges from the Banderpunch

Glacier. These rivers converge near Sankri village, about 30 km downstream from both sources of the rivers. Nestled inside a mountainous setting, the basin is a semi-elongated one with high relief ratio (>90), steep slopes (25°–30°) and high drainage density (>3.5 km/sq km), as computed from the different DEMs. The basin terrain and stream network is extracted from each DEM, whose morphometric attributes are compared with the surveyed stream networks present in the topographical maps, with resampling of finer DEM datasets to coarser resolutions, to reduce scale-implications during the delineation process. Ground truth verifications for altitudinal accuracy have also been carried out by a GPS survey.

DEMs derived from the 1:50,000 topographical map and ASTER GDEM v2 data are found to be more accurate and consistent in terms of absolute accuracy, than those generated or available DEM data products, on the basis of morphometric parameters extracted from each. They also exhibit a certain degree of proximity to the surveyed topographical map.

113

Accessing the Impact of Land Use Land Cover Change on Runoff and Sediment Yield: A Semi-Distributed Modelling Approach

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Growing anthropogenic activities in last few decades affected local or regional hydrological cycle. The effects are often region specific and depend on the rate of modification of ground cover. This present study aims to analyse the impact of land use land cover changes on surface runoff, stream flow, and sediment yield over few decades in the Indravati basin, a large sub-basin of the Godavari River. Freely available spatial and meteorological data were used to set up a semi-distributed hydrological model, SWAT. Two scenarios were constructed to simulate and analyse the effect of land use land cover change on water resources by fixing the climatic variables. Model calibration (1997-2000), validation (2001-2003) and uncertainty analysis were performed with a semi-automated Sequential Uncertainty Fitting (SUFI-2) technique. Land use land cover changes have been analysed through satellite images and transformation matrix. Study results shows that expansion of agricultural land (1.61%), urban land (0.06%) and reduction in forest cover (0.87%) and grassland (0.82%) increased the runoff (3.35 mm yr^{-1}.) and sediment yield (1.81tha^{-1}) and decreased stream flow slightly (0.43 mm yr^{-1}). Seasonally, in both wet and dry periods, runoff and sediment yield increased but the rate of increase in runoff and sediment yield was higher in the wet season. At sub-basin scale, the effect of land use land cover changes on water balance components were more prominent compared to their aggregated form at the basin scale. Thus, it was evident that land use land cover change negatively affected the water resources in the study area. Findings suggest that complex properties of large catchments sometime pose a challenge to upscale the conventional relationship between land use changes, runoff and sediment yield from smaller sub-basins to the entire watershed. Moreover, the study reveals that uses of freely available spatial and meteorological data sets for large scale hydrological modelling can yield good results in accordance with uncertainty

analysis and they can be used for management decisions especially in developing countries where paucity of data is a major problem.

℘ URBAN GEOMORPHOLOGY ℘

114

Drainage Problems and Water Logging in Kolkata: A Comparative Study in Some Selected Parts of the City

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The city of Kolkata (previously Calcutta) has a long evolutionary history since the year 1690. The native habitable origin is said to be from the Sutanuti-Gobindapur area which is presently a part of the old central Kolkata. With time and the large exodus of people from the surrounding regions from Bengal, Bihar and even Bangladesh, the city continued to spread along the major transport axis on all sides. The recent inclusions of habitations to the Kolkata Municipal Corporation being along the Diamond Harbour Road at the south and south-western part; and Dum Dum Road towards Salt-lake and Rajarhat areas of Greater Kolkata, where it is observed that highly dense, unplanned and haphazard settlements have grown. This problem looms even at the core of the city in the College Street area that has been a part of the original habitation where very old houses and newly built apartments stand together in a most congested manner. At this point, the prime infrastructural need that is at stake is the proper drainage outlet that was not taken care of before these areas became so densely populated. This paper highlights the problem of water logging due to drainage inefficiency in College Street, Rajarhat and Behala areas on comparative basis. Purposive random surveys of the households have been done for the perception study to water logging. Auto-level surveys and DEM images have been processed to identify the changing elevation scenarios in these areas. The results show that insufficiency of drainage channels to cater to the ever increasing local users, marked unevenness and alteration in ground elevation, closure of the original wastewater canals and clogging of drains with non-biodegradable wastes to be the prime factors to this anthropogenic hazard. Proper maintenance of public areas, roads, drains, sewerage lines and canals along with proper planning of infrastructural facilities are necessary before developing an area as a built-up region.

115

Flood Hazard and Its Management in Lucknow City

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Flood is one of the characteristic features of the Lucknow city and is a regular phenomenon in the area due to its urban dynamics during the monsoon. In Lucknow city particularly two types of floods have been identified: one is purely topographical occurring along the flood

plains of Gomti river, which is aggravated due to urban flood dynamics and another type is in the form of localised waterlogging during the monsoon. The important factors of urban flooding in the study area are low-lying topography, heavy rainfall, unplanned urbanisation, increased surface run-off due to widespread concrete urban surfaces, and disappearance of natural drainage system like ponds, lakes, etc. and of existing drains due to indiscriminate encroachments. Choking of existing drains, improper and inadequate drainage system and faulty civil engineering have further aggravated the situation of urban floods in the city. Flood hazard in Lucknow city is thus, the result of interaction of all above mentioned factors which played a crucial role in creating flood havoc. One recent widespread flooding occurred in 2008 and was one of the largest since 1960 (HFL: 113.2 m) when Gomti was only 69 cm below the danger level. The floodwater of Gomti river inundated several parts of Lucknow in 2008, including the Gomti Nagar area of the city owing to incessant rainfall in the region. The flood in Gomti did not even spare Vipul Khand, the posh locality of Gomti Nagar area, where many bureaucrats and VIPs reside. Besides, the riverwater has inundated its nearby localities and caused major hardship for the city. In the present paper, probable flood affected areas have been identified as low lying areas having high waterlogging vulnerability through digital elevation model.

116

Geomorphic Analysis of Rural to Urban Landscape: A Case Study of Nasik Urban Agglomeration

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Understanding of landscape transformations from rural to urban is important for landscape planning in areas of mixed urban-rural land use on the periphery of many cities. Nasik city is the third most urbanised and industrialised city of Maharashtra state after Mumbai and Pune. The present work attempts to study and understand the nature and state of rural to urban landscape transformation that have occurred on the urban fringe areas of Nasik urban agglomeration. The study also aims to evaluate the impact of rural-to-urban landscape transformation on channel morphology, riparian areas of the streams flowing through urban fringe areas. Analysis shows that significant changes have occurred in landscape. The study also indicates that the rapid growth of city has destructive effects on the catchment areas of streams. Geomorphic features, drainage network, hills, and pediments are highly altered and modified as per requirement of urban infrastructure and urban development.

117

Importance of Urban Geomorphological aspects for Disaster Management: A Case Study of Siliguri, West Bengal

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Disaster management is a collective term encompassing all aspects of planning for and responding to disasters including both pre- and post-disaster activities, it may refer to the management of both the risks and consequence of disasters. Among the various natural hazards, earthquakes are considered to be the most catastrophic one and reducing its disastrous impact is most difficult due to its unpredictability and severity. The impact of earthquake hazards becomes more severe in urban areas as compared to rural areas due to population concentration, varying built-up environment and concentrated economies. Experiences reveal that till now, in India, the effort to mitigate the disasters relies only on structural and engineering measures. As far as planning is concerned, till now, its main role is recognised only in the post-disaster situation in terms of reconstruction and rehabilitation. Its role in a pre-disaster situation, i.e., for disaster mitigation is not realised. This paper focuses on the role of geomorphology in the prevention of natural disasters, where their impact has devastating consequences. Concepts such as natural hazards, natural disasters and vulnerability have a broad range of definitions; however, the most significant elements are associated with the vulnerability concept. Terms such as natural and human vulnerabilities are studied and taken into account for prevention and mitigation of natural disasters. The study area Siliguri lies in seismic zone 4 and is prone to earthquakes and tremor between 6.5 and 7.0 on Richter scale as evident from past events of earthquakes and also through local perceptions. The other aspects like epidemics and floods are secondary in the city. Therefore, this paper deals with only one aspect, i.e, earthquake. The objective of the work is to come up with micro-zoning of vulnerability of the city area and to propose vulnerability mapping as a tool for disaster management. Secondary data was mainly used and some primary survey was done for the paper. The outcome of the paper would be the general methodology for creating vulnerability maps for urban areas and to use it as a tool for disaster management in any other urban areas.

118

Extension of Natural Levee along the Hugli River in Chandannagar Municipal Corporation Area, West Bengal

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Chandannagar emerged as an urban settlement after engrossed by Du Plessis as the director of French Government in 1731. It is situated at the right bank of the Hugli river, on its natural levee. It is a part of the of lower deltaic plains of the Bengal. The elevation of the area varies between 5 and 7.5 m, and the general slope is less than 3°. The natural slope increases towards the western part of the region. The present paper is an attempt to find out

the extension of the natural levee in the present Chandannagar Municipal Corporation area. Dumpy level survey has been applied for detail contouring of the region to find out the extension of the levee region. The paper also tries to explain whether the levee region is interrupted due to human interferences.

119

Informal Land Use Causing Drainage Congestion in the Sonai Basin Area and its Surroundings, North 24 Parganas, West Bengal

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Sonai is a channel of the Hooghly system, originating from the Barti *bil* of North 24 Parganas district and terminating at Bagjola *khal*. It lost its rejuvenation capacity due to the unauthorised reclamation of the land by real estates. The present work focuses on the informal land use system and some implications related to drainage congestion and water logging of the basin area. As a result of informal urban expansion, water bodies are filling up continuously by waste materials. It is found that the clusters of houses are standing over the bed of the Sonai itself in Khardah town. Illegal constructions are resulting in haphazard urban morphology and degraded drainage function. Environmental health of the basin is deteriorating fast. To ensure an efficient urban sewerage system, an urgent need is to restore the Sonai. Keeping everything in view, the present work suggests some measures through a schematic management frame which may help in solving the urban flooding problem and other associated hazards. In order to achieve the aforesaid purpose, the authors have adopted certain methodologies comprising of pre-field, field and post-field studies. Empirical observations are also made in the basin areas. Finally, the geomorphic problems are identified, and the ways to tackle them are outlined.

120

Urban Flooding vis-à-vis Precipitation Trends in the City of Kolkata

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Urban flooding and waterlogging are common phenomena in both developed and developing countries. Kolkata (formerly Calcutta) is not an exception. The city started its journey in 1690 to become the former capital of India, and now the capital of the state of West Bengal. It has a huge pressure of population on the cityscape. The city's drainage system is very old and regular siltation has caused reduction of its carrying capacity; hence, heavy precipitation causes often leads to urban flooding. This paper attempts a critical assessment of urban flooding vis-à-vis precipitation in Kolkata, and the trend of such flooding in view of the city's drainage system. Downscaling of Global Climate Model (GCM) or Regional Climate Model is required for accurate prediction of the future precipitation scenario. Although, different models give us varied results, finding the best

model for future prediction of urban flooding is one of the focal issues of this paper. Observed daily precipitation data of Alipur in Kolkata for the period of 113 years (1901-2013) have been used for the analysis. The results show that the city is likely to face more urban flooding in the future.

121

An Assessment of Waterlogging Attributes: A Case Study of Southwestern Suburban Area of Kolkata

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The riverine city of Kolkata with its characteristic physical set up is a classic example of human induced influence on the entire hydro-geophysical characteristics of the region leading to several geomorphic hazards like waterlogging. This has a profound subsequent implication on social and economic facets of the inhabitants of the area. Here the forms of land instead of landforms play considerable role to affect the day to day activities of the urban population. Sometimes the very form of land with its micro-relief variations, if not properly planned, implemented and maintained, pose serious threats to the citizens. The lesser growth of urbanization in the southwestern part of the city (Behala) geared up substantially after 1980 to make room for huge influx of internal migration from the city proper. With the widening as well as construction of road connectors, the accessibility of these areas has improved to a great extent. This has generated a spurt of private land transaction and development activity in these areas. As a result, indiscriminate encroachment on green areas, wetland and water bodies are taking place. Wetlands made way for new neighbourhoods which are flood prone and drainage proved to be difficult, expensive and ineffective in the rainy season. The filling up of backswamp in a haphazard way leads to frequent waterlogging in the area paralysing the daily chores of life in the rainy season. In the absence of planned drainage facility, the local residents build their own household-based small drainage outlets themselves without any knowledge of or concern to the actual land condition. Thus over period on the faint slope of the delta, an anthropocene micro relief developed due to such reckless landuse leading to distortion of natural slope. Hence a messy drainage network has been evolved through decades of neglect. The research question as well as the objective is to find out the role of human-induced attributes in assessment of water logging of the area. The principal component analysis helps to find out variables, which are most strongly correlated in assessment of waterlogging situation.

122

Study of Urban Land Use: A Case Study of Bhairoba Nala Watershed Area, Pune, Maharashtra

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Water bodies have been historically endangered to deprivation due to urbanisation, agriculture and industry. The influence of urbanisation on watershed's micro ecosystems is difficult to evaluate, due to many interacting variables. Understanding land use change is critical, as these anthropogenic processes cause impervious surfaces which can have broad impacts on the environment. Mapping these land use conversion patterns is the first step to understand the urban progression. Due to increase in urban built-up spaces, many agricultural and barren lands are getting converted into residential and supplementary uses. Urban growth prediction models have been extensively studied with the overarching goal to contribute in sustainable management of watershed areas. In this present paper using a qualitative research approach, an attempt has been made to assess adverse effects of land use change due to urbanisation and its impact on Bhairoba Nala watershed area as a case study. This paper illustrates how combining a Remote Sensing (RS), Geographic Information System (GIS) and statistical models can help the understanding of land use change and the effects of watershed urbanisation. This work uses Q-GIS software to process land use data, PAST software and SURFER software to plot residual plots results carried out by multivariate as well as bivariate regression residual plotting of different variable were compared and the patterns of distribution with maps were prepared for change detection as well as to understand future trends of urban land use.

123

Changes in urban Water Bodies of Kolkata Municipal Corporation area: 1825-2007

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Different parts of Kolkata Metropolitan Corporation (KMC) area are currently going through a drastic change in environment. Being an urban place, Kolkata is dotted with a large number of buildings. Sometimes these buildings are coming up in the vacant places. With the demand of vacant place, the filling up of the water bodies has been a pernicious practice by the property developers as well as poor marginal people like slum dwellers.

The objective of the present work is to identify the water bodies of Kolkata Municipal Corporation and trace their evolution during the 1825–2007 period in GIS platform. To examine the change in number and area of water bodies in KMC, maps and satellite images of four different years (1825-32, 1941-42, 1964 and 2007) were used—Lottery Committee Map of 1825-32 (RF: 1/6,465), Survey of India map of 1943 (RF: 1/21,120), Corona Space Photo (Resolution ~ 2m) and IRS-P6 L4mx + IRS-P5 PanA image of 2007 (Resolution: 2.5

m). All the maps and images were georeferenced and the water bodies were extracted by digitisation.

The present study shows progressive reduction in number and areal extent of water bodies within the study period (1825-2007). This is experienced with the advent of high rise urban structures since the early 19th century. The study regarding the reduction of number and areal extent reveals that the rate of reduction is higher in the northern wards than its southern counterpart. The northern wards were primarily urbanised with the initiation of the British rule in India and experienced drastic reduction in water body areas. The spatial distribution of water bodies shows a shifting trend towards the eastern and south eastern fringe areas which reveals the rural to urban transformation characteristic of the city.
The decline of water bodies in the city area has resulted in a lot of problems, which includes water logging, over exploitation of ground water, lowering of ground water level, pollution and eutrophication. The solution to these problems is also addressed in the present study.

124

Rainfall Dynamics, Changing Cityscape and Waterlogging in Kolkata: Understanding Linkages

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Urban Waterlogging in Kolkata in every monsoon has become a common seasonal phenomena like many cities in the developing world. The historical records have documented the waterlogging in Kolkata in colonial era and since then the trend has increased manifold in a more intense form with the rapid urbanisation and consequent landscape changes. This urban waterlogging is basically related to the carrying capacity of the city's underground combined drainage and sewerage system built long back in 1855. The ageing, improper maintenance and structural subsidence have reduced its carrying capacity over the years. This structural impediment coupled with the anthropogenic intervention in form of changing urban cityscape has lead to the formation of waterlogging pockets in Kolkata during monsoon. In addition, the occurrences of high intensity rainfall related with the cyclonic depression during the late stages of monsoon have also act as catalyst to this problem. This work attempts to examine the linkages between the nature of monsoonal rainfall and the severity of waterlogging along with the study of changing urban morphology. It analyses the dynamics of monsoonal rainfall in Kolkata considering a range of factors. It also studies the variability of rainfall considering the rainfall data for two weather stations located in Kolkata. All statistical analyses are executed in SPSS (v. 11.5). Landscape changes are detected through satellite images processed in Erdas Imagine (v. 9.0). Thematic representations are done in ArcGIS (v. 10.1) and QGIS (v. 2.12.3. and 2.8.3). The study reveals that the rainfall variability both in temporal and spatial context coupled with the infrastructural lacuna and that urban sprawling have increased the vulnerability of flooding in Kolkata.

SUSTAINABLE RESOURCE MANAGEMENT, PLANNING AND GEOMORPHOLOGY

125

Geomorphology and Society: A Political-Economic Interpretation of Earthscapes

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Earthscape is a relatively new term to mean 'any part of the global earth system that can be seen in a single view'. This supposes to identify a piece of the earth's surface holistically, be it having predominant natural elements or it being heavily altered by anthropogenic process, or a mix of both. Since the Anthropocene is considered as a distinct geological age to recognise human beings the most prominent agent of irreversible landscape development, this epoch is marked by very intricate relationship between geomorphology and human society. The relationship, however, has been very dynamic which can be interpreted in terms of political-economic perspective of human history. The contemporary earthscape is definitely an accumulation of anthropogenic built-up elements produced due to continuous change in land use land cover for agriculture, mining, industries, urbanization, etc. The so called progress of human civilization bears several testimonies of exploitation of natural landscape by men over the last few centuries to necessitate conservation of the natural elements within the man-made cultural landscapes in the recent times. The feudal and colonial tyranny practically robbed the nature and also the people surviving on the natural resources. Degradation of natural landscape due to irrational and/ or over utilization was the ultimate outcome. The post-colonial period and also the recent globalization of trade and commerce have facilitated world-wide redevelopment of landscapes with much emphasis on high-intensive agriculture, destructive mining, imbalanced hydro-geomorphic environment, unsustainable urban-industrial growth, etc. Huge increase of population, especially in the global South, and significant shift in occupation pattern from primary engagements to tertiary service sector have promoted artificial landscaping (e.g. smart cityscape), which in many of the cases have been found to be socially exclusive favouring the limited number of wealthy people. This review paper, based on analysis of existing literatures and information, is an attempt to address some of these pertinent issues concerning geomorphology and society for human development through sustainable resources management particularly of the developing countries of the tropics, like India.

126

Spatio-temporal Analysis of Groundwater in Semi-Arid Region in Bhiwani District, Haryana

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Groundwater is a replenishable but finite resource. It is stored in the saturated zone below the earth's surface. Water level fluctuations are caused by the amount of rainfall that helps in recharging and discharging the groundwater in the aquifers. But excessive use of this

replenishable resource may lead to its depletion that will lead to the serious consequences. The present study focuses on the spatio-temporal analysis of groundwater semi arid region of Bhiwani district that lies in the South western part of the Haryana state. The groundwater level in the semi arid region, is totally dependent on the rainfall and as there is no river in this area, therefore the water usage is totally dependent on the groundwater, which is the main reason for its depletion in the study region. The present study is based on the secondary data such as Groundwater Level, usage of groundwater in different sectors and Rainfall on temporal basis which have been collected from District Ground Water Cell, Bhiwani and the rainfall data from Sadar Kanoon Go Branch. Further, the study also analyses the correlation between groundwater recharge and occurrence of rainfall in the study area. All dataset has been compiled using Excel and then various thematic maps have been prepared, analysed and interpreted using ArcGIS 10.0 Software.

127

Climatic Constraints on Agriculture, with Special Reference to Crop Production, Combination and Diversity

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Agriculture is highly dependent upon the climatic elements like rainfall and temperature. A significant change in these parameters has an influence on crop combination, crop yield and also crop diversification. This paper attempts to present a relationship between crop and climate for West Bengal based on the statistics of major crops (2010-11) and climatic datafrom 1901 to 2010. For this purpose MANN-KENDALL Test is used for trend analysis of climatic elements and climatic variability. To analyse climatic variability, consistency of rainfall has been compared with productivity Index and crop diversification Index. Results indicate that areas having significant positive rainfall trend are highly productive and the areas with maximum variability of rainfall followed the adaptive strategy of crop diversification.

128

Estimation of Water Budget for a Sub-Catchment Area in Bhagirathi-Hooghly River Basin, West Bengal: A Case Study

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Water budget estimation is an important tool to assess the current status and trends in water resource availability in an area over a specific period of time. Almost everyone is influenced by the water budget estimates because they are often central elements of policy making. Stakeholders directly involved in decision making may require more detailed information about the water available. Precise evaluation of water budget is essential to water assets

administration and feasible improvement in sub-catchment area. Keeping in view, the goal of this paper is to gauge the water budget of a sub-catchment area of Bhagirathi-Hooghly basin, stretching out from Katwa to Nabadwip. Sub-catchment area delineation map is prepared with the help of GIS. Hydro-meteorological and physical information for last forty-five years are gathered from primary and secondary sources. The full process of water budget is analysed by different hydrological techniques with empirical methods. The sub-catchment area is portrayed by one rainy season and two dry seasons amid the year. The rainy season has four months term and dry season, eight months. The outcome of this study may be incorporated to adopt the future water allocation problem and control and redistribution of water resources in time and space of sub-catchment area.

129

Identifying Problems and Analysis of Change Detection of Land Use Land Cover in Hyper Arid Lands of India: A Case study

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Indian arid ecosystem is characterised by limited and scarcity of seasonal precipitation. It has been identified that crucial problem of Indian desert is stress of human and livestock population on fragile and vulnerable ecosystem which endangers the potentiality and sustainability of the region. Long term incidence and occurrence of meteorological stress in an arid environment have a positive correlation with the vulnerability to desertification risk. The meteorological stress makes land incapable and threatens its sustainability. This situation renders harsh and unfavourable periodic environmental strains on human beings, livestock population and plant species. The study of land use and land cover change in Geography is very important to understand the human-environment interaction. While on the one hand, land cover is the depiction of the physical surface of earth, land use, on the other hand is a strictly anthropogenic phenomenon, which, most simply means the human use of land. A change in the land use land cover is an indicator of human induced landscape change and thus, a measure of the scope and intensity of human influence on environment. In the present paper an attempt has been made to enquire the several processes of land degradation hazards in operation in hyper arid environment and future prospects in the study area.

130

Prospects of Land Use and Land Potentiality towards Sustainable Development in Kalej Khola Basin, Sikkim: A Geo Environmental Approach

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The present work is aimed to establish a comprehensive, analytical and scientific background of land use - land potentiality prospects which will fulfill the basic objectives of sustainable developmental strategies. The study area is Kalej Khola basin which is under

Tista river system and comprises of hilly, rugged physiographic alignment with moderate to poor land potentiality. A geo-environmental approach, primarily based on detail field study and semi-quantitative analysis of land use change magnitude with a probable determination of land potentiality, is used here. For the present work, objectives are as folows: Identification of the present land use in meso and micro level, analysis of soil macro nutrients as NPK and other basic characteristics and preparation of land use change detection map following their magnitude of positiveness and negativeness towards the probable prediction of land potentiality in a semi-quantitative manner. For ensuring the study and coping the results related to the hierarchy of land potentiality zones, data are used both from primary and secondary levels. Secondly, collected soil samples are tested and analysed for determining the nutrients as well as other components which have a direct control on land use changes within a particular time span. Thirdly, using the Landsat data of 2005 and 2015, block level land use change detection has been done in a positive and negative magnitude and formulated in a semi quantitative approach. All these have revealed a strong correlation between nature of soil and land use changes, which is roughly tends to positive in eastern part and gradually decreasing toward the western less mature soil covered rugged riverine segments of middle Himalayan part of West Sikkim. The second phase of results consist of hierarchy of land potentiality zones comparing the land use change detection, which is moderate to poor in those areas where the negativity of land use changes are moderate to very low and other sections are related respectively.

131

Shifting Course of a Part of the Kaljani and its Impact on Landuse and Human Existence in a Part of Chapatali Village, Alipurduar-I, West Bengal

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From the days of hoary past, the existence of human habitation is generally influenced and congruent with the riverine flow. Shifting in the course of a river and modifications in channel morphology is a common feature in sub-Himalayan West Bengal. The present paper is a modest attempt to examine the magnitude of shift in the course of river Kaljani during recent years and to evaluate its impact on land use land cover pattern along with vulnerable human livelihood. To arrive at suitable deductions, a detailed primary and secondary survey was conducted on a part of Chapatali village in Alipurduar-I block to observe the dynamism of the river and the adaptive challenges of the inhabitants' concomitant to the frequent changing course of this river. At present, Kaljani river shows sign of gradual northward shift and the palaeochannel of the river is slowly turning into expansive agricultural tract on account of newer alluvium deposition in bed of the palaeochannel. Flooding is the obvious outcome of this prolonged and erratic fluvial behaviour. Henceforth, embankments are built along both sides as a management practice. But now-a-days, with progressive shifting of the river beyond the embankments, flood continues to be a pressing problem that demands immediate attention. The river probes into the nearby settlements inducing human displacements. It bears an impact on their daily life chores. In this present study, the focus is

given on adjustment of human life with the vagaries of the river course and to analyse the effectiveness of anthropogenic endeavour to cope up with the dismal situation.

132

Analysis of Recent Trends in Groundwater Levels in Selected Areas of Barddhaman District, West Bengal

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In the present study an effort has been made to evaluate the seasonal and annual trend of groundwater development on selected groundwater regime of Barddhaman district, West Bengal. Two parameters have been selected to understand the situation of groundwater regime in the studied areas: (i) Depth to water level in Pre-Monsoon and Post-Monsoon, and (ii) trends of water level (2000-2015). Depth to water level data was collected from 13 groundwater monitoring wells in the community development blocks of Jamuria, Manteswar, Memari-II, Katwa-I and Katwa-II of Barddhaman district by the Central Groundwater Board, India. Long-term water level fluctuation has been analysed by comparing the decadal mean water level data with depth to water level data. Seasonality dominates the variants. Depth to water level data has shown significant changes during Pre-Monsoon and Post-Monsoon seasons. During Pre-Monsoon season, majority of the wells (54%) show water level between 20-40 m bgl. whereas, in Post-Monsoon season only 39% of them show water level between 10-20 m bgl. Annual fluctuation of water level also shows variation in it. Continuous falling trend of majority of the analysed wells in term of depth to groundwater level indicates continuous declining of groundwater level with an increasing rate higher than the previous decade. Declining trend of groundwater level is more profound in the area of older alluvium zone where agricultural activity is responsible for limitless withdrawal of groundwater for irrigation purposes.

133

Erosion - Deposition Induced Changes in Socio - Economic Utilisation of Mid-channel Bars: A Case Study of the Hugli River

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Morphodynamic characteristics of the tidal Hugli river, West Bengal, form many mid-channel bars in its upper part. These bars are utilised for different anthropological activities like agriculture, fishery, tourism, power plant development and so on. For the present work, four mid-channel bars – Gournagore, Bidhyanandapur *char*, Sabujdwip and Mangaldeep – have been selected from the Hugli district, between 23°01'19" – 09'11"N and 88°26'13" – 32'34"E to represent evolution, human interference, management etc. The mid-channel bars are also used for the agriculture, which leads to modification of their geo-environmental status. Gournagore char is slotted for development of a Power Plant since 1994.

Mangaldeep, a newly developed char is planned for use in tourism. The tourists undoubtedly play an important role in the nearby bar of Swabujdwip since 1984. However, due to lack of proper planning and sustainable management decisions, their main purpose is often ignored. In light of the above, the present study aims to find out the pattern of human-environment relationships seen in the bars. It also aims to help policy formation by identifying the causes of the hazards over space and time and their impacts on the bars.

134

Estimation of Flood Discharge for Damodar River to Reconnect Its Earlier Channels

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Damodar fan delta has lost flood water dispensing capacity due to its ineffective drainage network as the major distributaries like Kana Damodar and Gangur are disconnected from the main channel at Selimabad and Palla point respectively in the district of Burdwan due to construction of embankment. This study attempts to estimate the minimum flood discharge required in the main channel to link the disconnected channels with an aim to analyse the feasibility of flood water diversion through these channels. Study has been done at Jamalpur, Selimabad and Palla for estimating discharge at different stages. It has been assumed that the discharge at Selimadad and Palla is same as that of Jamalpur because these three sites are situated within a short distance from each other and there is no significant tributary or distributary in this reach. Rating curve has been prepared for these three sites and extended by logarithmic method as found necessary. Difference of bed level between Damodar and the disconnected channels has been measured through levelling. It is revealed after field survey that presently the disconnected channels are at a higher elevation than the level of the main stream. It has been estimated that about 1,925 cumecs and 1,300 cumecs discharge in the main channel is required to reconnect the channels of Kana Damodar and Gangur respectively.

135

The Effect of Human Interference on the Flow Character of Thoubal River, Manipur

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Thoubal river in Manipur has come under immense pressure due to various kinds of anthropogenic interference in the fluvial system. Human induced bed material extraction, flood plain excavation, abandoned channel excavation and harvesting of sand brought down from the nearby terraces and hills has disturbed the equilibrium of water discharge, sediment load and flow character, and has degraded the water quality in the process. This paper focuses on the effect of the anthropogenic activity on the river system. The area of study

stretches downstream of the Thoubal multipurpose dam to Yairipok. Based on a careful and detailed analysis of sediment size and quality of water and study of the pits developed due to excavation, the paper highlights the need for immediate attention to the problem. The paper further argues that at present the problem may appear to be a local issue but if it is not taken seriously and controlled immediately, it might affect the whole fluvial system. In such a scenario, the river would lose the ability to maintain its natural equilibrium and thus turn into a hazard.

136

Evolution of an Oxbow Lake and its Impact on the Adjacent Society: A Case Study of Bhagirathi Cut-off at Purbasthali, West Bengal

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Oxbow lakes are natural inland water bodies generally found in the riverine floodplain on either side of the river as a form of palaeochannel. People inhabiting near an oxbow lake have access to some ecological and economic benefits viz. water purification, flood control, food storage, water quality, agricultural production, fisheries, and recreation. Misuse of an ox-bow lake may be hazardous to the adjacent people as it becomes polluted and silted up by anthropogenic activities. Thus sustainable and proper utilisation of the ox-bow is needed for economic development of the concerned area. The present study focuses on Purbasthali oxbow lake created by river Bhagirathi on its right bank near Nabadwip town of Nadia district, West Bengal. The present research addresses the emerging scenario of the lake and analyse the impact of evolution of the lake on the adjacent society in terms of agricultural changes, occupational restructuring, economic vulnerability and migration of the local people. In this work, satellite imagery of different time periods (1973, 1990, 2004, and 2014), toposheet and field data (water and sediment quality, dimensional changes of the lake, household data) are used to detect the present condition of the lake and the rate of eutrophication. Finally, for the development of the society, two hypothetical alternatives viz. development of society without lake and development of society with the lake have been critically assessed based on ground verification. The cost benefit analysis is inclined towards development of society with the lake, as it entails the philosophy of sustainability which will protect the lake ecology and environment from further deterioration.

137

Rainwater Harvesting in Watershed Scale at Drought Prone Districts of West Bengal

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Analysis of climatic records of Purulia, Bankura and Paschim Medinipur, collected from IMD, Pune shows that temperatures of post-monsoon months are increasing steadily in almost all the districts. Rainfall is concentrating in the monsoon months. A considerable percentage of annual rain concentrates in a single storm rainfall event and this percentage

may be as high as 35%. Apart from this, the cumulative effect of undulating terrain, coarse and bare soil, and location in the interfluve zone between the Kangsabati and the Shilabatiriverlead to immediate runoff and water scarcity during prolonged dry period in the area under study. Month wise runoff, evaporation and infiltration were calculated to compute thewater budget for small sub-watersheds in the upper catchment. Analysis shows that retention of 5 to 8% of annual runoff may be sufficient to solve water scarcity. Rainwater harvesting by constructing check dams, excavation and restoration of ponds and roof-top rain water harvesting may be effective to address the problem. Calculation shows that a reservoir with a water holding capacity of 6445 litre may be effective to manage water demand of a family of four-members in worst drought condition that has a recurrence period of 20 years.

138

Geomorphology & Rehabilitation of Environmental Refugees of Sundarban: A Study of Jibantala Colony, Sagar Island, West Bengal

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Ghoramara, a small island situated in the Hugli estuary, is facing rapid coastal erosion for the last four decades. As a result, a large number of people lost their homes and livelihood. From time to time, many families were shifted to various parts of Sagar, a large and stable island situated south of it. Such a rehabilitation programme for 150 families was initiated in 1995 at the Jibantala area of Sagar island. The colony is situated on a reclaimed mudflat 3 km from the eastern mouth of Chemaguri, a major tidal creek of Sagar that bisects the island into two. At monsoonal spring tides, the Chemaguri often rises above the embankments of the resettlement colony and inundates large areas. The saline tidewater cannot drain out easily and parts of the colony remains waterlogged for weeks. The colony inhabitants are forced to collect potable water as well as freshwater for household use from distant tubewells and ponds that are owned by other people. This often leads to social discordance and even skirmishes. To solve this problem, the local government constructed a lock gate at the eastern mouth of the Chemaguri to prevent the tidewater from entering into it. But it is found that a similar lock gate at the western mouth of the Chemaguri resulted into degeneration of its western section. If water entry to eastern part is also controlled through lock gates, with time the Chemaguri will degenerate completely and will result into collapse of the natural drainage of the eastern Sagar.

139

Fluvial Dynamics and its Impact: A Case Study on Panchanandapur and Surrounding Region, Malda District, West Bengal

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River in its lower course has very low gradient, which always forces it to flow in an oscillating manner. In such condition, dynamic nature of the river accompanied with bank

erosion is very common in every rainy season. The present work deals with the problem of migratory nature of the channel, mainly along the left bank of river Ganga at Panchanandapur and surrounding region in Malda district. River shifting associated with severe bank failure at Panchanandapur was active till 2006 and after 2006 the process gradually ceased due to diversion of main flow from main channel to central channel. This study is a modest attempt to investigate and analyse the causes, mechanism and past and present trend of river shifting related with bank failure. The methodology of the study comprises of relevant literatures including the reports of Irrigation and Waterways Department of Government of West Bengal, reports of Keshkar and Preetam Singh Committees, Contingency Report of Malda district etc., and followed by intensive fieldwork. This work also used topographical maps, satellite imageries in RS-GIS environment. The collected primary and secondary data are analysed to understand the status of river shifting and bank erosion and its effects on this particular fluvio-geomorphic region. It is found that the migratory nature of the Ganga in the study area controls the natural lifeline of the local inhabitants. As a result, a large section of population are suffering from land loss and has become jobless. In this context landscape diversity measuring indices are estimated to develop plans and strategies to cope with such hazardous situation. Possible remedial measures have also been suggested.

140

The Study of Developmental Perspectives of Paschim Medinipur of West Bengal by Dividing the District into Physical Compages: A Geographical Review

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In the postmodern era of geographical development, spatial concept is getting immense importance. For the geographical analysis both the ideographic or regional and nomothetic or systematic approaches are followed. In present study a regional analysis is done by dividing a region into various compages or small complex interactive compartments for better resource management. The study area is the whole Paschim Medinipur district which is curved out from the erstwhile Medinipur district .Owing to its geographical position, the district has most varied geomorphological and physical aspects. The north and northeastern portions of the district cover the eastern part of Chhotanagpur plateau and consist of hard lateritic formation with highly undulating surface. Middle part shows little undulation and thick alluvial deposition and the eastern part is entirely plain land. Kangsabati, Subarnarekha, Dulung and their tributaries drain the district. The vegetation concentration is found in the western part only and the middle and eastern part is favourable for agriculture. After detail study of the physical and agriculture attributes, an attempted is made to divide the district into 95 small interactive wholes or compages. The compage map is prepared following the boundary of the Gram Panchayats of the district along with the superimposition of various maps like soil map based on taxonomic soil classification, vegetation coverage map, drainage map (distance from the river), groundwater level map, agriculture, irrigation facility etc. for getting composite characteristics of the district. After

the details study of the physical characteristics of the compages, these are categorised based on their potentialities. The critical problem-oriented compages are identified through cumulative ranking method. Finally, some suggestive measures are taken for the recovery of the problems and developmental perspective by proper utilisation, sharing and distribution of the available resources.

141

Assessment of Drinking Water Quality in Jorhat Municipality

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Water is an important constituent of all living organisms present on the earth and has most significance for humans for adequate life. The quality of water is mostly polluted by weathering, erosion, municipal as well as industrial wastewater. The municipal and industrial waste water is the major cause of pollution while surface water runoff is a seasonal, mostly polluted by climatic condition. Water quality monitoring has a high priority for the determination of current conditions and long term trends in effective management rendering a major impact in the anticipation of water transmitted diseases. Almost the entire municipality harness water from both surface and groundwater for public distribution through four organisations, viz., Jorhat Municipal Board (since 1951), Assam Urban Water Supply and Sewerage Board, Jorhat, (since 1998), Swajaldhara Scheme (since 2007) and Marwari Thakurbari Scheme (since 1970). Water samples have been collected from these distributing sources locating thirteen sample sites within the Jorhat municipality consisting of 19 wards. Parameters like total dissolved solid, pH, turbidity, hardness, chlorine, calcium, magnesium, total alkalinity, and fluoride were determined. Heavy metals mainly iron and arsenic were noticed which makes it necessary to monitor water quality regularly used for drinking purposes. The research work deals with the evaluation of water quality in Jorhat municipality. Moreover, the work is beneficial to investigate the causes of various diseases associated with the water being used.

142

Geomorpho-economical Study of Pune in a Smart City Perspective

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Geomorphology of Pune has changed quite a lot since the last three to four decades. The urbanisation of the city and ingress of rural population has created imbalance in the economical infrastructure. This imbalance and economical turbulence is very difficult to manage. Geomorphologically, Pune city has sprawled beyond normal management. Pune has been recognised as the 'Smart City' in the month of July 2015. In this paper the authors have attempted to draw an extended geomorphological map of Pune and its nearby vicinity. In this regard the help of GIS has been taken. The development of the city and various

concrete structures have created hydro-ecological imbalance leading to water scarcity, and depletion of other natural resources. This has also resulted lesser rainfall and architectural landscape. The 'circular economy' is different than the present 'linear economy', to which most of the townships are adhered too. A circular economy is the one which utilises most of its waste materials in production process. This requires innovation, science and technology, and if properly implemented, has far reaching implications for environmental preservation. A case study of Pimpri-Chinchwad and its sewerage system also is taken up by the study to illustrate the situation at Pune.

143

Soil Conservation in Relation to Crop Productivity on Subtropical Soils in Tons Alluvial Plain, Uttar Pradesh

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Agricultural land in Tons Alluvial Plain is being degraded with soil erosion. In the region, there is a long history of soil erosion due to its relief characteristics, soil type, climate and anthropogenic influences. In fact, the faulty agricultural practices, lack of irrigation, erratic rainfall, fragmentation of holdings, deforestation, overgrazing and junction of two erosion surfaces are the main geomorphic, ecological and anthropogenic factors due to which the ravine geomorphology of the Tons Plain Region has come up. Over such region, population pressure necessitates cultivation of steep slopes while the Government prohibits cultivation of slopes >25°. But, the enforcement of this law would result in food shortages in the region due to lack of suitable land with slopes below < 25°. The most appropriate way to curb soil erosion in the region is to devise affordable agronomic means of reducing soil loss, which do not decrease crop productivity on sloping land currently under cultivation.

The research aims to test the hypothesis that contour cultivation along with application of straw mulch can decrease runoff and soil erosion rates on sloping land in Tons Alluvial Plain under cultivation and to assess the impact of these conservation measures on productivity and soil nutrient status.

Thirty runoff plots, located in three different slope angles (3°, 10° and 27°), were used to examine three cropping treatments in a replicated plot design. Treatments were downslope cultivation, contour cultivation and contour cultivation plus straw mulch. Runoff and soil loss were measured after every storm event. Soil nutrient status was measured at the beginning and end of each cropping season. Crop growth parameters and soil physical properties were measured throughout the cropping seasons.

The results show that on 10° slopes, contour cultivation alone is a suitable for soil conservation. However, use of straw mulch can hold soil moisture and increase the nutrient status and crop yield on 27° slopes. It is recommended that these measures should ensure maximum soil conservation even in extreme rainfall conditions.

144

Watershed Prioritization through Morphometric Evaluation: A Comparative Approach

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Watershed as an ideal unit of natural resources owes particular attention in response to growing human dependence on water and land resources. Realistic evaluation of watershed hydrological behavior can effectively enhance the watershed planning and management systems through studying the inter-linkages between the terrain, slope, land use, drainage and soil elements. Contextually, the quantitative morphometric analysis of the linear, areal and relief elements of a watershed is getting much popularity for conducting such a tedious activity. The prioritization of watersheds and its micro units are quite efficient to cover a wide spectrum of processes and their drivers operating thereon and thus can plausibly delineate the key areas that should get priority during designing watershed plans. The present study went through analysing the quantitative Morphometric constituents of the Jaldhaka River Basin located in the Eastern Himalayas and its southerly sloping foredeep region. Out of a set of methods that are getting popularity during watershed prioritization, this work only highlights a comparative approach comprising the simple Weighted Composite Analysis (WCA) against the Principal Component Analysis (PCA) for the entire Jaldhaka Watershed and its constituent 16 sub-watersheds (SWs). For about most of watersheds the priority scores are either remain the same or fell almost similar for both techniques. However, the results obtained by PCA were seem to be more realistic than the WCA as it highlights the primary variables only which are prominently more correlated to each other rather than the WCA which needs a large set of variables which may incur biased results as SWs recording larger values may result in larger priority scores.

145

Managing the Paradox of Water Scarcity and Abundance in Chhabalpheli - Burir Abad, Baruipur, West Bengal

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The study has been carried out in Chhabalpheli-Burir Abad Gram Sansad in Baruipur (South 24-Parganas, West Bengal), with special reference to the agricultural ecosystem vis-à-vis the water management scenario. Chhabalpheli-Burir Abad is located in a low-lying deltaic terrain characterised by dead or dying rivers and derelict water bodies, lying between two raised tracts – the Adi Ganga levee to the west and the Piali river to the east. The area experiences tropical monsoon climate with an average annual rainfall 1803.7mm. The fine textured silty clay loam soils with moderate to slow permeability are imperfectly drained, causing water logging during the monsoon months, necessitating drainage by the artificial

aid of pumping. Groundwater is found at great depths. The primary land use is agriculture and monoculture of paddy is predominant in spite of copious rainfall and surface water resources. The study is mainly based on primary data collected through field survey and mapping, questionnaire survey and repeated discussion to familiarise with the state of living and livelihood practices. Certain details have been collected from literature review. Scarcity of water in Chhabalpheli-Burir Abad is a serious problem due to inadequate storage facilities in shallow, silted and derelict water bodies, lack of tidal inflow from the Piali river to supply the canals and uneven distribution of surface water bodies leaving vast stretches of land without any water sources. Groundwater occurring at great depths cannot be extracted economically for irrigation. The low lying aspect coupled with the silty and clayey soil results in poor drainage and excessive water logging, necessitating artificial pumping for drainage. Thus, the area suffers from water scarcity in spite of copious rainfall, resulting in retarded agricultural development and poor economic condition of the farming households. This paradoxical condition can only be handled by rainwater harvesting and planning of agricultural landuse maintaining a balance between the physical and socio-economic conditions of the area. The solution lies in designing a system wherein rainwater collecting in the farmlands can be stored for use after the monsoons. Chhabalpheli-Burir Abad Gram Sansad has been divided into some areal units or Water Users Areas based on certain criteria, to be managed by a Water Users Association consisting of the beneficiary farmers. The monsoon rainfall has to be harvested in the existing water bodies. An economically gainful, socially acceptable and ecologically sustainable cropping pattern has been suggested for the area along with alternative livelihood options.

146

Wasteland Management for Sustainable Development of the Lower Jia Bharali Basin in Sonitpur District of Assam, India

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In the present study, an attempt has been made to evaluate the status of wastelands for its management through optimum utilization of existing natural resources. With this objective, a detail study of the major terrain and morphometric parameters that influence land management is made through preparation of thematic maps using satellite imageries and toposheets in GIS environment. A multi criteria evaluation of the study area is carried out adopting GIS tool to obtain a land suitability model for cropland, grazing land, forestry and woodland forestry land-use options.

147

Impact of Land Use Change on Groundwater Hydrology – A Study on Chundia River Basin, West Bengal

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Conversion of the land use from agriculture to fisheries or shallow water bodies is very rapid in Chundia river basin of Purba and Paschim Medinipur district of West Bengal due to seasonal water logging. The present work focuses on the impact of land use conversion on the ground water hydrology. Land use and land cover in both dry and wet season for the years 2005 and 2015 were digitised from Google earth satellite imagery for change detection with the help of ArcGIS, version 10.1. During this period, in dry and rainy season, agricultural land was lost by 2.83% and 0.81% of the total area respectively; but fishery or shallow water bodies had been expanded by 2.62% and 0.61% in the same period. Groundwater level had also been lowered for providing water to the permanent fisheries during dry season. Flow direction of the ground water and hydraulic gradient were changed with the change of hydraulic head. Hydraulic gradient became steep at the transitional zone between agricultural land and fisheries that indicates huge withdrawal of ground water for fisheries.

148

Sustainable Land Management Practice by Aptani Tribe, Eastern Himalaya, Arunachal Pradesh

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The degradation of land in Himalayan region have become a major concern for the environmentalist. The immediate need of its conservation and the optimal utilization of the available land resources is highly required. A sustainable development of land resources can be carried out only after a proper assessment of its capability and suitability. The good knowledge of the land capability and its suitability combined with good information of soil characteristics and its management can give a fruitful result in production and sustainable agriculture. The land management practiced by Apatani tribe of Arunachal Pradesh is an brilliant indigenous technique which is not comparable with any other tribe in the state. The main objective includes, to observe the existing land management practice by the tribe and to carry out land capability classification of the study area. The data that were used to carry out the above mentioned objectives include the topographical maps (SOI), remote sensing data products (IRS-1D LISS-IV and Cartosat DEM) and climatic and soil related data. A LULC map is prepared by visual interpretation of satellite imagery and different land capability classes were prepared using USDA classification. The land capability classification was prepared by taking the parameters such as, slope (%), existing landuse, altitude, geomorphic units and nearness to settlement. Based on that six land capability

classes were identified. The capability of land decreases towards the higher lands. In the upper ridges, the quality of the land is very poor due to decreasing in the thickness of soil cover. Whereas the capability of land is high in the valley floor due to the thickness of soil cover, good irrigation facilities, nearness to the settlement and road.

℘ GEOMORPHOSITES AND GEOTOURISM ℘

149

Geotourism Hotspots in West Bengal: Some Concerns and Suggestions

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Geoheritage sites on the earth provide impartial and well preserved record of the physico-chemical and biological processes and illustrate the evolutionary history of the planet earth. Geoheritage sites representing an earth science interest are recognised and included in the Global Geopark Network (GGN) by the United Nations Educational Scientific and Cultural Organization (UNESCO) for providing support in their conservation and protection. India too has its share of valuable Geoheritage sites. There are many interesting Geoheritage sites spread all over India of which Geological Survey of India (GSI) has identified about 90 Geoheritage sites so far. These Geoheritage sites are having high potential for development of Geoparks and for promotion of Geotourism; therefore protection of these sites are felt mandatory as they provide means for teaching geoscientific disciplines and broader environmental issues including Geohazards related issues. The paper discusses Geotourism Hotspots of India and the problems in establishing Geoparks in Geoheritage Sites in general and Hotspots of West Bengal State in particular. This descriptive type multiple case design study rely on document and archival records as the source of evidence. It is based on the critical analysis of the secondary data and is supported with the author's participatory observation on the realistic activities of the Geological Survey of India which declares important Geoheritage sites in India and makes request to state governments in India to issue necessary notifications and instructions for protection and conservation of such declared Geoheritage sites. The study searches and suggests the ways and means for inclusion of Geoparks in India in the GGN of the UNESCO as well for reducing disaster risks by promoting geotourism and sustaining development in the areas of Geoheritage sites. It also identifes the reasons for not getting recognition for inclusion in the GGN and the UNESCO support as Geoparks.

150

Estimation of Total Potential Values for Tourism Destination Sites: A Methodological Approach for Coastal Sundarban

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The development and promotion of coastal tourism are essentially needed for sustainable development, economic upliftment, and social benefit of the people of southwestern Sundarban, if it is planned methodically in the sensitive region. Tourism has become a major thrust area for the local development of the coastal belt of Sundarban for the seaside attractions and forest environment. The present work formulates a simple methodology to estimate numerically about the tourism potential for the tourist destination of the region where oral survey is conducted among the various respondent. The weighted sum method is a popular multi-criteria decision making tool that has been adopted in the present study. Various social and physico-economic attributes have been selected by this method to quantify them through rank scaling techniques. The concept of clusterisation for optimisation of tourist infrastructure cost has been used. This methodology has been applied to he four areas of southwestern Sundarban – Sagar, Bakkhali, Frejerganj and Henry island – for estimating their tourism potentialities .Final observation indicates that Bakkhali and Henry island has more potential tourism value than Sagar island and Fraserganj areas.

151

Geotourism and Wetland Conservation: A Case Study of Bariti *Bil*, North 24 Parganas, West Bengal.

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Geotourism is a kind of tourism which is based upon a combination of natural resource attractions and cultural attractions in such a consistent manner so as to promote, protect and ensure a sustainable development of the geomorphological site as a whole. The purpose of the present study is to examine wetland utilisation and protection through the lens of geotourism. The study indicates that geotourism development would help to achieve three major goals in wetland conservation and development: profit (economic), people (socio-cultural) and place (biodiversity rich regions). Based on a questionnaire survey accompanied with closed focus group discussion and secondary data sources the study on a wetland named Bariti *bil*, a seasonal natural cyclical wetland in North 24 Parganas of West Bengal, was conducted to evaluate the socio economic benefits derived from the wetland resources, geotourism potential of the wetland as a source of revenue generation, and finally its sustainability in the long run. The results indicate a biodiversity rich wetland with a potential for becoming a good tourist spot in future with only introduction of proper

techniques for sustainably conserving the wetland along with resource utilisation and poverty reduction.

152

Promoting Rural Economy through Geomorphosite-geotourism: A Study on a River Source Area and Tor

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Geomorphosite-geotourism is an important sector of tourism. In this type of tourism, landforms and landscapes are described to tourists with geomorphological explanations. In geotourism it is seen that tourists are mostly attracted to visually appealing areas. But there are several visually unattractive places on the earth which bear immense geomorphological significance like the river source area, loess plains, blind valleys, paleo-channel, tors and many others. Amongst these the river source area of Ajay in Bihar and Mama-bhagne pahar of Birbhum in West Bengal as significant geomorphosites are being dealt with. River source area is a geomorphologically vital part where the vibration of the present day civilisations can be felt. But it is seen that the villages of river source areas in India mostly lead a non-riparian livelihood with a weaker economy. Moreover, such remote river source villages do not have any recognition. Similarly the tors of any region are just scenic beauty to the tourists where most of them do not have any knowledge of such unique formation. This paper is an attempt to develop geomorphosite-geotourism at the Ajay River's source area at Saraun village, of Bihar and the tor at Mama-bhagne of Birbhum, West Bengal. This type of educative Geomorphosite tourism is not only capable in educating the tourist through edutainment but also develop the source region's rural economy.

153

Geomorphosites and Geotourism in India: Some Issues

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Certain geologic elements of nature qualify as geomorphosites and becomes worth for conservation as Geoheritage sites. Geoheritage sites not only showcase the imprints of land and rare aesthetic natural artefacts but also signals the Geohazards, the risks in the dynamic Geosphere. These sites promote geosciences literacy on environmental issues and geohazards. These sites are getting modified, damaged or partially destroyed by anthropogenic activities. Considering the scientific, cultural, aesthetic, social, and economic values of these, and the dire need for conservation of geodiversity for an understanding of earth sciences through appreciation and learning through Geotourism, the present study is made to develop the Geoheritage sites for protecting earth's legacy. The study is based on survey of literature as secondary data. India, with its diverse physical attributes, is a storehouse of rare aesthetic natural artefacts. The paper aims to highlight the Union and State Governments' initiatives on Geoparks and Geotourism. It describes the unique

landscapes that illustrate the geological processes and evolutionary history of the earth as Geoheritage sites and examines on the ways and means of protecting, conserving and valuing these geological treasure through Geotourism. The Geopark sites attract tourists and support sustainable socioeconomic and cultural development. Since the artefact of nature and landscape once lost can never be retried or damaged and can never be brought back to its original form, the paper discusses on the dire need for promotion of Geotourism. The paper discusses on the need for developing Geoparks and other issues related to promotion of Geo tourism. It also discusses the Geomorphosites in northeastern India maintained by the local communities by charging the tourist a minimum amount as user fee or entry fee. While analysing the initiatives of both the Central and State governments in India in developing Geoparks, this paper examine the impediments coming across the way of development of Geoparks. The paper concludes that the active involvement of all stakeholders in general and the local community in particular is a way for protection of Geoheritage sites, and promotion of sustainable socio economic

154

Management of Geomorphosite as a Tourist Spot: a Study of the Mama-Bhagne Hill, Dubrajpur Block, Birbhum District, West Bengal

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Geomorphosites are the geomorphological landscapes that have scientific, aesthetic, historical, cultural and socio-economic values. The Mama-Bhagne hill, a tor in Dubrajpur, is a good example of a Geomorphosite covering an area of 0.074 km^2. It is a unique landform of Birbhum district because any such isolated hillock is not found in the nearby places. The nature of its formation and expressions of landscape are unique and attractive, the balancing rocks on the hill are rare features, so such unique landscape can become very good tourist spot if the local as well as zonal authorities take some steps for its proper management. The prime objective of this study is to describe the geological background of the Mama-Bhagne hill, to examine the myths related to the hill and to promote geotourism in the study area.

155

Geomorphosites in New Zealand: their Assessment, Threats, Vulnerability and Management

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New Zealand is a unique country of geodiversity having both large-scale and individual geomorphosites. Of these at least two types, viz., (i) Volcanic and geothermal region of central North Island (specially the Taupo-Rotorua region) and (ii) UNESCO's World Natural Heritage Site of south-western part of South island consisting of high mountains (Southern Alps), glaciers (viz. Frank Josef, Fox), fiordlands (viz., Milford sound) and National Parks deserve special mention.

An assessment of this volcanic geomorphosite reveals existence of large or stratovolcanoes, polygenetic in nature, with high elevation cones and calderas (viz. Mt. Taranaki), crater and caldera lakes, active geothermal features of Rotorua, including spouting geysers, bubbling mudpods, hot springs, colourful sinter terraces, faulted areas etc. – all bearing signs of interesting tectonic and geological features. Both orogenesis and geomorphic processes have resulted in the formation of the present landscape.

Threats and vulnerability arise from natural processes like erosion, mass movement, flooding and vegetation growth, Human interference include quarrying activities, construction of roads and railways and built-up areas due to urban sprawl. Being a major site for tourist attraction (both domestic and international), the entire region is vulnerable to environmental damage. Future possibility of volcanic eruption at any point of time also looms large as a threat.

Therefore, management measures should consider risk management (in case of any emergency) and providing information to the tourists together with conservation and proper protectionary measures for the entire region which is of high scientific (geological and geomorphological) value. This region has a high potential to be included in UNESCO's World Natural Heritage List as a GeoPark and Volcanic Heritage Reserve.

The Wahipounamu region covers an area of about 26,000 km^2. The region exhibits many classic examples of tectonic, climatic and glacial processes. The region is of cultural value as well since the native Maori people reside here. This region is basically exploited as a nature-based tourism activity area (viz., adventure tourism, recreational hunting, fishing etc.) at certain sites. The integrity of forests and alpine ecosystems are also threatened by introduction or invasion of new species of fauna (birds and animals), commercial hunting etc.

The Department of Conservation, GoNZ, already has a legislative mandate for protection of these natural resources/sites which have a high value in this region. The pressure points are to be managed to provide access to tourists but only where the conservation values at these sites are protected.

156

Eco-Tourism in the Sundarbans – An Appraisal

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The Sunbarbans is the largest single block of mangrove forest in the world covering 25500 km^2. The Indian portion of the mangrove forest was declared as Project Tiger in 1973. The forests are enriched with 64 species of flora and 1568 *species* of fauna according to the estimate of Zoological Survey of India. Eco-tourism is a recent concept which increases the tourism potential of a region by developing local economy without affecting the natural resource. .Eco-tourism also helps to flourish local folk culture and cottage industry of this region. The Sunbarbans has a great advantage of combining adventure tourism and eco-tourism in the same area. Most of the tourist spots in the region are under developed, with lack of proper communication, electricity, schools and health service. Almost every year

this area suffers from various natural hazards like cyclone, flood and river bank erosion. From 1951–2011 the population increased 4 times with subsequent reduction in forest cover. Due to the increase of population in Sundarbans, the mangrove cover has been reduced. For eco-tourism to flourish in Sundarbans first step should be to develop road network for all weather use. Many of the islands have no electricity and they depend on solar energy, which has a limited production capacity. So, government should to take necessary step and long term development policy for electrification of the scattered islands. The Government is now promoting home stay tourism project, but that can only be achieved when the related facilities are developed. Generally 80% population of the Sunderbans region depends on agriculture. Eco-tourism is one of the mean to develop the areas socio-economic condition by participation in it and help to reduce huge pressure on natural resource.

157

Geomorphosites Based Seasonal Economy in Cold Desert Region of Northwestern Himalaya

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Geomorphosites are geomorphological landforms that have acquired a scientific, cultural/historical, aesthetic and socio-economic value due to human perception or exploitation. They can be single geomorphological objects or wider landscapes and may be modified, damaged, and even destroyed by the impacts of human activities. It is of paramount significance in cold desert region of northwestern Himalaya i.e. the Lahaul and Spiti district of Himachal Pradesh and Ladakh district of Jammu and Kashmir, as the particular trans-Himalayan region has variety of geomorphosites that makes it an exotic seasonal tourist centre. The research focuses upon the study of seasonal economy based on geomorphosites in these districts. The study is largely based on the fieldwork conducted in the study area in May–June, 2012, October, 2013, June 2014 and June 2016. The data have been collected through structured questionnaire survey and field observations at various seasonal *dhabas* around areas having unique geomorphic characteristics. These *dhabas* act as the centres for seasonal economy in the region that is regulated by the geotourism activities based on these geomorphosites. The analysis regarding the human response in terms of seasonal economy to diversity of geomorphic factors and SWOT analysis has been done accordingly. Overall, the major issue is inaccessibility which needs to be taken care with better management efforts. Potential geotourism sites have to be further identified, explored and developed in the region and the existing sites have to be preserved and retained in order to harness the tremendous potential of geotourism and thereby boosting the seasonal economy.

158

Evolution of Tilla-lunga Topography: Surface Process of Paleo Channels, West Tripura District, India

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The present work deals about the evolution of Tilla-lunga topography in the 983.63 km^2 West Tripura District. The research problem is to identify the origin of the tilla lunga landforms. The objectives of the paper are to identify morphology of tilla-lunga topography along with the process involved. The satellite images like SRTM DEM (90 m) and Survey of India toposheets (79M/1, 79M/5, 79M/6, 79M/9, 79M/10 of 1930-31; R.F 1:63,360) are used for the preparation of the physiographic maps. The cross-section and litho-facies has been prepared for identification of the geomorphic process. The litho-facies includes paleo current, thickness of bed and architectural elements. The GPS-receiver is used for identifying the location of the survey sites. The tilla and lunga are genetically divided into depositional and erosional landform respectively. The lunga is morphologically younger than tilla. The first order landforms are Baramura Hill, tilla, lunga and flood plain. Tilla and lunga exists 20-80 m and flood plains are below 20 m. Tilla is further classified into second order units like Upper Tilla (<60 m) which comprises of massive graded sequence and lithified molted clay, Middle Tilla (40-60 m) comprised of graded sequence, and lower tilla (>20 m). The lungas mainly originated in middle tilla. Thus, present-day tilla and lunga are forming rib and furrow structure. The major architectural elements are Fsc-St-Fl-St-Fsc-Gm-Gms (facies 1, 1.1), Gt (facies 2, 3), St-Sp-St (facies 4). It is concluded that lungas are the paleodrainage basin and tillas are the denuded uplands.

159

Changes in Meander Morphology in Lower Disang River, Assam

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Types and rates of change in river meander morphology and the relation between mechanism of change and emergent planform morphology has been analysed for the Lower Disang River, Assam. The purpose of the study is to examine the extent to which morphological changes of the river fit the conceptual models of development. Topographic sheets and GoogleEarth images were used to examine rates and patterns of planform change over the last 95 years on an approximately 200km reach. The river shows an increase in its sinuosity from 1.8 in 1919 to 2.09 in 2014. Development of new meander loops in formerly straight reaches and growth of meander loops through extension and expansion has resulted in the increase in the length of the river by ~27km.The average migration rate of the river is 1.11m/yr which varies along the reaches with some meandering reaches remaining relatively stable. The highest migration rates occurred with meander bends having a curvature ratio between 1.0 and 3.0, which does not perfectly fit into the existing models.

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