32nd Conference of the Indian Institute of Geomorphologists (IGI)

Focal Theme:
Geomorphology for Human Adaptation to Changing Environment

21-23 January 2021, West Bengal State University

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Message

At the outset, I wish all of you a very Happy New Year 2021. Stay safe, take care and remain alert from viruses that are existing and those who will soon be raising their heads. Their rise is our fall. We must remain circumspect, therefore.

Professor Subhamita Chaudhuri has requested me to provide a write-up that will essentially be a welcome address of the Vice Chancellor in the Inaugural Ceremony of the 32nd Conference of the Indian Institute of Geomorphologists (IGI), on the focal theme "Geomorphology for Human Adaptation to Changing Environment".

The Inaugural Function is being held today, January 21 2021, at the Auditorium of the West Bengal State University.

Very renowned Geographers, Environmentalists, Professors and Professionals including students and scholars on the subject are present here today.

Most of you know more than me on the subject of Geomorphology. I welcome all of you in this university that is still at a growing stage. With your support and cooperation, I hope in another 10 years' time the university will be a full-fledged teaching and research university.

Everything is in a state of flux as the Greeks long back said. Sweeping changes are taking place before our eyes and not before our eyes. Some changes are drastic, some incomprehensible,

some slow but long-lasting, some violent, some life-shattering, some benign. Of all these, man-made or man-caused changes are remarkable. Just imagine, in the last fifty years the global population has increased from about 3 billion to 7 billion. In another 25 years, the global population will increase by another 2.5 billion. How such changes will affect adaptation and geomorphology is anyone's guess. Climate change is a reality and all can see the Ailas or Umphuns, and their ravaging beauty and beastly destruction. The course of river changes, the lure of modern life causes traditional life to change abruptly. All these have effect on geomorphology. And also geomorphology influences human existence and civilization.

I think that the Conference will consider many such issues and try to create a roadmap for our existence and sustenance.

I welcome all of you and wish you all well. I wish the Conference all success.

Basab Chaudhuri

Vice Chancellor,
West Bengal State University

Greetings and welcome to all delegates who are attending the 32nd Conference of the Indian Institute of Geomorphologists (IGI) hosted by the Department of Geography, West Bengal State University, either in person or virtually. West Bengal State University is catering to the needs of higher education since 2008. The Department of Geography was established in the same year and the department is offering courses on Applied Geomorphology since inception. The Department has been encouraging students to participate in the IGI Conferences in order to give them exposure to the contemporary trend in geomorphological research. Although our University is young in age but the zeal of the University and the Department is very high. We are honoured that the Department of Geography was given the opportunity to host the 32nd Annual Conference of the IGI. We do hope that the Conference will raise interest in Geomorphology among the students.

Due to the outbreak of COVID-19, the 32nd IGI is being organised in a hybrid mode, where except the Inaugural Session all other Technical Sessions will be held through the virtual platform. We are optimistic that the academic deliberations in this conference, held in a condition of 'new normal' will be as fruitful as the other years.

The 32nd Conference of IGI is centered on the focal theme of '*Geomorphology for Human Adaptation to Changing Environment*'. The human influence in geomorphology has a long history, but in the last two decades our concern for global environmental change has brought the role of anthropo-geomorphology into focus. Climate change, is now a reality, and will have important implications for many geomorphological processes and phenomena. Large uncertainties exist with respect to hydrological response, the frequency of tropical cyclones, the response of glaciers and ice caps, the response of beaches to rising sea levels, and the state of wetlands and deltas. Human activities may affect the global geomorphological processes through complex feed-back mechanisms. Given the uncertainties of so many of the environmental changes, there is a great need to obtain a better understanding of the rates and mechanisms of landform response with regard to sensitivities and thresholds, and to appreciate the consequences of deliberate manipulation of environmental systems by humans.

A variety of sub-themes have been kept, which are integrative in nature, encompassing different aspects of geomorphology. The conference is expected to provide an appropriate platform for researchers from multiple disciplines such as Geography, Geology, Hydrology,

Earth Science, Environmental Science etc. to meet and share their valuable knowledge and experiences.

There is an overwhelming response from the participants belonging to multidisciplinary background from all over the country. We thank each and every one of you who have contributed their research articles and hope that the scientific discussions in these three days will be enriching and beneficial to your research interests.

Prof. Subhamita Chaudhuri

Convener,
32nd IGI Conference
Department of Geography, West Bengal State University

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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 32nd Conference of the Indian Institute of Geomorphologists, 191 abstracts – including three plenary lectures, one S.R. Basu Memorial lecture and one special lecture – are received for ten focus areas having both national and international relevance in contemporary research in geomorphology. These are as follows.

FOCUS AREAS OF THE 32ND IGI CONFERENCE

1. Geomorphology and landscape ecology ✧

Landscape ecology studies the natural and anthropogenic processes in light of their present functionality and attempts to forecast the geomorphic form. The spatial distribution of anthropogenic structures is always adjusted to topographic conditions and the micro- and meso-elements of topography are often totally destroyed by terrain modifications, such as levelling. The degree of human impact on landform is based on a number of geomorphic indicators like rate of soil erosion, surface dissection, artificial excavation features etc. Based on these indicators, Geomorphology and landscape ecology can make significant contributions to landscape planning.

2. Slope movements: assessment and management ✧

Slope movements take place due to decrease in shear resistance, which result from either internal or external causes. The internal causes usually involve changes in the physical or chemical properties of the material. External factors which lead to an increase in shear stress involve natural or human induced disturbances. The effective management of slope failures addresses those conditions that prepare the slope material for failure and those forces that actually trigger the failure. The main geomorphological role is to assess and delineate the susceptible zones on the basis of past and present visible evidences and carry out Geotechnical site investigation for implementing proper management technique.

3. Geomorphic response of fluvial systems to flood management and river regulation ✧

Natural Rivers are sensitive to human interference which causes change in channel characteristics. Direct consequences of engineering works including channelization, dam construction and diversion; have been long recognised, but the indirect effects like alterations of land use on channel reaches are more recently being appreciated. These transformations cause significant changes in the channel system through increased rates of erosion or deposition. Fluvial geomorphology can also present innovative approaches to flood prevention, river maintenance and floodplain restoration.

4. Geomorphic response of coastal systems to natural and anthropogenic stressors✧

The dynamism of the coastal zone results from complex interactions among the natural processes, which has been further complicated by rapidly growing human interventions. Over half of the world's coastline is modified by hard engineering structures, constructed for land reclamation, trade, resource exploitation and coastal protection. Any integrated approach towards sustainable management of the coast therefore must be interdisciplinary in manner, bringing coastal geomorphologists and coastal planning authorities under the same umbrella.

5. Geomorphological responses to urban development✧

Urbanization is an anthropogenic mechanism of changing the cityscape that produces a variety of adjustment in man-environmental relationship. In last few decades, the anthropogenic activities are transforming the natural landscape which consequently alters the nature of the study of geomorphology. Urban geomorphology, a recent but useful branch of applied geomorphology, deals with factors such as topological signature, hydro-lithological processes, which are significant in determining the rate of urbanisation. An urban geomorphological investigation can evaluate the resource potential, stability of ground surface and land use planning of urban areas.

6. Monitoring and mapping geomorphic processes and forms✧

With innovations in the field of remote sensing, the application of geoinformatics has become essential in modern geomorphological research. Geoinformatics is a combined approach of science and technology which deals with collection of spatiotemporal geographical data, modification and production of a set of information according to the requirements of the user. In recent geomorphic research, the hierarchy of different process-based systems are represented in a conceptual and quantitative manner by using geomorphic modelling, correlating geomorphic forms and processes.

7. Geomorphology of extreme events ✧

The increasing frequency and severity of extreme events are becoming apparent over multi decadal timescales. Occurrences of high-magnitude events like extreme rainfall, tsunami, catastrophic landslide, etc. triggers significant changes in landforms. This branch of geomorphology is a unique discipline examining the impact of different extreme events on the landform and to analysing the societal adaptation to these.

8. Geomorphosites and geotourism ✧

Geological or geomorphological 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 the geomorphological heritage sites call for a need to recognise and categorise these by assessing their scientific, cultural, aesthetic, social, and economic values. Popularisation of the geomorphosites can be achieved through geotourism, which promotes visits to locations, conservation of geo-diversity and an understanding of earth sciences through appreciation and learning.

THE HOSTS

The Host Locality

The host locality is situated at Barasat, the northeastern suburb of Kolkata located at 22°43′N and 88°28′E. It is the headquarter of North 24 Parganas District of West Bengal, and is a part of the Kolkata Metropolitan Development Authority (KMDA) area. Barasat is also the name of a sub-division centering the municipal city. Being a regional transportation hub, Barasat is the junction for both rail and road network. The city is close to the Netaji Subhas Chandra Bose International Airport (6 km), covering approximately 34 km2 area.

Situated within the Ganga Delta, its elevation varies between 10–12 m. The India-Bangladesh border at Petrapole is located 70 km northeast of Barasat. The nearest river is the Hugli, about 12 km to the west from the western fringes of the city. Barasat has a tropical climate similar to the rest of West Bengal. The region experiences monsoon season from early June to end-September. The climate is characterised by dry winter and humid summer months. The Bay of Bengal coastline is located 130 km south of Barasat. Whereas, the World Heritage Site of the Sundarban mangroves is about 75 km away.

The Host University

The West Bengal State University <https://wbsu.ac.in> was established in 2008 as the first public university in the North 24 Parganas District. One of the premier Universities of West Bengal at present, it now runs 30 academic departments which include wide range of subjects related to language, literature, social science, science, commerce and management. As of 2020, the university has 54 affiliated institutes. The University has been accredited with 12B by the UGC in 2015.

The University campus is located at Berunanpukuria, located at Ichhapur-Nilgunj Gram Panchayat, 5 km west of Barasat. The Government of West Bengal has been generous in supporting the University and the process of modernisation in the University has been noticeable in recent times. The University has modern infrastructure including ICT-enabled smart classrooms for students. The library has almost attained full automation, offering service not only to students, scholars and teachers of the University but to researchers from other institutions as well. The University is expected to create or offer opportunities for further academic collaboration, consultancy and innovative ecosystem in diverse inter-disciplinary fields. It is also taking necessary steps to create an environment-friendly culture to focus on its natural biodiversity and resources.

Since its establishment, West Bengal State University has spread the light of education to the remotest corners of the district of North 24 Parganas where the minority population is quite large. The University has a significantly large number of students enrolling at the PG level,

including a substantial number of female students, students coming from remote areas and students belonging to marginal and minority communities. The University has taken up an earnest effort of imparting higher education to a diverse group of students of which a large proportion is first generation learners, coming mostly from socially and economically backward classes. Above all, the University provides a sustainable academic environment coupled with quality teaching and research in terms of national and global standards.

The Host Department

The Department of Geography of the West Bengal State University was founded in 2008. The department offers a two-year full-time M.Sc. course as well as the PhD programme in Geography. The department admits 30 students in the M.Sc. course. The thrust areas of the department are Geomorphology, Application of Remote Sensing and GIS and Regional Development and Planning. The department emphasises on applied geography and field work which aim at giving hands-on-training on the application of theoretical knowledge in solving real-life geographical problems. The department tries to provide a stimulating research and learning environment together with quality teaching by appointing eminent guest faculties from different institutions.

The main facilities of the Department include:

- A Map Library.
- An RS/GIS Laboratory with state-of-art facilities.
- A Pedology and Sedimentology Laboratory.
- Cartographic Survey Facilities of the Department include advanced survey equipment like total station, theodolite, current meter and GNSS system..

The department arranged a National Seminar on ‘Development and Environment’ in 2016 and a value-added course on Ecology and Sustainable Waste Management in 2019. Besides, it has organised a number of workshops related to the CBCS curriculum in the last couple of years.

PRESIDENTIAL ADDRESS

Susceptibility of the climate resilient landforms of the coastal tract of Odisha and West Bengal

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I.t gives me a great pleasure to thank all the members of the executive council of IGI who recommended my name for the post of President of IGI for the year 2020 and all the members of the institute who have elected me to the post. It is indeed a matter of great honour and privilege to get this opportunity to address a gathering of eminent geomorphologists, scientists, researchers and students in the field of geomorphology. I am also happy that the 32nd IGI Conference chose "Geomorphology for Human Adaptation to Changing Environment" as its focal theme which is of immense relevance in the present global scenario. I would also like to thank the organisers for their effort in organising this 32nd IGI Conference in the present situation.

Introduction

Coastal parts of Odisha and West Bengal are highly vulnerable to erosion, sediment shifts and saltwater inundations as well as the rapid loss of coastal habitats. The climate resilient landforms of the depositional coast are sufficiently degraded and are unable to act as buffers against storms and tidal inundations. They are sensitive to the dynamic behavior of coastal environments in response to global climate change phenomenon and human interventions.

Sea beaches of Odisha coast are backed by wide and elevated beach berm surface but beaches of West Bengal coast represent low lying gently sloping to near horizontal shore platforms of fine sand materials. Coastal sand dunes are flanked by sea beaches and health of dunes depends on the availability of sand from the wide sandy sea beaches. Relatively, higher and older sand dunes are located along the coastal belts of Ganjam and Puri districts of Odisha coast in comparison to the low-lying areas of West Bengal and Odisha. Weathered and oxidized sands are unconformably lying at the basement under the younger dunes indicating two different sea level high stands.

Deltaic tidal flats, estuary fringe tidal flats, back water fringe tidal flats and bay fringe tidal flats of tropical coasts of West Bengal and Odisha are climate sensitive and thickly vegetated with tidal woodland forests. Physiographically, the tidal flats dominated by mangrove forests are located at the sheltered areas behind the barrier spits in Bhitarkonica, Mahanadi delta and Subarnarekha delta.

Human intervention into the coastal systems by different measures of drainage control, sediment control, erosion control, land use conversion and infrastructural development

activities were widespread between 1770–2020. On the other hand, the depositional coasts were facing sediment starvation and rise in sea level with global climate change. Under such conditions the sensitivity of the resilient landforms is tested in the present work with standard methods to examine their buffer functions in protection of low land areas.

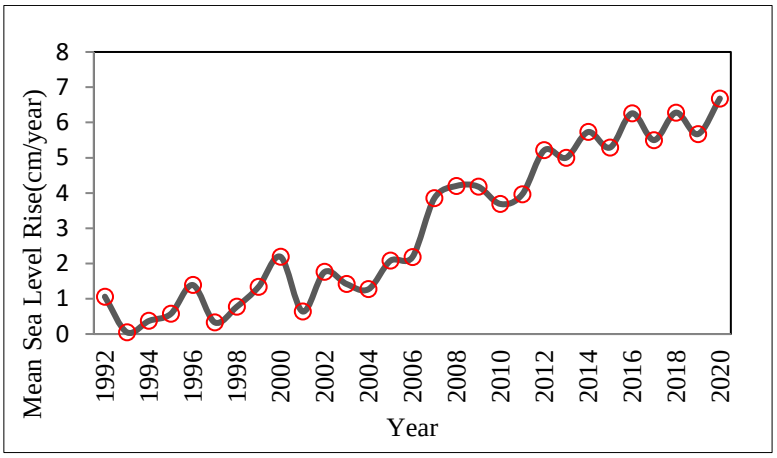

Figure 1: The current trend of Sea level rising process in India (1992-2020). Data Source: AVISCO-NOAA

Various geomorphic signatures of coastal vulnerabilities were tested in the field since 1985–2020 like reduction in height of sand dunes, beach lowering, beach narrowing, beach ridge modifications by human settlements and coastal wetland degradation by erosion, salt water inundations and mangrove destruction during storms.

Materials and Methods:

Numbers of variables of the coastal belts have been used in calculation of Coastal Sensitivity Index (CSI), Exposure Index, Adaptive Capacity Index and Coastal Vulnerability Index (CVI) to estimate the vulnerability of landforms to sea level rise and storm impacts

Result and Discussion:

Temporal changes of the depositional landforms (sea beaches, sand dunes, barrier spits, beach ridges and tidal flats), coastal sensitivity Index of the landforms to the sea level rise and cyclonic storms, and susceptibility of coastal low lands occupied by human settlements and agricultural fields to coastal hazards are discussed in this study.

Status of the resilient landforms at the sea face:

1. Odisha and West Bengal coasts are fringed with attractive sea beaches from Gopalpur to Bakkhali section along the shoreline of the Bay of Bengal. Sufficient wave energy of summer monsoon and sediment supply has developed sandy sea beaches. Beach types and associated hydrodynamics are adjusted with energy level and sediment supply over a time period. Previous records of SoI topographical sheets, multi-temporal satellite images, old maps and navigational charts are compared with the decadal field survey data to document and identify the dynamic behaviour of coastal landforms. Beaches were wider, straight, low gradient and slightly elevated in comparison to the present day conditions. Wide and extensive sea beaches (over 1 km in width) with thick deposits of sands protected the coastline from direct wave attacks by dissipating wave energy and were resilient to the

storm impacts. River Rushikulya, Mahanadi, Brahmani, Baitarani, Subarnarekha and Hugli estuary discharged huge amount of bed load sediments into the coastal zones during monsoon months with sand-sized grains to feed the sea beaches attached with the shorelines. Beach adjustment was also involved with both cross-shore and along-shore transport of sands. Steep beach face backed with wide and elevated beach berm surface of Odisha coast represents reflective beach profile and low slope beach profile with extensive sand flats and rhythmic topography of West Bengal coast indicated as dissipative type of beaches.

Presently, beaches of West Bengal coast have been suffering from starvation of sands, and the long shore currents transported sands from the beaches in alarming rate in the previous decades as a result of which base clay is exposed in many places. This transformed the beach into wave-abraded mud banks. During storm surges the lowered beaches are susceptible to over wash process. The fore shore beach berms of Odisha coast are also experiencing erosion in places like Gopalpur, Puri, Konark, Paradweep, Gahirmata etc. (Brooks, 2020).

2. Beach ridges are predominantly swash built landforms of shore parallel sand ridges when abundant sediment supply and storm surges influenced sand deposition beyond the shoreline. A succession of beach ridges occurred in Subarnarekha delta plain of formerly prograded coasts as a result of sea level variation in early Holocene to Late Holocene period. Topographically, they are higher (8 m to 10 m) and occupied by human settlements and vegetation. These beach ridges are overlain by relict dunes in many cases. Successive beach ridges are separated by widely spaced low lands of swale topography (2.5 m to 3.5 m in height) with marshes, water bodies and agricultural lands in the chenier plain coast. Such landforms are also observed in Baitarani-Brahmani delta, Mahanadi delta and around Chilika lagoon fringe areas. The old beach ridge deposits are eroded and former soil horizons have been exposed on the shore cliff of Talsari, Kirtania and Udaipur section in Subarnarekha delta (Paul, 1996a).

3. In the coastal parts of Odisha and West Bengal sand dunes were active elevated part along the beach fringe areas of shorelines (Rouchelle *et.al.*, 2011). The vegetated and stable sand dunes of significant elevation (over 20 m in height) protected low stands behind them from storm surges. Coastal sand dunes are sources of sand supply to the wide sea beaches. These types of aeolian deposits in Odisha and West Bengal can be categorised as — ii) fore dune ridges, ii) back dunes, iii) old reddened dunes, iv) transgressive sand sheets, v) parabolic and blow out dunes (Paul, 1994; Paul, 1996a).

Figure 2: Degraded coastal sand dunes by the impact of storms in West Bengal Coast (Sagar Island and Mandarmoni)

Figure 3: Erosive tidal flat with damaged mangrove vegetation on the sea face of the Sundarban

In Sagar Island, Fresarganj and Bakkhali sections of the Sundarban coast, extensive fore dunes were fringed with wide sandy sea beaches (Paul, 2002) during1980s and 1990s along the shorelines. The dunes of Kanthi coastal plain were extensive and marine terraces from Udaipur to Mandarmoni were significant with fore dunes, back dunes, parabolic and blow out dunes. However, the Ganjam and Puri districts of Odisha coast were noted for extensive and lofty sand dunes of different categories.

Both the height and spatial extension of coastal sand dunes are largely degraded and reduced particularly by human impacts and storm effects in the regional coastal belt of the northern Bay of Bengal at present (Fig. 2). Storm surges with frequent landfall of landfall of high magnitude cyclones converted the original sand dunes into transgressive sand sheets which are poorly vegetated and advance landward with a steep wall of sand (Hesp and Thom, 1990).

4. Barrier spits and barrier islands are elongate accumulation of sands formed by waves, tides, winds and longshore currents, often impound the terrestrial drainage and block off a lagoon along the coasts (Woodroffe, 2002). Odisha and West Bengal coasts represent river mouth spits, lagoonal spits, and detached form of barrier islands. Barrier types are also classified in relation to sea level change and stratigraphic characters, viz. still stand barrier, transgressive barrier and regressive barrier (Roy *et.al*. 1994). The Chilika spit, Gahirmata spit and Talsari spit are affected by erosion and barrier breaching process during the high magnitude storms.

5. Tidal flats of delta fronts, estuary fringes act as stable buffers against the storm and swell waves along the coastal belt of northern Bay of Bengal in the recent past (3000 to 1000 YBP). Vegetated tidal flats can accumulate sediments in different rate to elevate their surface in adjustment with rising sea level. Mangroves can accumulate sediments at the rate of 6 cm per year to adjust with the rate of sea level rise up to 5.5 mm yr^{-1} but if the rate of rise is above 6 mm yr^{-1} the threshold limit of sediment accumulation rate by mangroves will be affected severely (Saintilan *et al*., 2019). Mangrove of the deltaic tracts were badly damaged in the notorious cyclones of 1988, 1992, 1999, 2007, 2019 and 2020 along the coastal belts of West Bengal and Odisha due to salt water inundations over a long period, wind damages, salt sprays

during landfall (Paul *et al*., 2018). The equilibrium profile of tidal flats can be upset during storm episodes. The wide range of tidal flats with mangrove forests acted as a good buffer against storms in the recent past but today they are experiencing threats of erosion and inundations (Paul, 1997).

Status of Climate Resilient Landforms

Odisha coasts and West Bengal coasts are classified on the basis of their geomorphological characters for spatial analysis of resilient landforms as —A. Open marine sandy shores, B. Bay fringe coast, C. Deltaic beach ridge coast, D. Lagoon fringe shores, E. Delta plain and delta front coasts, F. Coastal fringe estuarine delta and G. Coastal fringe tidal delta.

Susceptibility Index of the climate resilient depositional landforms as per the coastal classes is assessed aimed at maximizing sustainable management of the coastal zones under climatic stress. The sensitivities, exposures, adaptive capacity and vulnerability of depositional landforms are tested to find out their resilience capacities along the selected coastal sections of Odisha and West Bengal. For calculating the susceptibility of seven land classes values of Sensitivity Index, Exposure Index, Adaptive Capacity Index and Vulnerability Index are Estimated, each represented by 10 variables to identify the stresses, exposure types, resiliencies and vulnerabilities.

Climatic resilience

Seven classes of climatic stresses have been identified which disturb each class of accretionary landform in the Bay of Bengal shorelines. A sensitivity index is prepared on the basis of available climatic stresses for each class of landforms in the region (Pamela *et al*. 2010). On the basis of such index values the high, moderate and low sensitive areas of sedimentary depositional landforms have been identified. It is observed that the bay-fringe coast and deltaic beach ridge coasts may act as resilient landforms if the desirable management options are practiced.

Table 1: The sensitivity of the depositional landforms under climatic stresses in Odisha and West Bengal Coasts

A. Climatic Stress												
Sl No.	Coastal Landform Class	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	Climatic stress*
1	Open Marine Sandy Shores	6.0	5.0	4.5	3.0	4.5	4.5	3.5	3.5	4.0	4.5	134.4759
2	Bay Fringe Coast	5.0	5.0	5.0	4.0	4.0	4.5	3.5	3.5	3.5	5.0	138.9012
3	Deltaic Beach Ridge Coast	5.0	5.0	5.5	4.5	5.0	5.0	3.5	4.5	4.5	5.0	234.131
4	Lagoon Fringe Shores	6.0	5.5	6.0	5.0	5.5	6.0	5.5	5.5	5.0	5.0	497.0583
5	Delta Plain and Delta Front Coast	5.5	5.0	5.0	5.5	4.5	6.0	5.5	6.0	6.0	5.0	449.6061
6	Coastal Fringe of Estuarine Delta	7.0	6.0	7.0	5.0	5.5	6.5	6.5	6.5	6.5	6.0	930.5556
7	Coastal Fringe of Tidal Delta	7.0	6.0	7.0	5.0	6.0	6.5	6.5	4.5	5.5	7.0	803.4971

*Equation ($\sqrt{S_1 \times S_2 \times S_3 \times S_4 \times S_5 \times S_6 \times S_7 \times S_8 \times S_9 \times S_{10}}/10$)

Weightage value for each variable is considered as 10

Here S_1: Climate Stress, S2: Ephemeral rise of seawater, S3: Shoreline change rate, S_4: Coastal floods or inundations; S_5: Overwash, S_6: Cyclone landfall concentration, S_7: Storm surge, S_8: River floods and sediment inputs; S_9: Sediment movements: S_{10}: High rate of SST.

Types of exposures

Seven classes of exposure of the coastal sections liable to attacks of marine hazards have been made. There are ten variables of such exposures which can produce impacts differently on the basis of the character, composition and location of depositional landforms in the coast. The exposure index shows fragility of the coastal landforms to the present and future climate stress. Management priority and management sustainability of coastal sections particularly depend on such understanding of critical factors. Armoring of sea beaches and sand dunes not always improve their resilience capacities if the exposures and functions of depositional land classes are not understood properly (Table.2).

Table2: The exposure index calculated for the depositional landforms of Odisha & West Bengal Coast

B. Exposures												
Sl No	Coastal Landform Class	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Exposure*
1	Open Marine Sandy Shores	3.5	3.5	4.2	5.0	5.0	5.0	5.0	4.0	4.0	4.0	143.4574
2	Bay Fringe Coast	4.0	5.5	3.0	3.5	2.0	4.5	4.5	4.0	3.5	5.0	80.9245
3	Deltaic Beach Ridge Coast	4.5	6.5	4.5	4.5	2.5	4.5	4.5	4.5	3.5	3.5	128.5679
4	Lagoon Fringe Shores	6.0	3.5	4.5	5.0	5.0	5.5	6.5	4.0	5.0	2.5	205.4987
5	Delta Plain and Delta Front Coast	6.0	3.5	4.0	5.0	4.5	5.5	6.5	4.5	5.5	3.5	241.9301
6	Coastal Fringe of Estuarine Delta	6.5	7.5	5.0	4.5	2.0	6.0	7.0	5.5	7.5	3.5	364.7234
7	Coastal Fringe of Tidal Delta	6.0	7.5	5.0	4.5	2.0	6.0	7.0	5.5	7.0	3.5	338.5335

*Equation($\sqrt{E_1 \times E_2 \times E_3 \times E_4 \times E_5 \times E_6 \times E_7 \times E_8 \times E_9 \times E_{10}}/10$)

Weightage value for each variable is considered as 10

Here types of exposures: E_1: Future climate exposures (sea level rise); E_2: Shelf width; E_3: Swell waves (Summer months); E_4: Wind waves in southwest Monsoon; E_5: Wind waves in northeast Monsoon; E_6: Storm surges (Cyclone regimes); E_7: Topography (Low land/High Land coasts) ; E_8: Shoreline configuration (concave, convex, straight, broken); E_9: River mouth (wider and deeper); E_{10}: Buffer types (sea beaches, dunes, beach ridges, barrier spits and tidal flats).

Types of adaptive capacities

Desirable quality of coastal habitats can improve the adaptive capacities of tidal flats, sand dunes, beach ridges, barrier spits and sea beaches in the dynamic coast. Variables of adaptive capacities are identified to calculate the Adaptive Capacity Index based on given weightage. Under conditions of sediment starvation, shortages of freshwater input and failure in managing the climate change impacts, adaptive capacities of coastal habitats may not get sufficient scope to improve.

Here the types of Adaptive Capacities include — A_1: Extent, integrity and continuity of Habitats; A_2:Resistance and Recovery (short term/long term); A_3: Habitat Diversity (high/ moderate/low); A_4: Management potential (managing climate change impacts on habitat); A_5: Sediment supply and transport (critical factor); A_6: Available back shore width as adaptive space; A_7: Frequency of high magnitude cyclone attacks; A_8: Environmental regulations implemented (CRZ); A_9: Rate of habitat modifications (resource use conflicts); A_{10}: Engineered protective structures (Habitat Isolation)

Table 3: Adaptive capacity index estimated for the depositional landforms of Odisha and West Bengal coast

C. Adaptive Capacities												
Sl No	Coastal Landform Class	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Adaptive capacities
1	Open Marine Sandy Shores	2.5	2.5	3.0	2.5	5.0	3.0	6.0	2.0	5.0	2.5	32.4756
2	Bay Fringe Coast	2.5	3.5	3.5	3.0	3.5	3.0	3.5	2.0	4.0	5.0	36.75
3	Deltaic Beach Ridge Coast	3.5	3.5	6.5	6.0	3.5	2.5	3.5	4.5	4.0	5.0	114.7519
4	Lagoon Fringe Shores	3.0	3.0	5.0	4.0	4.5	0.5	6.5	2.5	5.0	2.0	25.6534
5	Delta Plain and Delta Front Coast	5.0	5.0	4.5	4.0	4.5	4.0	6.5	2.5	5.0	5.0	181.4008
6	Coastal Fringe of Estuarine Delta	5.5	5.5	4.5	3.5	5.0	5.5	7.0	5.0	5.5	4.0	317.625
7	Coastal Fringe of Tidal Delta	7.0	6.0	4.0	3.0	3.5	5.5	7.0	5.0	5.5	4.0	273.3229

Equation ($\sqrt{A_1 \times A_2 \times A_3 \times A_4 \times A5 \times A6 \times A_7 \times A_8 \times A_9 \times A_{10}/10}$)

Weightage value for each variable is considered as 10

Coastal vulnerabilities

Vulnerabilities are inability of the sections of depositional alluvium coast to cope with the global climate change phenomenon (Table.4). The variables of vulnerabilities include physical, hydrological, climatological, social and ecological. Vulnerability reduced the resilience capacity of coastal accretionary landforms. Coastal Vulnerability Index (CVI) is one of the major indices to estimate the susceptibility of resilient landforms. Coastal fringes

of estuarine delta and tidal delta show the highest value of CVI in the regional settings of depositional coast (Sahana *et al*., 2019).

Types of Coastal Vulnerabilities considered are —$V_{1:}$ Geomorphology (landforms, drainage, sediment input) $V_{2:}$ Coastal slope (gentle/moderate/high);$V_{3:}$ Relative sea level rise rate (global rise, regional subsidence); $V_{4:}$ Shoreline erosion/accretion rate(shoreline change rate); $V_{5:}$ mean tide range (regional diversity); $V_{6:}$ Mean wave height (Regional diversity); $V_{7:}$ Cyclone landfall concentration (moderate/high/very high); $V_{8:}$ Population pressures (Density of person per km^2); $V_{9:}$ Loss of coastal buffers (reclamations, developments); $V_{10:}$ Mangrove ecosystem function (reduction in supply of fresh waters)

Table 4: Coastal Vulnerability Index assessed for the depositional coasts of Odisha and West Bengal

D. Coastal Vulnerabilities												
Sl No	Coastal Landform Class	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	Coastal vulnerability *
1	Open Marine Sandy Shores	6.0	3.5	4.5	5.0	2.0	5.0	4.5	4.0	5.5	1.0	68.3941
2	Bay Fringe Coast	4.5	5.0	5.0	4.0	3.5	2.0	3.0	3.0	4.0	1.5	41.243
3	Deltaic Beach Ridge Coast	4.5	4.5	4.5	5.0	4.0	2.0	3.0	3.5	4.0	4.5	83.0004
4	Lagoon Fringe Shores	6.5	4.0	5.5	6.5	1.5	5.0	5.0	3.0	5.5	2.0	107.25
5	Delta Plain and Delta Front Coast	6.5	4.0	5.5	5.0	2.5	4.5	5.0	5.0	5.0	5.5	235.1612
6	Coastal Fringe of Estuarine Delta	7.0	5.0	7.0	7.5	7.5	2.5	6.0	6.0	4.5	6.5	602.3217
7	Coastal Fringe of Tidal Delta	7.0	5.0	6.0	7.5	7.5	2.5	6.0	3.0	4.5	6.0	378.8429

*Equation ($\sqrt{V_1 \times V_2 \times V_3 \times V_4 \times V_5 \times V_6 \times V_7 \times V_8 \times V_9 \times V_{10}}/10$)

Weightage value for each variable is considered as 10 (ten)

Susceptibility of the resilient landforms:

Climate resiliencies of coastal landforms are tested by Susceptibility Index. High index values indicate low susceptibility for the depositional landform classes of the various coastal sections. Among them five categories of susceptibility index include Very High (Rank-I), High (Rank-II), Moderate (Rank-III), Low (Rank-IV) and Very Low (Rank-V). Susceptibility varies on the basis of diversity of coastal sections along the Bay of Bengal in the region. Such variables should be considered in the sustainability of coastal management (Fig.4). The Sundarban coastal tracts represent high sensitivity score, high exposure score and high vulnerability score for which their susceptibility score is very low.

Spatial diversity of climate stresses, exposure types, adaptive capacities and coastal vulnerabilities of the regional coastal settings are estimated into index values to find out the susceptibilities of resilient landforms. The seven types of landform classes of the Bay of Bengal fringe coasts are finally ranked into five categories of Susceptibility Index. Result of

such study indicated that the Bay fringe coast of Chandipur (Odisha) is still susceptible in climate resiliencies. However, the Sundarban coasts of estuarine delta and tidal delta are largely affected by climate stresses, exposures and vulnerabilities to show low susceptibilities of resilient landforms through the mangrove habitat of tidal flats, which represent adaptive capacity to cope with the marine hazards.

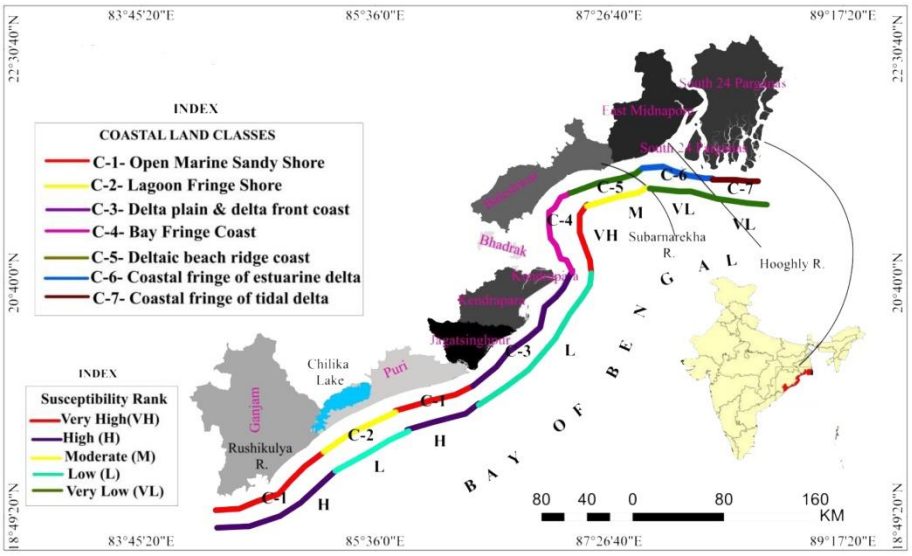

Figure 5. The calculated Susceptibility scores for the resilient landforms of Odisha and West Bengal Coasts with their ranking of susceptibility

Conclusions

Northern Bay of Bengal fringe coasts of Odisha and West Bengal are hotspot of climate change impacts. Coastal landform classes adjust to hydrodynamics, availability of sediment, seasonal climate variations and history of sea level changes behave differently at different sections of the coast. Global climate change phenomenon and human interventions into the coastal systems created period of disturbance regimes under which the ancient resilient landforms of depositional coast are also suffering.

Coastal management success depends on the understanding of such critical factors of environmental issues.

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ANNUAL REPORT FROM THE SECRETARY GENERAL, IGI

The Indian Institute of Geomorphologists (IGI) aims to promote research on methodological advancement in the field of geomorphology in India. The idea of forming an association was conceived by Prof. Savindra Singh, Department of Geography, University of Allahabad during an International Conference on Geomorphology and Environment held from January 17 to 21, 1987 under his convenorship in the Department of Geography, University of Allahabad wherein more than 200 delegates from Europe 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 research being carried out on geomorphology and allied disciplines in different universities and laboratories in the country,
- To encourage young research scholars doing research in geomorphology by giving awards and certificates.
- To give more emphasis on research 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 29 annual conferences of IGI with different focal themes have been organised at different places important being Andhra University, Waltair (First, 1988); Rajasthan University, Jaipur (twice); Poona University (twice); North Eastern Hill University Shillong (twice), North

Bengal University, Darjeeling; Vishwabharti University Shantiniketan; Tamil University, Thanjavur; Annamalai University, Chidambaram; M. S. University of Baroda, Vadodara; Tirunelveli (Tamil Nadu), University of Allahabad (thrice), Kurukshestra University, Kurukshetra; Jammu University, Jammu; University of Delhi, Delhi; Banaras Hindu University, Varanasi; Tripura University, Agartala; Anna University, Chennai (2011); M. S. University, Baroda (2013), Vidyasagar University, Medinipur (2014), North Eastern Hill University (NEHU), Shillong (2015), University of Calcutta, Kolkata (thrice). In the year 2017 under the banner of IGI a mega event of Geomorphologists i.e. 9th ICG was held in Vigayan Bhawan, New Delhi during 6 to 11 November, 2017. This was the first international conference on geomorphology held in India and the second ICG in Asia. The ICG is the official conference of the International Association of Geomorphologists (IAG) and is held once every four years. The first conference was held in Manchester (U.K.) in 1985, the second one in Frankfurt (Germany) in 1989, third one in Hamilton (Canada) in 1993, fourth one in Bologna (Italy) in 1997, fifth one in Tokyo (Japan) in 2001, sixth one in Zaragoza (Spain) in 2005, Seventh one in Melbourne (Australia) in 2009 and the eighth one in Paris (France) in 2013. The main objectives of the conference were – (i) to bring together leading and young geomorphologists to exchange and share their research findings on all aspects of geomorphology, (ii) to provide a platform for active researchers to present and discuss trends, innovations, challenges and solutions adopted in various fields of geomorphology, (iii) to advance knowledge related to earth surface processes, extreme events and natural hazards for the benefit of the society, and (iv) to foster capacity building for young researchers. Nearly 388 foreign delegates and 178 Indian delegates participated in the conference there were participation from 46 countries. IGI also released the Atlas of Geomorphosites in India during the inaugural function of 9th ICG conference. I must congratulate Professor Savindra Singh, President, 9th ICG; Professor Sunil Kumar De, Convenor, 9th ICG and Professor V. S. Kale, Professor Suando Bandopadhyay and the entire IGI family for making the event successful. The 30th conference of IGI was held in the Department of Geography, Jamia Millia Islamia University, New Delhi during 03-05 October, 2018. The 31st IGI conference was held during12-14 November 2019 in the Department of Geography and Applied Geography, University of North Bengal, Siliguri.

The publication of Journal of Indian Geomorphology is smooth and updated. The last volume was released in the 31st IGI conference. The family of IGI has grown rapidly with its life members exceeded to 597. It has been observed that young geomorphologists are coming up very fast and they are doing quality research in the field of geomorphology. The IGI initiated to organise young Geomorphologists forum every year. The EC of IGI accepted the proposal of Prof. Sunil Kumar De to start awarding of fellowship to two Young Geomorphologists every year. The EC placed on record the appreciation and thanks to the all members of steering Committee for selecting the President and Vice President of the IGI Young Geomorphologist Forum based on their academic career. Steering Committee of Young Geomorphologist declared the result — Dr. Shreya Bandopadhyay as President YGF for the year 2020 and Dr. Sayantan Das as the Vice President YGF for the year 2019-20. YGF organised the event successfully during 2–5March in Geography Department, University of Calcutta.

All the life members have contributed much in the growth and progress of this organisation. I wish the 32nd IGI conference a grand success under the dynamic leadership of Dr. Subhamita Chaudhuri (Convener), and all the faculties and the students of Department of Geography, West Bengal State University, Barasat (West Bengal). I take this opportunity to

extend a very warm welcome to all the delegates attending through online mode from various parts of the country.

I wish the conference a grand success.

Prof. A.R.Siddiqui
Secretary General
Indian Institute of Geomorphologists (IGI)
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PROFESSOR S.R. BASU MEMORIAL LECTURE

Geo-science Today in Environmental Impact Assessment Perspective

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Environmental Impact Analysis (EIA) is a process-response system analysis to study multifarious alterations in natural/physical processes induced by anthropic activities and to identify the rational balance between Environment and 'Human Capital and Mobility'(HCM). The primary aim of the EIA study includes reconstruction and evaluation of natural/physical phenomenon in relation to anthropogenic impact through short-/long term monitoring of geo-environmental parameters to conclude on specific guidelines for 'Geo-Bio-Cultural' interactions and socio-economic development.

Anthropogenic activities with built-up environment, in general, facilitate landscape heterogeneity by modifying the rhythms of natural disturbance. So, environmental impacts may vary in directness, intensity and duration depending on the nature of the human action and the affected biotic-abiotic communities. The degree of recovery potential mainly depends upon life forces, type and degree of impact on 'natures own built system' intimately related with hydrodynamic circulation. In this regard, the term "Impact"(I) refers to the relationships among a project, landforms and natural processes(both exogenous and endogenous)and can be expressed as: I= Ga x F x Ha; where, Ga—Geomorphic asset (i.e. landscape value); F—Fragility refers to stability/ resistance of Ga; Ha—Human activities/impact. The indicators (i.e. variables involved) used for the analysis can vary considerably according to their specific nature and origin e.g. spatial distribution, biotic-abiotic relationship and synthetic parameters.

The main tasks/work elements of Geo-science in EIA include—

- Spatial characterization of 'rock/soil- water- vegetation' interrelationships and effect of various exogenous and endogenous processes active in the area under interest with regional perspective.
- Generation of convenient database on the physico- chemical parameters and their space- time relationship/distribution.
- Modeling of natural processes, thereafter, using the generated datasets to predict where and when they are likely to occur with futuristic approach.

It is to mention that, complex geological components are reflected on the earth's surface primarily by geomorphological indicators. So, identifications of geomorphological indicators is essential, in first instance; subsequently the geological studies could be carried out for specifying the geological indicators. In a techno- economic developmental project the prediction of geological risks in the area could easily be done by applied geomorphological studies. It is worth mentioning here that geomorphological indicators vary with various geomorphic process oriented environment e.g. fluvial system, coastal system, soil/land degradation, slope instability etc.

Geo-environmental mapping (GEM) plays facilitator role in EIA in terms of—

- Unraveling the impact of anthropic development on biophysical environment through space and time indentifying the factual and functional parameters.
- Framing guidelines for rational balance between Environment and HCM through technological adjustment and social adaptations.

In the present day context, the 'Geo-spatial Information Technology' may be considered as an added advantage for GEM, being a multivariate/multi-scale approach in human orientation for EIA – require knowledge based expertise.

'Technology push' without considering the terrain condition and societal settings is breaking natural resource assets as well as facilitate environmental deterioration.

ABSTRACTS OF PLENARY LECTURES

I

Delving Antarctica: Experience of Extremities

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Antarctica, the remotest, coldest, windiest, driest, loneliest continent of the world is famous for extreme environment. It contains almost 80 % of the world's freshwater, yet it is the largest cold desert on Earth and in spite of receiving much more solar radiation than anywhere else in the world during the summer, it is the coldest place on Earth. The continent is the coldest place on Earth because of the long polar night and the low inclination of solar rays during the summer. Here, no human habitation exists except a few scientific research stations, field research is very difficult and expensive, thus it became a continent for science. This lecture is basically focused on the experience of the extremities experienced by the author during the 39th Indian Scientific Expedition to Antarctica (ISEA) organized by National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Science, Government of India. India is having two very well-equipped research stations namely Maitre and Bharti in Antarctica for conducting various interdisciplinary studies specially focusing extreme environment. The thickest ice sheet covering the continent for several thousands of years, has conserved the evidences of changing environment with special reference to atmospheric composition and climate change. Due to the combination of these extremities, Antarctica plays a major role in the global climate system. Antarctica can give necessary information for better understanding of the extreme environmental processes and the response of ecosystems to climatic and environmental change. This continent covers about 13.66 × 106 km2 area representing about 10% of the worlds and 30% of the land surface of the Southern Hemisphere. About 40% of the coastline is made up of thick ice shelves with grounded ice walls and glaciers. Sea ice constitutes the remaining 60%. Major portion of the continental shelf has undergone extensive glacial and aeolian erosion. Greenhouse effect and climate change are having intense impact on the polar ice caps. We experienced extreme hot days ever recorded in history during the 1st week of February, 2020. This increase of temperature is responsible for melting of the Antarctic ice sheets, which would increase global sea levels, is one of the major concerns of the 21st century.

II

Facets of Extreme Hydrological Events in India

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Extreme hydrological events, such as severe floods and droughts, are an integral part of the monsoon climate. Large and extreme flood events have been and continue to be one of the most widespread and recurring geomorphic hazards in the Indian subcontinent. The year 2019 was a year of excess monsoon rainfall and extreme events. The monsoon of 2019 recorded the highest monsoon rainfall total since 1994, and the monsoon of 2020 recorded the second highest rains after 1994. Although 2019 flood-year occurred after a gap of 25 years, some of the most unusual floods and extraordinary rainfall events were recorded during the non-excess/non-flood years between 1994 and 2019 in different parts of the country. Some of the extraordinary rainfall and flood events during this interval include – the 2005 urban floods in Mumbai and Chennai, 2008 flood on Kosi, 2009 flood on Krishna, the Leh flash flood in2010, the Kedarnath flash flood in 2013, the 2014 flood in Kashmir, the 2015 urban flood in Chennai, the Kerala floods in 2018, etc. In spite of structural and non-structural measures of flood control adopted during the last few decades, extreme hydrological events continue to present a recurring hazard in many parts of the country. Available instrumental, historical and geological records indicate that high-magnitude and extreme hydrological events have also occurred in the past in the different river basins of the sub-continent. Changes in the frequency of large-magnitude and extreme floods are one of the expected consequences of climate change. Recent studies, based on climate models, project significant increase in the precipitation extremes as well as flood risk in the sub-continent under warming climate. Adaptation to increased risk of flooding is, therefore, an essential strategy for reducing the severity and cost of impacts of the extreme events in the near as well as distant future. However, this requires objective and precise definition of large and extreme events, proper scientific understanding of the mechanisms, characteristics and regularities of high-magnitude events and basin-wise hydro-geomorphic mapping. In this presentation, the above mentioned as well as some other facets of the monsoon floods in India are described and discussed.

III

A Geomorphic and Geoarchaeology Approach to Understand 'Out of Africa' through the Thar Desert Corridor

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Stabilized dunes, arid paleosols formed within the dunes and calcrete nodules/horizons associated with Lower to Middle, Upper and Mesolithic stone tools reveal the occupancy of early stone age man in the Thar desert. Detailed geomorphology of the arid to semi-arid desert, Palaeolithic findings and supported by U/Th and OSL dating methods reveal that during the last ~200 ka major pluvial periods were ~200 ka (MIS 7.3), ~160-150 ka, ~126-115 ka (Climatic Optimum), ~90-80 ka, ~55-50 ka, ~30 to 26 ka, and 7-6 ka, and these periods coincided with the phases of intense high summer monsoons. The major periods of enhanced aeolian sand mobilization and accumulation, as well as high dune-building activities, were evidenced during the transition to/from the peaks of vigorous monsoon, especially at ~190 ka (after the MIS 7.3), ~140 ka, 125-100 ka, 75-65 ka, 24-17 ka, 14-12 ka, 5-3 ka and 2-1 ka. Thus, interdisciplinary work carried out in the Thar Desert on the Late Quaternary deposits reveal that the region has been a major corridor for human migration 'Out of Africa' and occupation in a semi-arid to arid landscape at least since MIS 5.

IV

Terrain Analysis: Theory and Application for Land Management with Examples from Kerala

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Terrain analysis is one of the sub-fields of geomorphology that finds wide application in land management, agricultural development, land use planning, military purposes, and geo-environmental appraisal across the world. There is renewed interest in terrain analysis to address the problem of competing use of land and design sustainable land management practices. As a part of earth surface science, the core research question of terrain analysis is to investigate the process-response system, resulting in landforms and describe their qualitative and quantitative characteristics. This paper intends to discuss the theoretical foundation of terrain analysis and application drawing examples from Kerala. The bulk of the information on the theoretical foundation emanated from the literature review and field observations. The other data related to the scheme of classification, mapping, and land management have been generated while working on a state-level project on terrain analysis of Kerala and executing several other projects requiring terrain data. Application of Geomatics forms part of the mapping exercises.

Terrain analysis begins with the classification of land. Segregation of land surface into various units or identification of terrain units is based on an axiom that there are delineable discontinuities or boundaries, at a given scale, along the otherwise continuous field of landscape. These discontinuities result from various morphogenetic processes that operate on the earth surface. Distribution of mass and energy, the force of gravity, tectonics, and anthropogenic forcing impacting the redistribution of mass and energy control the boundaries and characteristics of the land segments. With this theoretical premise, terrain classification scheme has been worked out as applicable for Kerala.

Among the three approaches, genetic, parametric, and landscape, the landscape approach following geomorphic principles is found to be the most appropriate for land management. The geomorphic processes operative in Kerala are marine, fluvio-marine, fluvial, and denudational at the generic level. Kerala is a net sediment producer with the dominance of denudational process. The specific origins giving rise to the landforms under each of these generic levels are accretion, erosion, and complex manifesting distribution of mass and energy. The attributes used for four hierarchic levels of terrain classification in Kerala consist of climate, geomorphic process, and physiography for level I, lithology, structure and erosional state for level II, landform, morphography, and morphometry for level III, and elementary geo-form for level IV. While primary productivity and decay and decomposition constitute the process data at the level I identifying terrain province, it is the soil properties and slope process that govern level IV representing terrain components. The scale of mapping ranges from <1:10,000 for level IV to >1:250,000 for level I. The legends to terrain maps are interpretative highlighting information on the main origin (processes), specific origin

(dynamics/ state), slope, dissection, internal relief, drainage density, soil type, land use, and environmental evaluation. It helps to communicate as much information as possible through maps, and intelligible to professionals from other disciplines and resource managers including common people. Unit wise management initiatives have been worked out in the case of terrain components identified at the Panchayat level with a mapping scale of 1:5,000. Apart from unit wise land management initiatives suggested at the watershed level, a separate exercise has been attempted to highlight the terrain-based conservational requirement. While conservational requirements are proportional to the degree of slope under denudational landform, in the case of fluvial landform the landscape element like river channel and water bodies themselves warrant conservation due to fragility and imbalance in their mass and energy composition. In the matter of land suitability analysis based on terrain, the approach can be parallel dealing with terrain analysis and socio-economic analysis simultaneously, or successive where socio-economic analysis follows terrain analysis and terrain units act as an aggregator for socio-economic data.

Terrain analysis has a large potential for societal application. It is a useful exercise for science-society integration and co-management of natural resources. It creates a platform for collating multidisciplinary knowledge to delineate and characterise landforms and investigate landscape diversity. The advent of geomatics has enlarged its scope and interpretability. There is enormous demand for terrain data at different scales- district, block, panchayat, and watershed to support local-level planning and environmental management. Geographers, more particularly geomorphologists, should take up this challenge and promote the research on terrain analysis.

ABSTRACT OF SPECIAL LECTURE

I

Delineating Groundwater Security of India: where Science Meets Policy

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The significance of ensuring groundwater security is no-where more evident than in South Asia, specifically India. Huge groundwater-dependent population, uncertain climate-reliant recharge processes, transboundary upstream water sources, major geogenic-sourced, non-point contaminants, archaic irrigation methods and human practices, and indiscriminate landuse changes with urbanization, have rendered the Indian groundwater scenario to become a global paradigm for water scarcity, for both quantity and quality.

Using a combination of ground-based in-situ groundwater level data, NASA satellite-based estimates of groundwater storage, numerical analyses and simulation of global models on groundwater storage changes and artificial intelligence, long-term, decadal-scale groundwater quantity changes over the Indian subcontinent were delineated. For the first time, estimation of the volume of existing usable groundwater across Indian states show rapid depletion of usable groundwater storage in Assam, Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal. In these areas, increases in agricultural food production have resulted at the cost of non-renewable loss in groundwater volume at an alarming rate.

Observed and satellite-based estimates show highest groundwater storage depletion rates in Assam, Rajasthan and Uttar Pradesh. A water-affluent state like Assam, has lost ~2% of its usable groundwater resource in last one decade, and is in the brink of suffering drought and famine in impending years. In contrast, scenarios of groundwater replenishment, potentially caused by policy interventions are observed from these analyses. Rejuvenation of groundwater storage in western and southern parts of India suggest that proper, pervasive groundwater governance may optimistically lead to possibilities of transforming the country from a “groundwater-deficient” to “ground-water sufficient” nation, and providing sustainable water availability. The work has significantly contributed to support and evaluate the Government of India missions like MNREGA on groundwater rejuvenation in India, which potentially influenced country-wide artificial recharge programs.

ABSTRACTS OF YOUNG GEOMORPHOLOGISTS COMPETITION

I

Landslide Susceptibility Assessment along National Highway 1D from Sonamarg to Kargil, North Western Himalaya

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The National Highway 1D from Sonamarg to Kargil is known as one of the most landslide susceptible areas in Kashmir and Ladakh divisions. The aim of the present study is to delineate landslide susceptibility zones along the National Highway 1D from Sonamarg to Kargil, north western (NW) Himalaya. Based on landslide influencing geo-environmental factors such as slope angle, landuse/landcover, distance to faults, precipitation, soil, slope aspect, lithology, altitude, distance to streams, and distance to road; a detailed landslide susceptible map is prepared. A weighted pair wise comparison matrix is generated using Analytical Hierarchy Process (AHP). The geo-environmental factors and their derived weights through AHP were then overlain using the index overlay module in ArcGIS 10.2 supplemented by MS Excel and MATLAB. The relationship between the conditional and trigger factors was carried out by analyzing landslide events. The results show that the area of 913.55 km2 is covered by very high and high landslide susceptibility zones constituting 55% of the study area. These are the most tortuous and rugged zones with high occurrence and impact of landslides. The study also identified and mapped a total of 317 landslides along National Highway 1D through rigorous multiple field surveys and secondary sources. There is a frequent incidence of traffic disruptions along the road. Thus, there is an urgent need to mitigate the landslide hazard particularly to avert the disruption from Sonamarg to Leh road, which causes huge inconvenience in terms of human and economic losses.

II

Analysis of Circularity Index of River Basins in Greater Himalayan Range, Nepal

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This research paper aims at analyzing the tectonic stability of river basins in the Greater Himalayan Range, Nepal. For this, circularity index of river basins is used as the parameter. The study area extends between latitude 25°59' N to 31°N and longitude 79°29' E to 88°30' E. The Greater Himalayas are mostly marked by complex geology, topography which is affected by erosion and active tectonic forces. Circularity index is calculated for the river basins. These are the rivers originating in the Greater Himalayas and flowing southwards. The river basins are delineated on toposheets (scale 1:250,000). On this scale, these rivers seem to be of the 3rd or 4th order. The circularity index values are calculated for the delineated river basins. The value of the circularity index ranges from 0 to 1. The more the basin developed in a mountain ridge are circular, the more stable it is. If the value of the circularity index for

a basin is more than 0.5, it is regarded as circular. On the other hand, if it is < 0.5, it is considered as elongated and tectonically active. Out of the total 10 river basins, the maximum value of the index is 0.77 and the minimum is 0.29. Most of the river basins show the values < 0.5 or up to 0.5, except one with 0.77. It is concluded that this part of the Greater Himalayas is fairly tectonically active.

III

Glacier Dynamics in the Chhombo Chhu Watershed of Tista Basin between 1975 and 2018, Sikkim Himalaya (India)

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Glaciers in the tropics are considered to be more susceptible to temperature changes associated with climate change. Accessibility of detailed and precise glacier inventories in the Tista basin is therefore crucial. In this study, we have observed noticeable changes in the glacier area between 1975 and 2018 in the Chhombo Chhu Watershed (CCW) of the Tista river basin in the Sikkim Himalaya. The CCW consists of 74 glaciers (>0.02 km2) with a mean glacier size of 0.61 km2, covering an area of 44.8 ±1.5 km2 in 2018. Change detection analysis was based on the glaciers' outlines obtained from hexagon KH-9 (1975), Landsat 5 TM (1989), Landsat 7 ETM+ (2000), Landsat 5 TM (2010) and Sentinel 2A (2018). This temporal analysis reveals a glacier shrinkage of ~ 17.9 ±1.7 km2, an annual retreat rate of 0.42 ±0.04 km2 a–1. Clean glaciers exhibit more area loss by 11.8 ±1.2 km2 (0.27 ±0.03 km2 a–1) than partially debris-covered (5.0 ±0.4 km2 or 0.12 ±0.01 km2 a–1) and maximum debris-covered (1.0 ± 0.1 km2 or –0.02 ±0.002 km2 a–1) glaciers in the study region. The quantum of glacier area loss in the CCW of Sikkim Himalaya took its pace during 2000–2010 (0.62 ±0.5 km2 a–1) and 2010–2018 (0.77 ±0.6 km2 a–1) time frames. Field investigations of selected glaciers and climatic records also support the trend in glacier recession in the CCW, as a result of a significant increase in temperature trend since 1995, and, more or less, static precipitation. Glacier retreat rates in the CCW was almost similar to the Changme Khangpu basin and other selected glaciers in Sikkim Himalaya, but relatively higher than the counterparts (i.e., western and central Himalayas). Thus, this glacier inventory and area change analysis will provide valuable information to the glaciological and hydrological community for the future modeling and planning of the water resources in Sikkim state of Eastern Himalaya.

IV

Modeling Bank Erosion Potential Sites in the Upstream Section of Farakka Barrage in Malda District (India) using Binary Logistic Regression Model (BLR)

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The constructions across the rivers bring potential threats to the overall river behavior. The construction of the Farakka Barrage (1975) across the Ganga at Malda district (India) started a problem of water piling at the upstream of the barrage and extended up to the Bhutni Island (40 km upstream). The seepage mechanism allows the entry of rising flood water to the banks and again released when water level recedes gradually. It creates many voids in the bank walls and causes bank slumping. The erodible sandy composition of the left bank increases high risk of bank failure. The present study intends with the objectives of finding the most important causative or driving variable in causing high bank erosion in recent times (2020) using Binary Logistic Regression model (BLR). The Cox and Snell R Square value of 0.382 and Nagelkerke R Square of 0.525 indicate a suitability of the model. The omnibus test of model coefficient gives the likelihood ratio (224.433) for the overall model fitting (p value 0.0). The model predicts correctly 254 sites as low bank erosion (LBE) and 111 sites as High bank erosion (HBE) category with 84.4% and 67.3% accuracy. The influential statistics (standardized residuals, Cook's distance, leverage statistic) measure the overall influence of each case in the model. The DF Beta checks the step-by-step inclusion and exclusion of influencing predictors in the model without having particular influencing parameter greater than 1. The BLR model predicts the presence of high probability of bank erosion (>90%) from Paschim Narayanpur (Manikchak Block) to Jotananta (Kaliachak-II Block). The soil bearing capacity significantly expresses highest odds (87.6%) of predicting high probability of bank erosion. The model produces accuracy up to 87.4% and also indicates the important role of LULC dynamics in promoting bank erosion.

V

Application of Remote Sensing and Morphometric Indices in Mapping Flood Vulnerability of Upper Cheyyar Sub Basin through MCDM Techniques

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There is a continuous change in climatic patterns over the recent decades which, in turn, results in unusual rainfall and as a consequence, flash floods. It is necessary to investigate the flood vulnerability zones especially in river basins to minimise the impact of flash floods. The present study is carried out in the Upper Cheyyar sub-basin which spreads in 8 Taluks of Thiruvannamalai and Vellore Districts of northern Tamil Nadu. The geographical extension of the study area is around 2,090 km2, in which 25 % is covered by Jawathu Hills, which is frequently affected by flash floods. The study area has experienced unprecedented flash flood during the recent cyclone (NIVAR) in December 2020, unfortunately several hundred hectares of land were submerged due to the flood. The study area needs demarcation of flood vulnerable zones to reduce the impact. In this study, ALOS-PALSAR DEM with 12.5m spatial resolution has been used to generate the streams and delineate the study area. The main aim of this study is to prepare sub-watershed-based flood vulnerability zonation by using the morphometric parameters. Ten parameters that can act as a driving force for flood, were selected for the analysis. Each parameter is weighted and ranked based on influencing proportion to the chance of flood through the Compound Factor (CF) analysis and Multi-Criteria Decision Making (MCDM) methods of Technique for Order Preference by Similarity

to Ideal Solution (TOPSIS) and VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) has been used to delineate the flood vulnerability zones. To estimate the appropriate technique for exact assessment, the correlation tests of Spearman Correlation Coefficient Test (SCCT) and Kendall Tau Correlation Coefficient Test (KCCT) are attempted and best technique for assessment has been identified and mapped for flood vulnerability.

VI

Rainfall Runoff Analysis of High Runoff Potential Watersheds using Antecedent Moisture Condition

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This paper deals with the relation between rainfall and surface runoff in high runoff potential basins in Pune City, Maharashtra, including Mangalwar Peth, Wadgaon Sheri, Hadapsar and Kondhwa-Ghorpadi. Part of the Mula–Mutha basin, these watersheds have been most affected by urban flooding in recent times. Landsat TM data of 1989 and 2018 were used for the computation of surface runoff. Regression analysis was carried out to extract population calibrated impervious surfaces (IS) considering IS to be the function of band values, NDVI, TC band II, slope, elevation and population density. For runoff computation, curve numbers (CN), obtained from the standard tables provided in the National Engineering Handbook-4 (NEH-4) published by the USDA, were derived by analysing the land use land cover pattern and hydrological soil group for each watershed and were incorporated in the standard equations given in the SCS-CN method. All storm events producing direct runoff from 1981 to 1990 and 2011 to 2015, were characterised into AMC I, II and III categories using which CN were recomputed as CN I, CN II, and CN III. Further, the estimation of the potential maximum retention (S) and the runoff and runoff volume were carried out. Major changes in the land use land cover pattern from 1989 to 2018 showed a net growth in built up area in all basins, leading to the increase in IS in the watershed which have gone well above 80%. This has led to a substantial increase in surface runoff and consequently the surface runoff volume from 1989 to 2018. Mangalwar Peth and Wadgaon Sheri show the highest runoff in 2018. The number of storm events getting included in the category of runoff potential storm events exhibits an increasing trend. Overall, with increase in rainfall, an increase in surface runoff has been observed over 3 decades.

VII

Impacts of Climate Change on Glacier Behaviour and Socio-Economic Environmental Changes: A Study on the Western Himalayas

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The impact of climate change on areas associated with glacial activity is very crucial. Changes of mass balance, snow melt runoff are the parameters, which are directly related to climate change. And due to the climate change, there are various effects (problems: environmental changes) on glaciers. This research work aims to analyse the impacts of climate change on glacier behaviour and socio-economic environmental changes. And the specific objectives of the study are to identify the change in the length of Chhota Shigri glacier due to change in climate over the past years from 1984 – 2020 and to assess and analyse the socio-economic environmental changes conditions and how it can affect local people. Google Earth Pro Images and climate, socio-economic perception data has been used. The socio-economic and other allied perceptions were collected from the study area through random sampling survey method. The data is analysed in two modes, i.e., statistical and cartographic analysis, with the help of MS Excel, Google earth Pro, ArcGIS, and others applications. ELA measurement has been used to represent the glacier behaviour and other socio-economic factors are represented through quantitative and qualitative way. It is observed that glaciers have flinching/declined by a length of about 884 meters from 1984 to 2020. This study is very important because, climate change is the most valuable and thinkable theme, in this current era as well as the future also. These types of studies try to highlight the climate change related issues, global changes, and human adaptation conditions. If we do not take steps to avoid the worst impact of climate change, future generation will judge us harshly as we failed to uphold our moral and historical responsibilities.

VIII

Mapping of Artificial Recharge Zones Using Morphometric Variables and Remote Sensing Through Fuzzy Integration in Kodavanar Watershed, Tamil Nadu

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Groundwater is an indispensable natural resource where its availability is shrinking in recent decades due to over exploitation. Accordingly, the rate of consumption and natural accumulation is inequitable in several parts of the country as the current rainfall has no immediate effect in recharging groundwater. So, there is an urgent need to identify the artificial recharge zones for recharging aquifers. The aim of the present study is to map artificial recharge zones in the Kodavanar watershed, a part of the Amaravathi basin, which is facing severe groundwater crisis and needs recharge structures in appropriate zones for conserving groundwater. The morphometric parameters of linear, aerial and relief play a major role in understanding the nature of the topographical, hydrological, and geomorphic structures along with lithology. Eventually, the advanced remote sensing datasets and Geographic Information System (GIS) technique has rendered the application of visualizing the potential zones of groundwater. Thus, in the present study, parameters such as geology, geomorphology, rainfall, land use/land cover, slope, aspect, drainage density, lineament density, relative relief, and infiltration ratio has been utilised. All the thematic layers were reclassified with fuzzy triangular membership function and integrated with the global weightage for mapping artificial recharge zones. Thus, the zones as identified from the study

are suggested to the policy makers for immediate implementation of recharge structures for management and conservation of groundwater.

IX

Changes in Hydraulic Variables with Discharge on the Tapi River, India: Role of Channel Geometry

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Hydraulic geometry refers to the rate of change of hydraulic variables namely width, mean depth and mean velocity as discharge increases. An attempt has been made to find out the at-a-station hydraulic geometry of the Tapi River. Data regarding hydraulic variables associated with annual peak discharges commonly known as Annual Maximum Series (AMS) are available for four sites on the Tapi River. In addition to this, data are available for a large magnitude 2006 flood for the Ghala site. The data have been used to derive the at-a-station hydraulic geometry equations. The hydraulic geometry exponents (b, f, and m) have been plotted on Rhodes' ternary diagram. The results illustrate that the rate of change in mean depth (f) and mean velocity (m) with discharges are greater than the rate of change in width (b). The total variance values for two sites namely Burhanpur and Savkheda are close to the theoretical value (0.33). This suggests that the effects of changes in discharge are absorbed, more or less, equally by all the three variables. However, the total variance values for the remaining three sites namely Gidhade, Sarangkheda and Ghala are not close to the theoretical value indicating that the effects of changes in discharge are not absorbed equally by all the three variables, but by one or two hydraulic geometry variables. This fact, therefore, suggests that the alluvial channel of the Tapi River is not a true alluvial channel, which is self-formed through the independent adjustment of the morphological variables. The b-f-m or ternary diagram indicates that two sites fall in sector 6, two sites in sector 8 and a site in sector 2. The sector 6 represents the channel where Froude number and slope-roughness ratio increases and width-depth ratio and velocity-area ratio decreases with increasing discharge. Sector 8 shows the channel characteristics where width-depth ratio, velocity-area ratio, and slope-roughness ratio decrease and Froude number increases with increasing discharge. Whereas, the sector 2 reveals the decrease in width-depth ratio and increase in competence, Froude number, velocity-area ratio, and slope-roughness ratio with rising discharge. The conclusion is that the channel geometry of the Tapi River plays a significant role in efficient conveyance of monsoon floods through the changes in the hydraulic variables with increasing discharge. Another conclusion is that the hydraulic geometry of the Tapi River delivers a simple summary of the complex relations among its channel and monsoon flood characteristics.

X

Effect of Vetiver Grass on Root-Reinforcement and Slope Stabilisation along Unstable Riverbanks: A Case Study of River Ketia in Paschim Medinipur District, West Bengal

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The role of vegetation as a bioengineering tool in mitigating floods and riverbank erosion has long been acknowledged but still remains less understood and inadequately researched. Grasses, in particular, possess unique abilities in combating erosion, by providing dual support. While their above ground biomass reduces high flow velocity, the underground root network binds detachable erosive soil particles, thereby consolidating bank slopes. The effectiveness of Vetiver grass (Vetiveria zizanioides) as a soil and water conservation tool has been investigated along the banks of River Ketia, a spill-channel of the River Silai in Paschim Medinipur district of West Bengal. The impact of this grass' root network on the soil physicochemical properties was studied along with the contribution of the increased root cohesion to slope stabilisation. Mechanical reinforcement properties of roots were also examined using root tensile strength and root morphological parameters. While the uppermost (0-10 cm) layer of the soil showed an increase in Soil Organic Carbon (SOC) content, the saturated hydraulic conductivity (Ksat), decreased Bulk Density (BD) and increasing size of surface macro-aggregates (>0.25mm) all attested to the increasing stability of soil aggregates, due to the root reinforcement. With an increased root tensile strength in the surface layers, the Root Area Ratio (RAR) was also found to be satisfactorily high and Vetiver roots were also seen to enhance soil cohesion. A channel cross-section survey taken along the Ketia in the pre- and post-monsoon seasons of 2019-2020 showed changes in channel dimensions, with the Vetiver-protected right bank getting slightly aggraded while the left flank (bereft of such protection) was eroded. 2-D inundation modelling in HEC-RAS was done to examine the effect of the grass' aboveground biomass in reducing flood velocity and retarding overland flows. Vetiver grass can thus become a sustainable riparian erosion conservation tool, especially in impoverished/resource constrained rural communities of India.

XI

Assessment of Land Use - Land Cover Changes on Islands off The Coast Between Thane to Raigarh, Maharashtra

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The research paper aims at assessing the land use and land cover (LULC) changes on islands from 2000 to 2020. An attempt has been made to identify the types of islands in the study area and to know their emplacement with respect to near coastal relief. It is also attempted to study the geomorphic aspect in terms of distance from the coast, size of the islands and tectonic alignment of the islands. The study area includes the area off the coast between Thane and Mumbai, Maharashtra. The islands in this area are located and digitised on Google image. Total 12 islands are found in this area and it is mainly observed that most of the islands are situated on the continental shelf area. These islands are mainly of two types: continental and tidal. It is found that continental islands are, in general, bigger in size than the tidal islands. Temporal changes are noted on the islands using Google images by visual interpretation and then from Landsat images by image processing indices such as NDVI and SDVI. Several LULC changes are noted. There is a huge loss of forest cover through time on almost all the

islands. Development of human settlement alongside agricultural plots has been noticed, especially after the year 2010. Several areas are under anthropogenic influence and the deforested area such as the Elephanta Islands are under severe erosion.

XII

Erosion Modelling Using Morphometry and RUSLE: A Case-Study of the Mayurakshi Drainage Basin, Eastern India

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In this paper, an attempt has been made to ascertain the erosion susceptibility of the Mayurakshi Drainage System in Eastern India using the 12.5m resolution ALOS-PALSAR DEM dataset. Morphometric attributes viz. relief, surface, drainage textural and topographic parameters were systematically extracted for the entire study-area. Then, a multi-criteria decision making (MCDM) technique was carried out for ascertaining the erosion susceptibility of the area under consideration. Among a number of MCDM techniques, this study has selected the Analytical Hierarchy Process (AHP). The methodology followed in this paper is essentially different from the traditional AHP technique because while assigning weights to multiple parameters, the study has depended on the Principal Component Analysis (PCA) instead of the opinion of the experts which often differ among each other. The relative importance of each parameter was calculated from the loading ratios of different parameters under PCA. Furthermore, instead of taking only one PC, this study has taken six PCs with a combined explained variance of 96.24%. For each PC, separate AHP was performed and in total, eight AHP-based erosion susceptibility maps were prepared. Finally, these AHP-based erosion susceptibility maps were weighted with respect to their explained variances (obtained from PCA for individual component) and the final map displaying the spatial variation of the erosion susceptibility in the Mayurakshi Drainage System was obtained. The results were validated by the Revised Universal Soil Loss Equation (RUSLE). Receiver Operating Characteristic (ROC) Curve reveals model efficiency of 73.90% with the values of Sensitivity and Specificity of 51% and 78.60%, respectively. This implies that morphometry-based erosion susceptibility may be reliable in areas of lower erosion but tends to suppress the high-erosion areas. By and large, the area is characterized by lower susceptibility scores with the solitary exception of the middle domain of the Mayurakshi Basin. Here the erosion susceptibility is greatly elevated due to the fact that the rivers have to encounter and incise across a number of low-lying hills which may be considered to be offshoots of the Chhotanagpur Plateau. In other areas, the susceptibility of erosion is reasonably modest.

ABSTRACTS OF TECHNICAL PRESENTATIONS

☙ SUB-THEME: GEOMORPHOLOGY AND LANDSCAPE ECOLOGY ❧

01

Gully Erosion Susceptibility Mapping of the Upper Narmada Basin using Random Forest Machine Learning Algorithm

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Gully erosion is natural disaster and one of the most important mechanisms of land loss that causes serious problems worldwide. The main objective of this research is to use machine learning technique RF model to delineate the areas with the most extreme gully erosion susceptibility (GES). The mapping and analysis were achieved using R programming and ArcGIS 10.8 software. The gully inventory map (GIM) consists of 1501 gully erosion locations which were obtained using Sentinel 2 image and extensive field surveys. Out of the 1501 gullies in the study area, 1051 gully locations (about 70%) were used for training and 450 gully locations (about 30%) were used for validating the models. For GES modeling, 12 conditioning factors (GCFs) were used, and the relationships between the GCFs and gully erosion were evaluated. The GES maps were prepared using the RF model and divided into three susceptibility-based classes: low, moderately and highly susceptible GE classes. A very large part of the study region was found to be highly susceptible to erosion, which is clearly seen in the GESMs produced. The results of the validation proved the excellent ability of this model to forecast the GES. The outcome of RF model with (AUROC = 0.781775 for validation dataset) is accurate enough and better suited for GES modeling. The RF model can, therefore, be used not only in this study field, but also in other areas with the same geo-environmental conditions to model the GES areas. The results obtained in this research could be used for sustainable land use planning and gully erosion mitigation in the study area.

02

Influence of Terrain Parameters in Micro-Climate Conditions in Mountain Topography

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Topographic control on climate is an obvious and scientific fact. Microclimate of an area is governed by terrain parameters. Mountain areas have typical mosaic of varied weather conditions due to strong control of terrain conditions and situations. Earlier meteorological data used to be collected from a few selected places and interpolated for the rest of the area

with the assumption of a homogeneous surface. With advent of Satellite Image data on various spectral windows, it is possible now to calculate Land Surface Temperature (LST) for any area. It is well studied for annual and seasonal temperature variations across any area. The spatial scale variation of LST has not been studied in conjunction with terrain parameters, which controls the microclimate in mountain areas. This study incorporates terrain parameters like elevation, slope, aspect, curvature, Topographic wetness index and NDVI to explain LST variations. Itanagar, Naharlagun area of Arunachal Pradesh covering varied topographic and surface cover and land use has been taken as template for study. It is found that Topographic Wetness Index has maximum influence on land surface temperature followed by curvature of the surface. As expected, elevation plays a significant role, but altitudinal variations do not conform to normal lapse rate.

03

Controls on the Bioturbation by Mat Grazing Crab Population at Sagar Island, Hugli Estuary

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Remarkable onshore bioturbation by mat grazing crab population at Sagar Island are characteristically patchy in their distribution. Intensity of bioturbation, as measured from net bioturbated product (abundances of feeding pellets) and percent area bioturbation vary in the bioturbated patches. Primary controls on net (quantitative) bioturbation and rate of bioturbation appears to be the time available between the tide sand the feeding efficiency of the participating crab populations. A number of other local factors appears to play subtle role that influence the selection of feeding sites. These factors apparently include nutrient density, distance between dwelling and feeding sites (genus specific choices), sediment texture (primarily grain size), etc. Optimality of several conditions rather than the influence of any particular factor determines the aspects of bioturbation by Crab Grazers in the study area.

04

Scale Dependency, Rainfall and Lithology Control on the Hypsometry of the Western Ghats, India

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Basin hypsometry has been often used as an indicator of stages in landscape evolution and to study the influence of varying forcing factors (i.e., tectonics, climate, and lithology) on topography. This study investigates and demonstrates the impact of hypsometric properties on scale dependency (catchment area and perimeter) and various forcing factors through assessing differences in hypsometric properties derived from 1050 catchments generated using DEM in the Western Ghat region. Order-wise catchments (from 6th to 3rd) were derived to compute hypsometry integrals and plot hypsometric curves for each basin. A strong correlation between hypsometric integral and basin area-perimeter suggested that there is a

strong scale dependency on the 6th order and the 4thorder draining basin whereas the 5th order has a critical positive relationship with rainfall. For the 3rd order drainage basins, there is a strong correlation with lithology. This study suggests that the topographic evolution of the Western Ghat catchments is not independent but shows a regional and local variation with the influence of rainfall and lithology.

05

Anthropogenic Landslides and their Impact on Human Habitat: A Case Study from Central Lesser Himalaya, India

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Basically, roads are primary indicator of the developmental status of any area. But when these roads are constructed unscientifically, they become curse for the area. The slope failure processes occurring due to construction of roads are adversely affecting the socio-economic status of the area. The blockade of road owing to land sliding results into the detachment of the area from its surrounding as well as affecting the settlement and agricultural processes and seldom causes the loss of human and animal life. The 'Letibunga - Pokhri' link road is a major part of NH-37. Six cases of slope failure processes are investigated along the 19 km of this link road which occurred after the construction of road. An attempt has been made to study the road-induced landslides through detailed field observation and morphological measurements. The studied slope failure processes are categorized into three groups: debris slide, rock slide and rock slide cum debris slide. Geological cross sections were prepared for every location where outcrops were exposed. The Dip and Dip direction for planer failure were plotted on equal area, lower hemisphere stereographic projection with the help of computer programme Dips 5.1.1 (Rock science). Area prone for wedge failure and planer failure are identified on the basis of stereographic projection. Friction circle is considered 28° for mylonitic gneiss (Hoek and Bray). The type of failure identified is wedge and planer failure. Field studies indicate that the landslides are recurring and disrupting the traffic and transport on NH-37 after heavy precipitation during monsoons as well as winters. Slope failure processes occurred along a very small section of the road which lies in the mid-slopes of the watershed and occurred along rivulets or small streams. The impact of road-induced landslides can be assessed under physical as well as cultural environment as experienced by the inhabitants and observed during field study.

06

Prioritization of Sub-Watersheds of Dwarkeswar Basin using Multi-Criteria Decision-Making Techniques for Implementing Management Plans

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Soil erosion and land degradation are the main environmental problems of the fringe region of the Chotanagpur plateau. Excessive erosion in the form of rills and gullies provide huge

amount of sediment to the rivers of this region, leading to channel degradation, reservoir sedimentation, and flash flood. Therefore, identification of erosion susceptible areas at the sub-watershed level is necessary for the sustainable management of soil and water resources. There are various methods for identifying erosion-susceptible watersheds. The present study introduces a novel approach based on MCDM (multi-criteria decision making) techniques. Five MCDM models were used in the present study, namely, simple additive weighting (SAW), complex proportional assessment (COPRAS), additive ratio assessment (ARAS), technique for order preference by similarity to ideal solution (TOPSIS), and multi-objective optimization on the basis of ratio analysis (MOORA). Morphometric variables were used as primary inputs for the models. Spearman's rank correlation (SCCT) was used to determine the best model and measure the degree of similarity among the results obtained by different models. Rank correlation indicates that the COPRAS model has the highest accuracy in the prediction of erosion susceptibility. But the final ranks were given to the sub-watersheds by averaging the ranks obtained from different MCDM models. The TOPSIS model was not included for averaging because TOPSIS shows a negative correlation with SAW (-0.082) and ARAS (-0.179) models and a very low positive correlation with COPRAS (0.181) model. This combined ensemble method placed sub-watershed 10 and 11 in first and second ranks, respectively, on the basis of susceptibility to SE.

07

Disturbances in Fluvial Connectivity by Transport Infrastructure across the Catchments of West Bengal, India

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Problems in geomorphic connectivity, especially through the anthropogenic activities in fluvial system, are emerging issues for a critical understanding of transfer of water and sediments. The development of linear infrastructures (mainly roads, railways, bridges, culverts, dams, etc.) of transport networks has led to the serious problem of landscape fragmentation and(dis)connectivity in fluvial system. West Bengal (WB), a state of India with 7129 km of drainage channel including 42% area under susceptible to flood, is also facing the problem of disconnectivity within the channels and in their vast floodplains mainly through the human infrastructures in terms of dams and reservoirs, embankment, roads, railway lines, bridges, culverts, and others development activities. To assess the potential disconnectivity in riverine floodplain through transport infrastructures across 20 catchments of the State, freely available existing GIS layers of rivers, roads, railways, floodplains (Active and Old), flood-prone area have been analyzed using multiple geospatial tools and field visits. Significant diversity in the results of drainage density, road density, railway density, crossing number, floodplain (active and old) area, and road within the floodplain area has been observed among the twenty catchments of the West Bengal. In particular, the study finds ~21% of the floodplain area is laterally disconnected from rivers and ~40% of the state' land comes within one-kilometre proximal distance between river and transport networks and ~13% transport network has also the probability of waterlogged during floods. Riverside embankment could raise the level of lateral disconnectivity by 260% compared to the transport network only. Overall, the study indicates a massive extension of transport networks on alluvial plain and

their multidimensional effects on hydrological connectivity, which suggests a river friendly comprehensive plan for transport network development in the future.

08

Assessment of Land Use Land Cover change and its Impact on Basin Hydrology in Purulia District, West Bengal, India

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The present study analysed temporal and spatial changes of land use and land cover (LULC) in Purulia district covering an area of 6300 sq. km. by comparing classified LANDSAT satellite images of 1990 and 2020 coupled with land-use transition matrix and Markov Chain model to derive functional information of the spatio-temporal change of the LULC classes. The same analysis was performed at watershed level. The results show that about 113 sq. km. of dense forest (21%) has been lost whereas, 452 sq. km. of fallow (35%) has been lost because of afforestation and expansion of agriculture. The conversion of dense forest to fallow with vegetation and fallow to fallow with vegetation were the major processes of deforestation and afforestation respectively. The loss of dense forest and gain off allow with vegetation were lumped with several govt. plantation programmes in the last few years. The transition from fallow to agriculture and from dense forest to fallow with vegetation were the dominant LULC transition processes. The probability of built-up area (98%), fallow with vegetation (96%) and waterbodies (95%) to remain in the same LULC were high. At catchment level, deforestation resulted in the increase in surface runoff and decrease in ground water availability, and therefore, reduced total water yield. The basin-wise water yield decreased up to 10-20%. Increased runoff exposed soil for further erosion. Future efforts of managing natural resourced should be based on this systematic interaction among landuse, water yield and soil quality in this area of difficult terrain where land is undulating, soil is infertile and water is limited.

09

Geospatial Assessment of Desertification Vulnerability of Sirsa, Haryana

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Anthropogenic activities and climate change are some of the major drivers of desertification, where general productivity of land decreases, and may subsequently lead to the loss of livelihood bringing in poverty, marginalization and then migration. In this study, we have tried to explore the probable causes of desertification at a district of Sirsa, Haryana, by considering multiple indices of physical and social parameters, and the integration into a GIS environment. Sirsa being an agriculturally dominant district, the livelihoods of the people are intertwined with daily interactions of climate change and increasing pressure in the fields to grow more amount of crops to feed an increasing population with rising threats towards land degradation makes this study very pertinent to understand the alterations being carried out on

a temporal scale. The pre-eminent methodological task in determining desertification vulnerability is identifying the vulnerable areas in the studied district through related indicators, formulate methodologies for the derivation of such indices, and derive a composite index integrating biophysical and socio-economic parameters. The study shows that areas having less rainfall, higher temperature and a higher concentration of human population having fewer social amenities at disposal, are at a higher risk of desertification, especially in the south-south-west and western parts of Sirsa.

10

Human as a Geomorphological Agent of the Anthropocene in the Kashmir Valley

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Anthropocene is an informal new epoch of geological time interval influenced by human processes. Over the past 3000years, human activities have modified the landscape and have become the active geomorphological agent in reshaping the relief. For centuries in the Kashmir valley, humans act as the modelling agent by the excavation of heights, filling of depressions and by slope terracing to level the topographic surfaces for their built-up environment. The valley basin is wide-open to various natural hazards for its geomorphic arrangement and seismicity. The formation of man-made landforms has increased the vulnerability to natural hazards. The present study analyzes the role of humans in modifying the existing landforms by forming the erosional and depositional landforms in the valley. For carrying out this work, field survey, topographic maps, historical documents and multi-temporal satellite images were consulted. The study represents some major anthropogenic landforms that have been shaped by human-driven actions, ranging from stone quarrying, brick quarrying, canal construction, railway networks, road networks, river embankment, golf courses, water reservoirs, train tracks, altering the angle of slopes, built landscapes, highways, buried water bodies to the floating vegetable gardens. The environmental impact of anthropogenic landforms in the Kashmir valley has been assessed for analyzing the geomorphologic consequences from human-introduced land -forms.

11

Anthropogenic Impacts on River System and Associated Landforms of Sai-Ganga Upland Interfluve: Causes and Consequences

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Technology-based human activities have greatly affected the existing natural systems and cycles of the Earth in the past few decades. This effect is clearly visible on river systems and their landscape ecology. This research aims to study the human-induced physical changes in fluvial landforms of the study area along with its causes and consequences. The Bakulahi River Basin has been selected for the study, having 177 km of stream length and ~850 km2 of the basin area. The Sai-Ganga Upland Interfluve region is the highest surface in Ganga Plain, with wide alluvial valleys, misfit streams and abandoned palaeo-landforms. The

alluvial valleys are being used for agriculture since centuries and experience a varying trend since the last ~three decades. GIS-based analysis of high spatial resolution imagery (Corona, Google Earth & Landsat-8) with a time interval of ~60 years and account of human perceived changes by the local population (gathered by structured interviews), are used to understand the extent and nature of anthropogenic impacts. The human impacts are mainly seen as catchment area reduction, channel aggradation, channel modification with encroachment and encroachment of oxbow lakes. Three main phases of human intervention to the river channel are identified. The emerging trends of human intervention in the alluvial valley are a serious threat to the sustainability of channel and can increase the flood risk to a great extent. The aggraded channel, increased waterlogging and significantly increased flood durations are very much evident in the studied basin. The role of the land consolidations by revenue department is also very critical in affecting the fluvial systems in the study area. The consequences of channel modification for flood mitigation are very serious and compel to rethink the mitigation strategies.

12

Estimation of Surface Runoff for Micro Watershed in Western Maharashtra using Remote Sensing and GIS Techniques

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Runoff is one of the most important hydrological variables used in most of the water resources applications. The problems caused by runoff can be seen not only in the study area but also in the world, especially in the hilly region. The use of hill slopes for agriculture in developing countries usually starts due to combination of the exerting growth of population and limited arable land. Heavy rainfall, soil degradation, steep slopes, sparse vegetation cover and other factors contribute to severe surface runoff and soil erosion hazards. In western Maharashtra, most of the watersheds show high potential for surface runoff and soil loss. No effort has been made to carry out such an assessment properly. Sanaswadi micro-watershed (11.5 sq. km) is selected for the study area. This study aims to estimate the surface runoff using Natural Resource Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS), as a Curve Number (CN) method with remote sensing and Geographical Information System (GIS) techniques. This method considers many factors, such as rainfall, land use/ land cover, infiltration rate variation, hydrological soil groups, etc. Soil map, LU/LC map and slope map were generated in a GIS environment. However, this method requires data on soil properties in terms of infiltration, texture and others. Approximately 28 soil samples and observations have been recorded. Every parameter of the NRCS equation has been determined and transformed into a digital format. Based on the results, sub-basins were classified according to their annual average runoff volume. The first priority was given to the second, third and fourth ordered basins with severe runoff. The second priority was assigned to the second ordered basins. Runoff noticed that the first ordered basin was much less; therefore, the third priority was given to these basins.

13

The Human Role on Changing Morphology of Jaldhaka River in Jalpaiguri and Coochbehar Districts: using Geoinformatics Techniques

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The present study deals with the anthropogenic impact on morphology of the Jaldhaka River in Jalpaiguri and Coochbehar Districts. Present condition of the river is becoming hazardous day by day due to various human activities. This is due to an exponential increasing of the human population in the Duars area that catalyses these adverse effects. The human impact on river morphology is displayed by the building of barrage and bridges, embankment and human settlements on the floodplains. It can be concluded that natural characteristics of the Jaldhaka River is cleaned out by several human activities in the name of development. This study acts as a key to improve our understanding of how humans alter rivers and to protect these rivers for future generations. Detection of course changes of the Jaldhaka River between the years 1913-2020 has been considered based on the availability of maps. These temporal changes of the Jaldhaka River have been identified from the 1913, 1930, and 1943, Survey of India (SOI)topographical maps (scale 1:253440) and 1990, 2000, 2010 and 2020 USGS LANDSAT image.

14

Morphometric Resolution of Laphri River Basin, Chotonagpur Plateau, India

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The morphometric study is a quantitative description and analysis of the terrain surface and any landform unit. In the present study, an attempt has been made to analyze the morphometric resolution of the Laphri river basin flowing in the western part of the Chotonagpur Plateau. Based on the secondary data obtained from the topographical map no. 73 A/4 on the scale of 1:50,000 of Survey of India, various parameters covering linear, areal, and relief aspects of morphometry have been adopted to study the morphometric characteristics of the said river basin. For the cartographic representation, QGIS (Version 2.14.21) software has been used. The results show that the watershed is classified as a 5th order drainage basin having a bifurcation ratio of 3.46, which indicates homogeneous rock type and drainage pattern is less disturbed by geologic structure. Hypsometric analysis indicates the mature stage of the river basin. More than 50% area is having low relative relief (20m – 88m) and more than 63% of the areas are under moderate slope (6° - 11°). However, this work tries to deal with the theoretical view on the river basin; this may be helpful to plan the land use pattern for the demographic change for the basin dwellers.

15

Degraded Wetland Environment in Aie-Manas-Beki Interfluvial Region of Assam

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Wetland environment is one of the most concerning aspects of study for the researchers in the present time. The ecologically diverse wetlands have undergone significant threat due to unjustified use by the nearby people arising out of fishing, cultivation, habitation, etc. The interface between man and wetland has been creating ecological problems to the wetland. The present study has been undertaken keeping this view in mind to examine the present status, causes of eco-degradation, and sustainability of both the people and wetlands. The study is based on primary data collected from the field, Survey of India toposheets and satellite imageries of different years which are subsequently analysed in a GIS environment. It is seen that the wetlands are surrounded by rural population having their occupational engagement with their sources of the wetlands. It is observed that there is very close relationship of economy of the rural people with the resources of wetlands. The wetlands are the principal source of water for agriculture and domestic purpose as well, ensure irrigation to croplands during the monsoon failure. The wetlands have now become potential areas for rice and vegetable production in winter season and fish in summer season. It is felt necessary to prevent increasing eco-degradation of wetlands due to various human activities in the study region. It is an imperative need to conserve the wetlands and protect their unique biodiversity as much as possible. The conservation of wetlands for their unique ecological status along with sustainability of the nearby people has become a big challenge for us. Some extenuating measures have been put forwarded for this purpose.

16

To Suggesting the Site-Specific Sustainable Management Plan for Improving the Existing Wastelands on the Basis of Available Resources

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Wastelands are degraded and unutilized lands except current fallows due to different constraints. Poor land practices have led to malnutrition and decline in production capacity of the soil. It is estimated that in wastelands the biomass production is less than 20% of its overall potential. It includes areas affected by water logging, ravine, sheet and gully erosion, riverine lands, shifting cultivation, salinity and alkalinity, shifting sand dunes, wind erosion, extreme moisture deficiency, coastal sand dunes etc. These degraded lands are ecologically unstable with almost complete loss of top soil and are unsuitable for cultivation due to decline in their quality and productivity. Subsidies and incentive programs aimed at promoting low-impact renewable energy deployment and establishing mitigation obligations that raise costs for projects that create land-impacts could improve the public support for renewable energy. Natural resource management is aimed at reversing the trend of resource deterioration, maintaining the ecological balance and sustainable economic development. Short as well as long term success in it can only be ensured by taking into consideration specific needs of beneficiaries by ensuring their participation at all stages of decision making and project implementation, through appropriate mix of modern technologies with indigenous technical

knowledge and by setting up local institution for planning, implementing and monitoring of whole project and beyond. In West Bengal, one of the most severely affected states by soil erosion, Integrated Wastelands Development Programme was initiated in 2004 to counter the natural resource depletion challenges. This investigation presents a detailed analysis of the programme from sustainability perspective which was measured by considering three dimensions namely social, ecological and institutional separately.

17

Assessment of Changing Landscape Ecology of the Subarnarekha Basin: Challenges and Management

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The study of landscape patterns and prevailing ecological processes in a riverine environment is significant for the sustainable management of natural resources. The Subarnarekha river basin is encompassed 25792.16 sq. km and about 30 % of the total population is tribal and are depending on agriculture and natural resources (forest, river water, minerals). This basin is also belonging to a rainfed region, about 80% of the total annual rainfall is occurred in four months (June-September) and the rest of the year is dry. But over exploitation, unscientific industrialization and mining, rapid urbanization, unscientific agriculture practices, and changing patterns of climate made the situation worse. So, assessment of landscape ecology in the context of identification and quantification of interrelations among landscape patterns and processes laterally with human interferences in a manner of spatial and temporal scale is very much necessary. A systematic methodological approach and organization of the landscape ecological indicators like the forest, water, soil, land use, and human community are incorporated on a local scale. Estimation of changes in landscape ecological indicators and their trends of the Subarnarekha basin have been performed by using a combination of geospatial and statistical techniques. Remote Sensing (RS) and Geographical Information System (GIS)techniques have been applied in change detection and map generation. Chen et al's location-weighted landscape index (LWLI) has been applied to study the role of landscape type in ecological processes. The correlations among the collected data and derived data have been examined by statistical methods to identify potential restoration sites for landscape ecology management. Finally, the entire study revealed that there is a need for involvement of geomorphologists, ecologists, soil scientists, climatologists, political stakeholders to manage the changing landscape ecology of the river basin holistically.

18

Sediment Yield and Rill Erosion Prediction using SWAT, Logistic Regression, Decision Tree and Random Forest Models in The Mayurakshi River Basin of Eastern India

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Soil erosion is one of the major environmental hazards causing severe land degradation in the subtropical monsoon dominated Mayurakshi river basin (MRB) of Eastern India. Hence, this study aims to delineate major sediment yield zones using ArcSWAT model. Furthermore, the present investigation also predicts the Rill erosion probability (REP) using logistic regression (LR), decision tree (DT) and Random forest (RF). Henceforth, a gully erosion inventory map was prepared using150 rill and gully erosion prone sites, out of which 70% sample points were randomly chosen for modelling and remaining 30%sites were used for model validation. Alongside, twelve conditioning factors including elevation, curvature, aspect, runoff, TWI, slope, geology, stream frequency, rainfall erosivity, NDVI, LS-factor and LULC were selected as spatial data base for model building. Multicollinearity among conditioning factors were performed using tolerance (TOL) and variance inflation factor (VIF). Lastly, ROC curve was used to predict the model authenticity. From the present study it may be concluded that sediment yield capacity is very high in undulating western most part of Mayurakshi river basin due to extensive rill and gully erosion as compared to other sectors.

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Darjeeling Himalayan Foothill Fans and there Ecosystem Services West Bengal, India

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The Darjeeling Himalayan region has been identified as one of the most ecologically sensitive regions of West Bengal and considered as a special region due to its unique geo-environment and biodiversity. The entire east-west orientation of Himalayan foothill zones are the piedmont regions of the Himalayan mountain which is considered to be an integral part of the ecosystem which is quite different in nature compared with others as the structural complexity. Alluvial fans are sedimentary accumulations of varying size, with a thickness of at least one hundredth their lengths. When sediment laden flows debouche from a mountain front to a low gradient basin, then by the deposition of the materials, alluvial fans are formed. An ecosystem is a community of plants and animals interacting with each other in a given area and also with their abiotic environment. Himalayan foothill ecosystems are identified as the most vulnerable region. They provide life support of huge population due to the perennial river system, forest cover, rich biodiversity, mining potential and many more. In the northern part of West Bengal, there are huge varieties of ecosystem services through the entire Himalayan belt, among these we may go further for micro scale observation of the interfluves of Tista to Jaldhaka river basin areas as there are many perennial rivers which are active as well as primary components which are continuously regulating ecosystem services. Ecosystem services provide varied benefits to humans gifted by the natural environment and form healthy ecosystem, healthy relationship, giving shelter to many species, pollination to many crops, climate stability of forest, giving scenic beauty to the region, these benefits are known as “Ecosystem Services”.

Data collection was done by primary questionnaire survey and direct observations as well as secondary data from journals and articles, govt. and non govt. organization, and previous work on related issue. This work was done for understanding the environmental components in ecosystem and ecosystem services of that region. Dynamics of the ecosystem were assessed

in terms of status and quality. The anthropogenic impact on the environmental components were also analyzed. Furthermore, scope of community participation and management for the governance of natural resources was seen.

20

High-Resolution Satellite Remote Sensing Reveals Major Land-Use Changes as Scope for Land Degradation Neutrality in Arid Rajasthan: A Case Study of Jodhpur District

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The problem of desertification has remained on the international agenda for the last six decades. Achieving Land Degradation Neutrality (LDN) is now the major focus of UNCCD for controlling desertification worldwide. In the Delhi Declaration at the meeting of CoP14, India has committed to achieving a LDN target of 26 million hectares by 2030. This calls for precise information on the state of natural resources, their degradation, and identification of local level pressure indicators for initiating suitable combating strategies. The use of high-resolution satellite images for such an assessment is one such option. Desertification is a major environmental problem affecting 21.5million ha or 62.9 % of the total geographical area of Rajasthan. A dominant aeolian land (~76% area), saline lands (<2 % area), rocky/barren land (~10 % area) including droughts, dust storms, cold waves are the major reasons. Western Rajasthan has the maximum area under hot arid regions (61.9 % of country's hot arid regions, along with a physical form of degradation, there is pressure from a 28.1 million human and ~30 million livestock population. However, with suitable land and water management, the region's 3.03 m ha culturable wastelands and 3.88 m ha fallow lands can be improved. The study used Arc/GIS software for analyzing the land use and desertification status of Jodhpur district using Sentinel-2A (10 m spatial resolution) satellite images for the 2020 period. NDVI was used to extract and map the areas under croplands. A desertification map of Jodhpur district was prepared. Results indicated maximum area under wind erosion in ~85% area under different landuses. Rocky/barren areas (969 km^2 area), salinity (216 km^2area), and rock mining in 83 km^2 area are the other forms of land degradation that show an increasing trend over the years. However, utilization of 5120 km^2 sandy area for irrigated crops and putting 67.5 km^2 wasteland area for solar plants have controlled the severity of sand movement.

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GIS-Based Landform and LULC Classifications in the Sub-Himalayan Kaljani River Basin: Special Reference to the 2016 Flood Event

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Progress in GIS technology has facilitated the topographic position index (TPI)-based auto-classification of landform units. Multispectral satellite images, when used along with terrain

analysis output, provide valuable information on different topographic parameters. The present work makes an endeavour to classify landforms using TPI and assess its distribution pattern across different land use land cover (LULC) segments in the Kaljani River Basin of Sub-Himalayas (1,479km2), which is spread across Chukha and Sarpang Districts in Bhutan and Alipurduar District of West Bengal, India. An attempt is also made to analyse the inundation pattern during the most recent major flood (2016) across the landform and LULC units. As found from the ALOS-PALSAR DEM of 12.5 m resolution, the basin is occupied by upper slopes (16.1% of the total area), mountain tops (7.5%) and gorges (5.4%) in the upper (northern) part, while its lower (southern) part is characterised by wide valleys (45.7%) and plains (16.9%). The areas occupied by gorges and midslope drainages in the mountains, besides the wide valleys in the foothills, are comparatively more exposed to fluvial erosion, as found from the topographic wetness index. Besides, the stream power is at least three times higher in the gorges as compared to the other landform segments. LULC classification using Sentinel-2A image of January 2020 reveals that the northern and central parts of the basin have plenty of vegetation cover (48.2% of the total area). Whereas, fallows (19.5%), farmlands (16.6%) and built-up areas (9.4%) are more common in the southern part of the basin. During the 2016 flood, three-fourth of the total inundation (areal extent: 82.5km2) occurred in the wide valleys and plains in the southern part of the basin. Whereas, noticeable waterlogging can also be found in the alluvial fan region of the foothills (20.2% of the total inundated area). About 49.0% of the inundation occurred in the fallow areas, followed by farmlands (30.6%) and built-up surfaces (12.1%). This indicates that more than 90% of the flooded areas are located in the human-modified terrain, highlighting its susceptibility to the flood hazard.

22

Changing Land-Use Pattern of Jhum Cultivation and Impacts on Environment in Resubelpara Block, North Garo Hills District of Meghalaya

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Shifting cultivation or slash and burn agriculture is a predominant land use practice in the tropics. In North-East India, shifting cultivation is locally called ‘jhum’ cultivation. This method of cultivation is particularly suitable in hilly areas. The Garo people of Resubelpara block of North Garo Hills district have been practicing jhum cultivation for their livelihood since ancient time. This study is an attempt to analyze the spatio-temporal dynamics of jhum cultivation in the block using Landsat data of 2010 and 2018. It also studies the impacts of jhum cultivation on environment of the block based on primary and secondary data. The study reveals that due to increasing growth of population, the area under jhum cultivation is decreasing and at the same time the period of jhum cycle is getting reduced. The effects of jhumming practice on the environment are experienced in terms of soil erosion, loss of flora and fauna, loss of forest cover, drying of perennial water sources etc.

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Evolution of Granitic Terrain as A Result of Fracturing Pattern

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Granitic rocks are one of the oldest and most common surface exposures in India. They are widely used as building stone and at many heritage sites for decoration purposes. Granite is a quartzo-feldspathic plutonic igneous rock having sufficient strength and durability. The mechanical and physical properties of granite such as strength, elastic modulus, Poisson's ratio, density, porosity, permeability widely vary as a result of damage sustained due to various processes over time. Granite is susceptible to weathering by variable climate conditions, leading to the formation of varied geomorphic terrain and finally into end product of regolith. The porosity of granite is very low and the effective fluid flow is only through fractures. Granite and related suites have well developed tectonic joints and foliation along with large number of microfractures which makes granite weathering very effective. Data of fracture permeability have been collected through available literature to understand fluid flow in granite under different stress conditions. Surficial joint intensity mapping was done in Bundelkhand granite exposures to understand the fracturing pattern. Foliation pattern have also been studied to examine the control of such anisotropic feature in developing overall geomorphic terrain. Detailed field mapping shows that granitic rocks have well-developed orthogonal joints along with highly foliated domains in some sections. Dykes which are vertical in nature is also observed running through the granitic terrain. The granitic rocks in general have very high fracture permeability at high stress above 10 MPa which closes most joint apertures as understood by examining large number of literatures. Fracture permeability is essentially reduced to zero beyond this. But at low stress relating to surficial conditions, joint closure is not very fast leading to open joint apertures causing fluid flow to deeper levels. The weathering becomes very prominent in such cases allowing intense strength degradation and intact rock damage. Grain size and mineral composition of granitic rocks are also highly variable leading to increase in rate of weathering. During weathering, the mobilization and reorganization of trace elements become very active and are affected by various processes such as dissolution of primary minerals. Therefore, weathering patterns are of primary importance in the development of many granite forms, though others are due principally to tectonic forces.

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River Environment in Badlands: A Neglected Dimension

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The planform pattern reflects a balance between all the fundamental ingredients of a river system. The infamous ravine infested Chambal is also not an exception to this rule of nature. The pristine, incised river Chambal lost its natural flow in many places for the past decade. Its creature, the ravines along its both the track of lower reaches, are no longer stable due to human intervention. Around 600 km2 of this thick ravine alluvial track of the Chambal has been levelled down for agricultural practice in the last few decades. As a result, the entire track of the river is disturbed in many sections, which gets further complicated by the uncontrolled sand mining activities. The fallout of the levelled land leads to severe soil erosion

after every rainy season and all the gully channels contribute a significant amount of sediments to the Chambal river system. Topographic, river discharge, silt, climatic and socio-economic data were collected from decadal remote sensing data along with CWC to explain observed land- use/cover changes and spatial changes in sediment transport and river morphology. Few active test sites like the villages of Esha, Bilpur, Kuthiana, Dholpur show a significant change in river morphology compare to the upper catchment of the river. On the other hand, various anthropogenic activities impacted on the rivers' natural flow in many sections which is one of the reasons for changing the planform over last four decades. The noticeable impacts of the river system are the change of ripple and pool sequence, formation and expanding of bars and increasing silt in the channel during monsoon and post monsoon season which is disturbing the natural habitat of the infamous endanger aquatic animal of the Chambal such as Gangetic dolphin, gharial and a large number of such species are on the verge of extinction.

25

Multi-Criteria Decision Based Evaluation of Wetland Ecosystem Health (WEH) of Mursidabad District, West Bengal (India)

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Wetland ecosystem provides a wide range of ecosystem services like production, water sanctification and ground water recharge, climate purification, nutrient cycle, flood decrease, biodiversity preservation and cultural services, etc. The floodplain region of the Ganga – Padma and the Bhagirathi rivers characterized by diverse type of wetlands, which supports livelihood patterns of local people. However, the wetlands are degraded day by day due to rapid urbanization and hydro-ecological changes. The present study investigates the status of ecosystem health in the wetlands of Mursidabad district at block level based on the pressure – state – response (PSR) model and analytical hierarchy (AHP) method from 2013 to 2020. Landsat images, census data and Google Earth data were used to get research results. We categorized the WEH score – sick, unhealthy, sub-healthy, healthy and very healthy category. The results show that 26.92% of block residing to sick category in 2013, but it has increased to 30.77% in 2020, while the percentage of blocks in very healthy category has decreased markedly from 11.54% to 3.85%. The wetlands in these blocks get degraded due to higher human pressure like – population density, urbanization growth rate and road density. Scientific protection and restoration techniques of these wetlands should emphasize in these areas to minimize the wetlands health degradation.

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Badland Dynamics in a Part of Tapi River Basin, Deccan Trap Region, Maharashtra, India

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Soil erosion is one of the most serious hazards human race is facing today. Four million hectares of agricultural lands have been rendered wastelands in India due to rill and gully erosion. The Deccan Trap Region of India is characterised by rocky terrain. Sediments are thin and occupy only restricted areas. The study area is a watershed along the Tapi Basin in Maharashtra where alluvial bank deposits are deeply dissected by intricate network of gullies to form badlands. These badlands have been intensively reclaimed for agriculture in the past few decades. Based on various sedimentological and morphological properties, an assessment has been done whether such types of land reclamation practices are permanent solution to the problem of land availability and agriculture in these areas. DEMs of three time periods were self-generated using IRS Cartosat I images and changes in the morphometric parameters were detected from them. A field survey was carried out to measure the current gully reactivation in the area. Results indicate that the region is indicating soil loss beyond the tolerance limit. A suitable landuse planning needs to be designed for these areas concerning geomorphic setup and sediment properties, because the present landuse methods will not stand through time.

27

Spatio-Temporal Changes in the Morphology of Sasur Khadi River using Geospatial Techniques

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Sasur Khadi River is a tributary of Yamuna river arises from Fatehpur district and reported a length about 40km and joins river Yamuna in Prayagraj city. The river is having major attraction because it flows along fertile plain, where a large number of settlements are scattered both side of river, but this River is towards its extinction. In this paper an attempt has been made a geographical analysis to detect the minor features and changes in the behaviour of the river course in spatio- temporal perspective. It has been observed that, the area where the human interference is more a lot of significant changes clearly visible, which is threat to river existence and potential revival. This paper makes an attempt to examine the spatio- temporal dynamics of the river profile at micro level. The paper also discusses the post and pre- monsoon conditions of the river and also the exploring the possible prospect of the river with reference to its relation with agriculture sustainability.

28

Changes in the Course of River Ganga and Impact on the Surrounding Landscape: A Case Study of Prayagraj Sadar (Tehsil)

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Rivers are important geomorphic forces as their courses undergo spatial and temporal geomorphological changes. These changes in geomorphology have impact on the surrounding landscape because the geomorphic processes inhuman environments affect human ecology

and are modified by human interventions. These changes affect the land use and Land cover in the surrounding area. These changes also affect the habitation and livelihood in the surrounding areas of the river. The present work deals with the changes in the course of the River Ganga and consequent geomorphological changes in the river course in the Prayagraj Sadar tehsil. The river morphology in the area affects the land use and in turn gets affected by the processes of Urbanisation and industrialisation and their impact on the river ganga. Since the area is famous for convening Kumbh Mela on the bank of this pious river, the mela- time artificial arrangements affect the river flow. The objective of the research is study river morphological response in a human controlled environment. This work uses GIS techniques to identify changes in the river course and impact on the land use and land cover of surrounding areas. This also requires field survey to assesses the localised changes and their impact of life and livelihood of people having their socio-economic association with this river. The work reveals that river course change in human environment is a process-response process where both geomorphological changes and human changes affect each other. The region has gone significant land use change and consequent impact on the life and livelihood of the peoples in the surrounding areas.

29

Identification of Landscape Changes due to Mining in and around Billi-Markundi Minig Area of Sonbhadra District

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Stone mining is one of the most important economic activities carried on in southern region of the Sonbhadra district due to its rich natural base. Identification of such sites are of prime importance from geomorphological point of view as it helps to gain knowledge about the geological evolution of the area by exposing under-surface rocks and materials. Billi-Markundi is a small area in Chopan block of the Sonbhadra District surrounded by Son river in the North and Rihand river in the west. Stone mining is the prominent activity in this region. Opencast stone mining of dolomite rocks is operational in this area and more then 60 open pits are found and large number of stone crushing units are under operation leaving a notable impact on the whole environmental landscape. Initially, the whole area has hilly landscape that has now been converted into open pits. Open lands are also being mined for stone extraction. This research paper attempts to assess and analyse the stone mining activities and tries to identify the changes that have occurred in the landscape because of stone mining activities in and around Billi-Markundi area and it also aims to find out the impact of stone mining on humans living in vicinity of this region. Study area is demarcated using google earth. Geo-spatial techniques have been incorporated in this study to fulfil the purpose of the study. The results reveal that the land use/land cover has changed a lot during last two decades. Human population living in vicinity are facing severe health issues because of dust particles coming out of stone mines.

SUB-THEME: SLOPE MOVEMENTS: ASSESSMENT AND MANAGEMENT

01

Sedimentological Characterization and Micro-Surface Texture Analysis of Failed Slope Materials and its Impact on Slope Instability, Garhwal Himalaya (India)

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The present study examines the sediment characteristics of slope material and the influence of geomorphic processes on slope instability in the Garhwal Himalaya. Many landslides occurred in the region, making it one of the worst affected areas of the world. These are mostly triggered by high-intensity rainfall, seismicity, and anthropogenic changes. We have collected twenty-five active landslides material for laboratory analysis. Grain size distribution, mineral composition, and micro-surface texture have been investigated to understand the landsliding mechanism. X-ray diffractometry of fine sediments was done to analyze the mineral composition, crystalline structure, and lattice strain of the slip zone. The composition of grain size and minerals significantly relate to volume and type of landsliding in the area. Quartz was an abundant mineral, with a higher concentration in the debris fall and rock slide, particularly in the Lesser Himalayan metasedimentary silicate rock groups. Microsurface features of quartzite rock with higher composition of quartz mineral, lesser strain, and little 'd' spacing within molecules show high shear strength and create greater resistance to slope failure. Surface microtextures on the quartz grains provide significant insight into the geomorphic process and depositional history of clastic sediments. The prominent surface features that are established in the sedimentary process are grain outline, types of edges, steps, pits, crystal overgrowths, ridges, etc. The surface features are mainly related to the transportation mode, run-out distance and time, and particle size. Nevertheless, features are equally a function of the particle's original grain shape in the parent material. A significant relationship between landslide types and the displacement volume related to grain size and mineral compositions exists in each of the slope failures investigated.

02

Landslide Hazard Risk Assessment along NH3: A Case Study of Bhuntar-Manali Stretch

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Bhuntar-Manali stretch is located in Himachal Pradesh in the Western Himalayas and is well known for its natural beauty and cultural heritage which makes it famous among the tourist places in India. The study area is prone to landslide hazard due to its location and physiography. The region is mainly linked with other parts of the country through National

Highways NH-3 (Old NH-21) and NH-5 (Old NH-22). Heavy rainfall with cloudburst causes floods and landslides, which is a common phenomenon over here. The study area is drained by the Beas River, which during monsoon destruct a lot by gathering severe landslides in Beas valley. Himachal Pradesh has a network of 33000km and 80 percent of these roads are vulnerable to landslides. NH-3 is one of the major National Highways in the state which connect important tourist destinations like Kullu and Manali. Secondary data from satellite imagery and Geological Survey of India as well as primary data of landslide from GPS Survey has been used. In the present study Multi Criteria analysis method using physical parameters like geomorphology, geology, land use land cover has been done to identify and analyze the landslide hazards along Bhuntar-Manali National Highway..

03

Assessment of Slope Stability using General Limit Equilibrium (GLE) Method in South Sikkim Himalaya, India

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Slope stability analysis is a computational extent for determining the stability of slope and it is performed to minimize the occurrence of landslides and slope failures. The fundamental criterion for stability analysis is the factor of safety against sliding which should be always greater than or equal to one for the slope to be safe. The objective of the study is to find out factor of safety (FOS) of the given slope under static condition using General Limit Equilibrium method (GLE). In this study, SLOPE/W has been applied for computing FOS under different shear surfaces. The study aims to determine geotechnical and geometrical properties i.e., cohesion (KPa), unit weight (kN/m^3) and friction angle of five landslide prone locations of Jorethang, Singtam, Melli, Mellidara-Turuk, and Farashey of South Sikkim Himalaya. The estimated safety factor value of all locations ranges from 0 to 0.5. It has been found that Daling group of lithological composition is very much prone to landslide events where safety factor is very close to 0. The frequent earthquake phenomena in South Sikkim Himalaya have given birth to numerous faults and lineaments which introduce favourable condition of slope instability.

04

Slope Evolution in Sedimentary Rocks due to Anthropogenic Activities

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Different rocks are exposed to different weathering rates and climatic conditions leading to the development of variety of geomorphic terrain with time. The Markundi Hill (Sonbhadra) characterized by moderate strength and highly jointed rock with rugged topographic features has experienced several episodes of mass movement phenomenon leading to change in surface topography. The study area is affected by Markundi-Jamwal fault which has caused elevation difference leading to increased weathering rates and mass wasting phenomenon.

Slopes resulting from such geomorphic feature in sedimentary terrain are affected by various parameters such as inclination of bedding, direction of slope face, intensity of fracturing and climatic conditions. Continuous erosion and transportation of sediments has resulted in periodic modification of entire landscape overtime. Different sections in study area have been analysed extensively in the field to investigate the parameters controlling weathering rates and increased incidence of mass movement. Mass movement is studied using kinematic analysis and slope mass rating while weathering has been studied using present condition of rock mass and rock mass classification techniques. Based on RMR values, studied sections can be categorized under poor to fair quality rock mass while based on SMR investigation, rock mass class falls in partially stable to unstable class, respectively. Kinematic analysis suggest that slopes are unstable. Plane and wedge failures are commonly observed along both left and right slope sections while toppling conditions are mainly observed in the right slope section. The mass movement is highly localized and very small in scale generally controlled by local structural attributes such as inclination of bedding planes, fracturing etc. while weathering rate is controlled by large continuity and inclination of bedding planes along with opening of joints due to anthropogenic activities.

05

Application of Saaty Ratio Scale for Landslide Susceptibility Mapping along a Highway Road Section in J&K, India

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This paper attempts to comprehensively study the landslide susceptibility mapping using Saaty ratio scale method along a highway road section from Bandipora to Gurez in J&K, India. Ten landslide geo-environmental factors which are investigated to form the probable analytical hierarchy process (AHP) matrix that is slope angle, geomorphology, stream power index, normalized difference vegetation index, distance to road, lineament density, drainage density, topographic wetness index, soil, and slope aspect were considered. The landslide inventory map which has more than 300 landslide events were mapped based on historical records of the Border Roads Organisation (BRO) of Srinagar, Bandipora and Gurez, as well as landsat7 ETM + images, Google earth images, and secondary sources. Google maps were used due to their high resolution and available GCP's which enable to identify the landslides precisely and in addition to that an extensive field survey was also conducted in course of the study in which the location and measurements of landslides were carried out using hand held GPS and tape. The analysis of the relationships between the landslide related factors and the landslide events were then carried out in a GIS environment. A weighted pair wise comparison matrix was generated using Saaty ratio scale to generate a landslide susceptibility map which was then overlaid using the index overlay module in ArcGIS 10.2 supplemented by MS Excel and Matlab R 2008a. The results show that the area of 38 percent is covered by very high and high landslide susceptibility zones of the present study. The villages which fall under these zones are Bonkoot, Razdhan Pass and Gurez are highly prone to landslide commotion. These are the most tortuous and rugged zones with high incidence and impact of landslides. There is a frequent incidence of traffic disturbances along the road. Thus, there is an urgent need to

mitigate the landslide vulnerability particularly to avert the disruption from Bandipora to Gurez road which causes huge inconvenience, economic and human losses.

06

Landslide Vulnerability Mapping (LVM) of the Darma-Byans Valley in Kumaun Himalaya using Weighted Linear Combination (WLC) Approach

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Landslides hazard is one of the most damaging disastrous phenomena that frequently lead to serious problems in hilly areas. The Darma-Byans valley is located in Pithoragarh district of Kumaun Himalaya. In the present study, weighted Sum (WS)method is used in the process to estimate for landslide vulnerability mapping (LVM). Eight geo-environmental parameters are classed and multiplied with its assigned weight and integrated to get the final output map. Analytic Hierarchy Process was used to determine the weight values of different parameters. Relative rating values are assigned for the subclasses of each thematic layer based on their corresponding impact on the landslide triggers, and within a thematic layer, each class was assigned an ordinal rating from 1 to 5. Thus, landslide vulnerability map (LVM) of study area was prepared. The LVM of Darma-Byans valley is divided into four vulnerable zones, namely low, moderate, high and very high. The findings demonstrate that maximum 64% of study area is under moderate class of natural hazard zone and high hazard zone is occupied by 35.79% of the total area. Very little percentage of area is covered by the low (0.08%) and very high (0.1%) hazard class zone. Probability of landslide vulnerability is also calculated in each hazard zone. IN DB weightage range goes up to maximum 36 so we categorise these weightages in category 4 where less than 10 nos. of total weightage covering the area of 1.42 km^2 and having chance of landslide occurrence is 0 to 28 % and so on. The result shows that there is a positive relationship between hazard class and probability area. As the hazard class increase, the probability of landslide vulnerability also increases. Resulting LVM and probability in landslide vulnerability were validated with field study and geospatial technology-based analysis. The final landslide vulnerable map (LVM) can be used for the further landslide hazard prevention, proper planning of future infrastructure and geo-environmental development in Darma-Byans valley.

07

Estimation Soil Erosion and Sediment Yield in The Bhind District, Madhya Pradesh (India)Using RUSLE And SDR Models

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Soil is one of the main components of the earth's surface. It is a mixture of different types of substances, such as minerals, sand, silt, clay, organic carbon, biomass, etc. All these substances play an important role for flora and fauna. Soil loss becomes a major environmental problem worldwide. Every year a large amount of soil is eroded and wasted.

As a result of reducing soil nutrition and soil fertility, which affects land productivity. In this proposed work, integration of RUSLE (Revised Universal Soil Loss Equation) and SDR (Sediment Delivery Ratio) models have been used on the ArcGIS platform to estimate the rate of soil erosion, and sediment yield of few major ravine catchment area of Bhind district. This is an exploratory study to run the soil erosion estimation model using open-source datasets to get a robust result of soil erosion. The datasets in this work have been taken from the various open data sources, and the different empirical equations have been used on the ArcGIS platform. The results of this study show that 4.62% area of the district is affected by high rate of soil erosion, while most parts of the district are affected by low rate of soil erosion. The highest rate of soil erosion has been observed in the area which is positively associated with the ravine zone. The sediment yield of the district has been calculated using the SDR equation, and the result shows that the district's total volume of sediment yield is 209473.40 tons/year. Applying this RUSLE model, the district's high soil loss risk zone has identified; Therefore, proper land planning and management strategies can control soil erosion in the district.

GEOMORPHIC RESPONSE OF FLUVIAL SYSTEMS TO FLOOD MANAGEMENT AND RIVER REGULATION

01

Assessment of Spatio-Temporal Behaviour of Channel Braiding Process and its Relation with Stream Power and Bank Erosion in Upstream of Ganga River near Malda District, West Bengal, India

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River bank erosion is a hazardous and common phenomenon at Diara region near Malda district in India during monsoon and post monsoon periods of every year. The left bank of the Ganga river is texturally very weak along the Diara region of Malda district. The present work explores the relations between stream power, braiding intensities and bank erosion in certain stretches of upstream of the Ganga river near Malda district of West Bengal in India. In the present study, we have tried to do a quantitative assessment of channel braiding process of the Ganga River by applying the Plan Form approach and equivalent measurement of stream power. A comparative study of discrete years has been done through braiding index to understand the morphological behaviour of the channel. This paper presents the dynamic behaviour of the channel pattern of the Ganga River System in Malda district over a time span of 40 years. This procedure addresses the selection of input parameters from digital satellite images comprising scenes for the years 1975, 1995 and 2015 with specific dates, from Rajmahal in Jharkhand district to Farakka barrage in Malda district. To obtain Plan Form Indices for the entire study area, required parameters were extracting through using GIS techniques. Stream power is measured through analyzing latest flood records and satellite images. The present study concluded that a wide spread and continuous braiding process has occurred in the study area due to aggradations of riverbed and temporal declination of stream power.

02

Formation, Migration and Morphodynamic Alteration of 50 Channel Bars in Darjeeling Himalayan Piedmont Zone, India

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Channel bars are common, striking fluvio-geomorphic depositional features of alluvial rivers. The study has aimed to investigate the formation, migration and morphodynamic alteration of channel bars (n=50) in gravel braided alluvial rivers in Darjeeling Himalayan Piedmont zone. Dynamics of micro to meso bar deposition is mainly accomplished by the channel

gradient, huge upstream landslide and variation of discharge. Multi-Criteria Analysis (MCA) method has been employed to explain the variation of Principal Component Analysis (PCA1, PCA2 and PCA3), both monsoon to post-monsoon. Bridge scouring, empirical aggradation and degradation values are 0.1 m- 1.05 m and 200kg. m^2s^{-3}-2500kg. m^2s^{-3}. Migration, re-generation and degradation of the micro bars with their optimum morphology show changes during the rainy season. In the upper (Δu_A), middle (Δm_A) and lower (Δl_A) piedmont region the bar dynamic area is 0.12-0.71 sq.km, 0.12-2.83 sq.km and0.10-5.43 sq.km respectively. 58-72% stability of the channel bars is observed in upper piedmont region. The coefficient of determination (R^2) of channel bar area and width is showing positive (0.63) relation.

03

Prioritization of Basin Morphometry through Remote Sensing and GIS Techniques in Debnala River Sub-Basin, Jharkhand

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In recent times, Remote Sensing and Geographic Information System becomes vital tools to assess the environmental problems and ensure the overall development of a basin area. These combined tools are effectively used to determine the quantitative description of river basin morphometry in a very lucid way. Morphometric analysis of river basin is a vital attempt to know the changing pattern of river and basin characteristics and to understand the problem related to land resource management. In this endeavor, basin morphometric techniques have been applied to understand the nature of soil erosion potentiality. In the present study, Debnala river basin (located in Purba Singbhum District, mainstream length 15.2 km, the basin area is about 103.45 sq.km) in Jharkhand state, a right bank non-perennial tributary of the Dulung River has

been selected. It originates in Jharkhand state at an elevation of over 134 meters and flows southeast to cross the border into West Bengal. In the lower course, it has an eastward course, joins with the Dulung at an elevation of about 47 meters. To create the morphometric grid (1sq. km x 1sq. km) over the basin, extraction grid wise various morphometric parameter under the linear, areal, relief domains of the basin area along with DEM Configuration have been used. After computing all the parameters of morphometry, a weighted rating has also been incorporated to find the priority of soil detachment rate in the basin area. The result shows that forty (40) sub-basins have a high rate of erosion potential capacity to produce sediment of the Debnala.

04

Spatio-Temporal Variation in Drainage Discharge and Sediment Load in the Godavari Basin

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Our study demonstrates the spatio-temporal trends and abrupt change points in the discharge and sediment load in the Godavari basin, India. About a half-century (1970-2015) daily time series data was assessed to compute the annual discharge for 57 gauging stations and sediment load for 25 gauging stations. We employed the Mann-Kendall trend test, Sen's slope, and Pettitt tests to estimate the trends, rates of changes and change points within the time series. Our results revealed acritical decline in discharge and sediment loads all over the catchment. A sharp change in the sediment supply was found in the 1990s. At Polavaram, the average annual sediment load in between 1970-1990 was recorded $170*10^{\wedge 6}$ t while it decreased to $56*10^{\wedge 6}$ t during 1991-2013. Further investigation suggested that the intense decline in sediment load in the Godavari River is related to the establishment of high-capacity dams in the period of 1985 to 1995 that entrapped a large amount of sediments within the reservoir and over floodplains, and rising the channel base levels making Godavari more susceptible to sediment-laden floods in future. The overall decline in water discharge is mainly the result of rainfall decline in several parts of the catchment.

05

Direction and Magnitude of Response of the Exponents of Internal Drivers to Changes in Fluvial Dynamics: A Case Study of Panchanoi Channel, Darjeeling Himalayan Foothills, West Bengal

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Channel sensitivity refers to the response of the internal drivers to reach short-term geomorphic stability due to any change in the external variables. The present paper deals with the surveyed cross-sectional data of Panchanoi channel, flowing through the Darjeeling Himalayan foothills and investigates the direction and magnitude of change in the b-f-m exponents of channel width, depth and velocity with the change of discharge at cross-section sites (CSS). It also reflects on the inter-relationships among the internal drivers of hydraulic geometry on the basis of reach-scale data, collected along the 23 km stretch of the Panchanoi channel from Sukna to Mahananda Para. The data of the controlling parameters like channel width, depth, velocity and discharge at selected CSS has been generated to determine the response of these drivers to channel dynamics. It may be concluded from the study that the width/depth ratio and Froude Number increase with the increase in discharge. The mean velocity however, increases at a slower pace than the increase in cross-sectional area and the channel bed-slope responds positively to the increase of discharge.

06

Assessment of Soil Susceptibility and Groundwater Potentiality Zones in the Upper Reaches of a Peninsular River Basin (India) through Morphometric Parameters

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Lithological characteristics of a geomorphic region control the soil erodibility and infiltration behaviour of water which influences the groundwater potentiality. These relationships between lithological characteristics and hydraulic activities can be determined easily through some commonly used morphometric parameters. The delineation of erosion prone areas and deficit or surplus zones of groundwater helps prioritize the soil conservation measures and drought management plan more effectively in the region. In this reference, the present study is conducted in upper reaches of the Tons river basin originated over the Northern Foreland of Peninsular India (NFPI) using geo-spatial and statistical techniques. Relief and drainage variables of the basin were extracted from topographical maps and CARTOSAT DEM (1 arcsec or spatial resolution ~32 m) images and analysed in GIS environment. The results of prioritization of all the 8 sub-watersheds (SWs) of the Upper Tons Basin show a pattern that the areas or the SWs are vulnerable to erosion are marked as deficit zones of groundwater also. The study suggests that the soil conservation measures should be first applied to SW-2 and1 then other remaining SWs. These areas need prevention measures such as vegetation cover, construction of small ponds, check dams or other water harvesting structures which will help to control high run-off and erosion, whereas the SWs with high infiltration characteristics can be developed for combating the problem of drinking water. This study can be helpful in soil and water management as well as fundamental study of morphometry of similar types of the basin.

07

Determination of Flood Susceptibility Areas of Torsa River Basin in Himalayan Foreland Basin by Applying Frequency Ratio Model

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Extreme weather events induced by rapid climatic change owing to irrational anthropogenic actions in recent times has dramatically increased the frequency and severity of floods across the world. Modelling the flood susceptible zones provide the much-needed requisite sustainable tool to prevent and mitigate the flood occurrence and its possible adversity on human society. The fundamental objective of the present study is to investigate the application of Frequency Ratio model in estimating the flood susceptibility areas of the Torsa river basin located at the eastern Himalayan Foreland Basin. Flood inventory data of 100 flooding locations for 2017 – 2019 is collected from National Disaster Management Plan and processed in ArcGIS 10.3 platform to prepare the flood inventory map with 70% training and 30% validation. Eleven major flood causative factors such as altitude, geology, slope angle, slope aspect, rainfall, drainage density, plan curvature, distance from river, soil type, topographic wetness index and land use and land cover are extracted from SRTM DEM with 30m spatial resolution. Each individual causative parameter is processed in ArcGIS 10.3 software to prepare individual causative maps for acquiring the essential values of fluvio-hydrological and spatio-temporal features of flooding parameters mandatory for the calculation of Frequency Ratio model. The flood susceptibility map computed on the basis of frequency ratio model is finally validated using Receiver Operating Characteristics (ROC) Curve

method to measure its scientific temperament such as accuracy and efficiency. The estimated ROC curve value for is around 0.761 which is considerably good and reliable for flood susceptibility determination.

08

Impacts on Sediment Transport and Channel Change in the Ganga River in Mirzapur District

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Multi-dimensional sediment transport models are valuable tools for conducting river engineering investigations. Frequently, river engineers are called on to evaluate the impacts of naturally occurring or man-made changes to river systems. These changes may result from altered watershed hydrology or sediment supply, construction of riverine training structures, or channel alterations to support navigation or environmental needs. Engineering studies are needed to evaluate both spatial and temporal sediment transport and morphology change concerns. An evaluation of short-term channel response in the affected river reach is required for planning and design purposes, while an understanding of long-term channel response is need to predict future project operations and maintenance needs. Traditionally, because of the computational time requirements of multi-dimensional simulations, models are run for relatively short periods of time on relatively short river reaches. Although this provides an indicator of initial channel response, it does not provide an indicator of long-term changes in river morphology. To reduce simulation time requirements, a quasi-steady approach can be undertaken for long-term simulations in large river systems with gradually varying hydrographs. Although riverine sediment transport and hydrodynamics are inherently unsteady in nature, the quasi-steady approach has proven to provide adequate problem resolution for supporting engineering decisions.

09

Examining Channel Migration and Erosion-Accretion Dynamics of River Raidak-I in Himalayan Foreland Basin (Eastern India) using Quaternary Sedimentary Facies Analysis and Geospatial Techniques

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River channel migration is a significant phenomenon in the alluvial tract of Himalayan foreland basin in India. Natural processes such as rapid sedimentation due to low channel gradient, high discharge during monsoon and non-cohesive bank materials primarily control the channel migration pattern and erosion-accretion dynamics of the river system in quaternary geological sites of sub-Himalayan alluvial floodplain of West Bengal. Additionally, human interference in the fluvial setting also regulates the channel dynamics in this area. This study deals with lateral channel migration rates and erosion-accretion dynamics

of different study reaches of river Raidak-I within the sub-Himalayan alluvial tract of West Bengal, India. River Raidak-I is well known for its notorious channel dynamics, the vulnerabilities through bank erosion, floods and bank line shifting. In the last century, river Raidak-I had changed its course due to natural as well as anthropogenic stresses. Natural factors include flood, heavy rainfall, and silt deposition while anthropogenic factors like construction of bridge, railway, road and deforestation are responsible for the channel migration of river Raidak-I. The study of geospatial techniques and quaternary sedimentary bank facies has been used to assess the reach-based channel migration rates and erosion-accretion dynamics. Channel planform shows a meandering pattern recording sinuosity index 2.14 in 2019. Variation of channel width (mean channel width of entire reach was 139.03m in1972, 146.84m in 1979, 88.58m in 1996, 107.76m in 2009 and93.94m in 2019), channel sinuosity (2.42 in 1972and 2.14 in2019) and the mean of all radius of curvature along the meander loops (237.5m in 1972 and 181.25 m in 2019) reflect the channel instability in different study reaches over 47 year spanning of study period. The study reveals that average rate of net migration along the left bank is higher in reach-2 (60.02m/y) than that of reach-3(33.12 m/y) and reach-1 (3.73 m/y) while on right bank, it is comparatively higher in reach-1 (96.38 m/y) thanreach-2 (68.92 m/y) and reach-3 (25.81 m/y). Therefore, this scientific study would be helpful for policy making purposes during long term flood management.

10

Geomorphological Explanation of Longitudinal Profile through Polynomial Regression Model (PRM): A Case Study of Chamta Channel, Darjeeling District, West Bengal

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Longitudinal profile of channel may be considered as the reflection of form-process relationship under the domain of fluvial geomorphology, where the existing relationship among the response variable (elevation in m) and regressor variables(independent) may not be explained by the simple linear relationship. The present paper deals with the critical explanation of the non-linear association among the controlling factors of representative (1.646 km) longitudinal profile of Chamta channel through polynomial regression model (PRM). The study has been structured on the basis of the level survey data, extracted from 14774 m to 16420 m distance in the downstream direction from the source of river Chamta (one of the ungauged streams under the Mahananda river system) to use in empirical equations. The degree of association (r^2) among the regulatory variables in 5th order polynomial regression model justifies the magnitude of explained variation of elevation in channel. 89 percent of recorded observations have statistically established the relationship among the 31 (25-1) controlling regressor drivers (channel discharge, velocity, cross-sectional area, wetted perimeter, hydraulic radius, stream energy, channel capacity, competency, channel bed slope, channel bank slope and more yet to be known variables) and constructs (amount of rainfall as climate, type with frequency of river-sided embankments as anthropogenic disturbance). It produces a specific longitudinal geometry of Chamta channel

by the process of degradation and aggradation. Geomorphic form-sequence, like; Riffle-Run-Pool-Glide (R-R-P-G) has also been detected along the representative long-profile of Chamta to refer the reach-scale irregularity instead of continuous concavity. Further test of multicollinearity may enhance the validity of the present research.

11

Tectonic Control on the Meander Pattern of Alaknanda River in Srinagar Valley (Garhwal Himalaya), India

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The geomorphologic evidences of tectonic activities in the Lesser Garhwal Himalaya along the North Almora Thrust (NAT) in the Quaternary period have been documented. The northern flank of Almora Nappe marked by NW-SE to WNWESE trending tectonic plane in Central Kumaun is called the North Almora Thrust (NAT). The continuous tectonic movements have resulted in the development of numerous N-S trending transverse faults along the NAT. One significant section at Srinagar along the thrust plane has been chosen for the study. The 11.5 km long and 2.5 km wide Alaknanda valley is locally known as the Srinagar Valley in Garhwal Himalaya. The main purpose of the present study is to investigate the tectonic control on meandering patterns and geometric properties of the meanders in the study area. The entire study has been carried out by Remote Sensing and GIS techniques on Arc GIS 10.1software. The approach of the study is that the Alaknanda River in Srinagar valley is divided into 8 meander segments of three reaches. Each segment consists of a river meander. The meandering course is a direct consequence of the tectonic features and it has been found that all the meander bends are tectonically controlled by the transverse faults/ lineaments. The earlier stages faults/lineaments are deformed by latter phases of deformation. However, the river turned its course at the displaced points and formed a meander bend or hogback feature. The tectonic control clearly reflects on the abrupt change in flow direction, distinct drainage pattern and shape and size of meanders. The prominent geomorphic evidences are 6 levels of fluvial terraces, meandering nature of river, offset drainage pattern, knick points, rapids, pools, straight and wide river channel, paleo channel, deep gorges, landslides etc. Planimetric geometry properties of each meander bend have been assessed and analyzed. Sinuosity index of the Alaknanda River is 1.34 in the study area which indicates that the river is sinuous to meandering. The average entrenchment ratio of the channel is 3.27 which shows slightly entrenchment channel. The average wavelength of the river is 1.4 km. There is strong correlation between amplitude and sinuosity index (r - 0.94) and width and length ratio (r - 0.96). Finally, it may be concluded that eight meander segments are controlled by tectonic features and have played a major role in increasing the sinuosity ratio in selected channel reach of the Alaknanda river course of the study area.

12

Morphometric Analysis of two River Basins using Geospatial Techniques in Kaljani And Raidak River, Cooch Behar, West Bengal

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Rivers are always enchanting to mankind forever. Freshwater plays main characteristics for the hydrological and terrestrial ecosystem and most important in economic, and political development. The present research aims to perform the morphometric analysis of Kaljani and Raidak River in Cooch Behar district, West Bengal. Kaljani and Raidak are the tributaries of the River Brahmaputra which covers the catchment area in Cooch Behar district are 11.71sq.km and 15.19sq.km. Remote Sensing and GIS have been used as an effective tool for describing and understanding of any drainage morphometric parameter. Morphometric parameters like drainage density stream order, stream frequency, stream length, Ruggedness index and bifurcation Ratio, are computed under three broad categories namely, areal, linear and relief aspects. The morphometric parameters have been identified using Shuttle Radar Topography Mission (SRTM) DEM in QGIS and ArcGIS by collaborating with different satellite images. We have selected these two rivers for better comparison of a homogeneous geomorphic region where we will able to exemplify the land use pattern and able to interpret the main source which relates to river bank erosion and some others expressions. These findings would help in better understanding of various morphometric parameters at play and thereby enhance our spatial understanding for logical decision making in order to formulate and sustainable management of the study area.

13

Economic Consequences of River Dynamics and Associated Bank Erosion: Study on Lower Reach of the Rupnarayan River

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Present study aims to monitor the planform dynamics of the river Rupnarayan in connection to in-channel depositional forms. In the way to adjust and readjust with the depositional forms, river shifts towards the left bank causing extensive bank erosion. Over the last 15 years (2005-19) almost 18 brick-kilns are totally destroyed and another 14 are partially eroded. More than 122bigha of agricultural land, 37 bigha of betel leaf vine and more than 60 households are engulfed into the river bed. Local people have lost their professions and the marginalised section especially the illiterate women cannot adjust this loss and cannot adopt new profession.

14

Sand Mining and its Impact on the Kangsabati River, West Bengal, India

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Instream sand mining has completely changed the morphological pattern and fluvio-dynamic behaviour of the Kangsabati River. The present work studied chronological changes (1926-2018) of planform pattern in different reaches through GIS environment. Morphological configuration and hydraulic behaviour were analyzed with the help of field survey and ADCP instrument. The study shows that the instream sand lifting has significantly reduced the Standard Sinuosity Index (SSI), altered braiding pattern, channel width, cross sectional area, hydraulic radius, active channel width and channel velocity.

15

Morphodynamics of the Meandering River: A Study along the Kaljani River in Bhuchungmari-Moamari Section of North Bengal Dooars, West Bengal (India)

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Rivers being the most dynamic and natural engines receive the maximum outcome of process-form activities over space and time. Displacement and shifting of course of the alluvial channels over the lower gradients result into severe bed-bank scouring activities temporally. The river Kaljani within the neotectonically active zone of North Bengal plains is an example of temporal variations of high sinuosity and braiding over the softer lithology. The present work is focusing on a temporal study from1970 to 2019. The Survey of India (SOI) topographical map of 1:50,000 scale has been used as the base layer along with multi-temporal satellite imageries (1990, 2000, 2010 and 2019). The schematization has followed digitization, rectification and overlaying of conformal layers extracted from the USGS website under the Universal Transverse Mercator (UTM) Projection system and World Geodetic System (WGS) of 1984 datum for 45N zones under GIS platform. Multi-temporal satellite data identified serious course changes of the selected reach of lower segment of the Kaljani River. The rectified multi-spectral bands are used to make the normalized difference water index (NDWI) for identification of the water content on earth surface followed by selective morphometric analysis e.g., sinuosity index, braided index and roundness of curvature to access the spatio-temporal changes accomplishing some derivative mathematical equations. Descriptive statistics viz. mean, standard deviation (SD), coefficient of variation (CV), skewness and kurtosis were used and explained maximum course oscillations. The authors tried to examine the fact for six temporal frames i.e., 1970, 1990,2000, 2006, 2010 and 2019 and received high sinuosity of all categories. Conclusively the work claims to set a documentary approach to examine the morphodynamics of an alluvial channel of Sub-Himalayan foothills.

16

A Comparative Study between a Failed and an Existing Hydro- Power Projects along the Nagavali River, Odisha-Andhra Pradesh

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The aim of the present study is to compare between a failed hydro-power project in Hathipahar and an existing project Thotapalli region along the Nagavali River and assess the maximum areal threshold up to which damage can occur during peak flood discharge. The Hathipahar region was situated over a piedmont slope of the eastern ridge (formed of Khandelite-granite) and consisted of few break-of-slopes. The Thotapalli Village located over rolling plain. After originating from a hill (1300m) of Kalahandi District, the Nagavali River flows through a narrow longitudinal valley between Eastern and Western ridges in Rayagada District, Orissa, debouches onto the rolling plain in Andhra Pradesh and finally meets with the Bay of Bengal. Google Earth and SRTM DEM have been used for demarcating location and spatio-temporal changes along the river as well as the reservoir. The micro level elevation model has prepared through field survey. Discharge level data of different flood years have also been collected from local Disaster Management Cell as Nagavali is a poorly gauged river. In the year 2003, the Government had decided to construct several hydro-power projects along the Nagavali River. Accordingly, construction started at Hathipahar region in Rayagada, Orissa and at the Thotapalli village in Vizianagaram District, Andhra Pradesh in 2005. During the construction of dam at the Hathipahar Region in July 2006, torrential rainfall occurred at the upper catchment of the river causing huge discharge and flash flood. As a consequence, the Nagavali River started to flow through the canal, dug during the construction, leaving its main course. After that single event that river has shifted about 550 meters westward and tolled about0.54 km2 loss of land and still possessing very active head-ward erosion and valley incision. On the other hand, Thotapalli site was not much affected by that flood and the construction of this dam and reservoir continued and completed in 2015. After two year of completion, another flood occurred in 2017, caused huge erosion and enlargement of the reservoir from 2.1 km^2. to9.16 km^2, the upstream course of the river merged with the reservoir and the width of the river increased from 172m to 1.6km.

17

Changing Bore Tidal Character and its Impact on Livelihood in Indian Sundarbans Since Last Decade (2010-2020)

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Almost all the deltaic regions of this world, somehow, are coping up with the issues related with Global warming and Climate change which are directly or indirectly forcing the predictable natural events to be unpredictable irrespective of the uninhabited natural regions in developed and developing nations. Particularly, the tropical deltaic regions of South and South-East Asian countries like India and Bangladesh, are on the threshold regarding these global issues. Recent development in weather forecasting systems by IMD has been relieving the people of Sundarban delta to some extent to reduce the vulnerability of the climatic hazards. But side by side, tidal forecasting and the changing behaviour of the bore tides has always been overlooked since a long time which is affecting the livelihood in the interfluves

of Sundarbans. On the basis of the changing character of the tidal bores since the last decade (2010-2020) along the Bay of Bengal, the author has tried to prognosticate the future impact of the changing character of the bore tides on the livelihood of the people thriving in different interfluvial parts of Indian Sundarbans.

18

Flash Flood Risk Assessment for Drainage Basins in the Himalayan Foreland of Jalpaiguri and Darjeeling Districts, West Bengal

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Flash floods pose significant threats to the socio-economic development of the Jalpaiguri and Darjeeling Districts. These districts situated in the piedmont zone of Sikkim–Darjeeling and Bhutanese Himalayas suffer from the flash floods, and cause tremendous loss of life and property every year. This study assessed flash flood risk of watersheds of the Himalayan foreland of Jalpaiguri and Darjeeling Districts in support of mitigation planning. Different hydro-geomorphological setup controls the magnitude, frequency and distribution of flash flood like topography, geomorphology, geology and climatology of the area under study. Land use/land cover and soils also have an integral relationship with run-off generation in the watersheds. Thus, we adopted a holistic approach considering the topographic, hydrological, climatological, geological, soil and land use/land cover factors to assess the relative susceptibility to flash floods of the watersheds of Himalayan foreland of Jalpaiguri and Darjeeling Districts. Jaxa 30m DSM, Landsat8OLI/TIRS and Sentinel 2A satellite images, digitized drainage network, geological, rainfall, soil and geomorphological map were analysed in GIS environment to infer lithology, land use, hydrological soil type and watershed morphometrics. The morphometric parameters were used to assign the relative susceptibility of the watersheds to flash flood, applying the weighted sum average method. Soil Conservation Service rainfall–runoff model of USDA and synthetic unit hydrograph were used to infer the hydrological response of the basin including curve number, runoff depth, time of concentration, lag time, peak discharge, etc. Final flash flood risk map was achieved by the integration of both the susceptibility maps. Higher weightage was given to the susceptibility map produced from run-off modelling and synthetic hydrograph parameters. The result shows that 63% of basins are fall in the high to very high categories of flash flood risk, 28% under medium and only 9% in the low categories of flash flood risk. Accuracy of the model was assessed using the flood inventory coupled with field diagnosis of past flood damages and available records. The resulting flash flood risk map could be used by the planners to adopt mitigation strategies to reduce the severity of the flash flood hazard.

19

Causes and Consequences of Changes in the Morphology of River Majhuee in Phoolpur Tehsil of Azamgarh District

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This paper analyses the dynamics of conversion of the landscape along with the river Majhuee created by anthropogenic activities in the Phoolpur Tehsil of Azamgarh District. River Majhuee is Tributary of River Tamsa which itself is a tributary of River Ganga. The river is presently at the verge of disappearance. The present deplorable state of river Majhuee is primarily attributed to the heavy encroachment in its bank zone. The government had distributed the land situated along the river to landless farmers in a haphazard manner that resulted in heavy deforestation, agricultural practices and soil mining in and around the course of the river. The present study has been done in a GIS environment through quantitative morphometric analysis which has been carried out for linear aspects and relief aspects. During the study it was found that the Majhuee river is in the endangered condition, the river bed is highly sedimented and the riverbank is eroded due to encroachment or agricultural activities.

20

Assessment of Fluvial Response to Active Tectonics through DEM-Derived Longitudinal Profiles in the Rangit River Catchment Area, Eastern Himalayas, India

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The Rangit catchment is located at Eastern Himalayas in the tectonically active mountainous state of Sikkim, India. The Himalayan Mountain Range is a product of collision of the Eurasian and the Indo-Australian plates since the Palaeogene. It is widely accepted that this tectonically-driven uplift is still continuing, as reflected by a large number of earthquakes in the area. Erosional regime of fluvial system, resultant geomorphic features alongside frequent seismic activities are bearing signature of tectonic activity, past and present tectonic perturbations on the surface over this area. Objective of this study is to assess the degree of tectonic and lithological control on the drainage network of the Rangit Basin in the Eastern Himalayas. Main Central Thrust (MCT) has significant influence on character of studied basin. Right and left bank of the catchment is well defined by The Main Central Thrust (MCT),which is demarcated between the Greater Himalayas and the Lesser Himalayas. It can be suggested that MCT is active during the Holocene time on the basis of remarkable difference in tectonic activity across two sides of the MCT.ALOS-PALSARDEM has been used and analysed to extract longitudinal profiles and their derivatives of 16 major tributaries of the Rangit River. Longitudinal profile shapes, stream gradient (SL) indices, longitudinal profile concavities and steepness were investigated to find out tectonic control on the Himalayan River. Prominent drainage anomalies such as above-grade conditions, exponential and linear fitting of longitudinal profiles, elevated values of SL indices, barbed drainage, over-steepened stream segments and fluvial hanging valleys are responsible for rapid erosion rates in the basin. This is well traceable especially in the lower segment of the Rangit Basin, interestingly which is located downstream of the MCT. Comparison study of steep segments with the geological and lineament maps implies that many of these anomalies are lineament-

controlled. Furthermore, a large number of such features do not conform to lithological intersections, suggesting a possible tectonic factor behind the occurrence of such anomalies.

21

Assessing Bank Erosion Potentials of River Ganga in Diara Region of Malda, West Bengal

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Continuous bank erosion of the River Ganga along the left bank in the Diara region of Malda District is a major hazardous problem of the region. The main objective of the present study is to identify the bank erosion potential and riverbank stability in the studied reach. The region is configured with the numerous shoals, bars and islands (char lands) like geomorphological features. For the study, Bank erosion hazard index (BEHI) and Near bank stress (NBS) models have been applied with the help of field investigation through field visits. Landsat satellite imageries and SOI topographical sheets have been used as secondary sources of information for the study of dynamicity of channel migration and magnitude of channel shifting within the Diara tract of Malda district. The study resembles importance in view of finding the nature of bank erosion to simply predict few strategies in general to alert the local inhabitants and here lies the novelty of the study.

22

Active Tectonic Influences on the Dulung River System in the Southwestern Fringe of Bengal Basin

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The influence of active tectonics on the hydro-geomorphological adjustment of the Dulung river system in the southwestern fringe of Bengal Basin has been assessed using the satellite images and on-field investigations. The river course is more altered and adjusted with the deformed Quaternary formations within the Chotanagpur foothill fault and Medinipur-Farakka fault (MFF) zone. The adjustments of drainage system are reflected by the analysis of morphotectonic, geological, morphometric, hydro-geomorphological attributes coupled with the channel patterns and form of profiles. On the basis of index-based tectonic potentiality, four tectonic potential zones are estimated considering the morphotectonic and hydro-geomorphological variables i.e., basement depth, Bouguer gravity anomaly, isobase, hydraulic gradient, lineament density, flow turn angle, sinuosity index, palaeo-channel density, relation declivity extension index (RDE-index) and transverse topographic symmetry factor (T-index). The four stages of river adjustment are associated within the middle – lower basin area. The river confluences gradually shifted in upstream direction, maintaining about

10–15 km inter-confluence distance. The recent and palaeo-courses of the Dulung and Subarnarekha rivers continuously shifts towards the south. The shifting nature of palaeo-courses and confluences in the highly tectonic potential zone suggests that the middle – lower basin area has been uplifted and southward tilted around the MFF zone.

23

Impact of River on Human Life: A Case Study in the Inhabitants along the Tista River of Jalpaiguri District, West Bengal

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Rivers are treated as the backbone for its utilisation, functions and diversities of any region. Our human life is facilitated by the dynamics and the changeability of the nature and behaviour of a river. A river is the lifeline for any region. The river basin provides the floodplain which is directly affecting the habitat, livelihoods etc. of the people. Rivers have an economic, political and social impact on the culture of the people. However, it also plays a negative character for the adjacent people as a result of physical and human induced events. Thus, river in a region plays a dual character as its behaviour in an alluvial channel. It is observed that the River Tista is utilised as a source of livelihood for the people of Sikkim and West Bengal and has its importance in the national economy. The River Tista is known as the lifeline of Jalpaiguri District as it plays a noticeable role in the development of the people. The mighty Tista is very important for the riparian people due to its water resources, small scale navigation and facilitating agricultural production. Here inhabitants are the riparian people, i.e., the population in the community development blocks, namely, Rajganj and Jalpaiguri (right bank), Mal and Maynaguri (left bank) along the Tista River of Jalpaiguri District which has been selected as the study area. Throughout this study, the authors have tried to analyse various fields where the Tista River influences the social-economical aspects of the inhabitants and highlighted the impact of increased human intervention on this river. For this purpose, primary and secondary data are collected and presented through various cartographic techniques.

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Tectonic Influence on Drainage Network in Chel and Neora River Basin

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The present study is concentrated to show the relationship between structural control and drainage pattern for establishing active tectonic influence on drainage network in the piedmont zone of the Sikkimese-Bhutanese Himalaya, between Chel to Neora rivers. The whole area is divided into two parts following the tributaries and main river- one is Chel river basin and another is Neora river Basin. Two dissected fan surfaces are there- Gorubathan-Rangamati fan surface and Matiali - Chalsa fan surface. The drainage pattern varies greatly

in connection, not only with the hydrology, but also with young tectonic movements. Satellite images and DEM data are processed with the help of different softwares. Lineaments, scarps have been identified from the nature of the flow path of rivers. Topographic cross sections and long profiles are generated from DEM. Digitization of rivers from satellite images, watersheds and thalwegs generated from DEM, delineating the drainage patterns to see the relation with relief. Morphometric study has been done by observing mountain front sinuosity (Smf), valley floor width to height ratio (Vf), asymmetry factor of river basin (AF), concavity and slope of river channel, hypsometric curve which differ significantly in different parts of the study area. The values of Morphometric indices of Chel basin are Smf>4<5, AF>21<22, Concavity>0.011<0.012; which indicates this basin is tectonically inactive, asymmetric and the river is supposed to be in senile state. Where in other hand the values are- Smf<2, AF<11, Concavity<0.05 of Neora river basin, which denotes it is slightly tectonically active with a marked break of slope in long profile of Neora river, this river basin is near symmetric and possibly eroded in nature. In many parts of AOI, stream courses are directed and influenced by lineaments. Any change in tectonics of this region may influence on the development of drainage network. This study can be improved more by studying other geological and geomorphological field-based information.

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GIS-Based Assessment of Channel Migration Evidence from Himalayan Foothills, West Bengal, India

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Channel migration is a significant geomorphological process in the floodplain region. Human interventions in the form of engineering constructions (bridges, embankment etc.) regarded as another dominant issue which is pulverizing the ways of natural channel adjustment as well as channel behaviour. In the study, the channel adjustment in terms of lateral migration lucidly illustrated with the application of modern tools of geoinformatics, i.e., the techniques of RS and GIS. At present RS & GIS are capable of detecting as well as representing the channel changes over space and time. Finally, state of the art techniques in Arc-GIS have been adopted to prepare the channel migration and the mouza (village) wise erosion-deposition map by considering highly fluctuating mouzas of the Kaljani River and its adjacent villages at the Himalayan foothill region. The primary data source was a series of time-sequential Landsat data of the years 1972, 1980, 1987, 1993, 1998, 2002, 2008, 2013, and 2019 spanning 47 years. During the study period (1972 to 2019) the average length of migration of the Kaljani River was 742.05 m and the annual rate was 15.79 m/year. Within this time frame, the shape area migration of the channel was 66.79 km² and the annual rate was 1.42 km²/ year. Present analysis helps to enhance the effectiveness of planning and management of land resources and ecological balances in these 45 adjacent Mouzas of the Kaljani River. In our observation, Ambari mouza is identified as the most vulnerable mouza. However, it will be very much helpful to establish certain plans for mitigating future hazards and to minimize human intervention to the natural system of the river.

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River Channel Morphology and Flood Plain Response to Large-Scale Engineering Works: A Case Study of Bakulahi River Basin, India

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An intensive study of alluvial watershed of the Bakulahi river basin reveals the nature of changes in fluvio-environmental geomorphology and hydrology over a period of record. These changes in the region have generated a number of geomorphic hazards like mass soil erosion, increased waste landing processes, rill and gully erosion, waterlogging and floods etc. For sustainable development of the region watershed management has become a necessity of the day. It is estimated that effective watershed management of the Bakulahi river basin may be performed by changing land management practices, that require large-scale channel engineering works as a solid framework. This framework may include the cutting of meander loops for straightening the course of the river channel, canalization, diversion of discharge of the channel in rainy season, grading of river bed slope, construction of symphons, remodelling and reconstruction of road bridges over the channel from source to mouth for enhancing the discharge of the river. Itis presumed that by cutting the length of the river through large-scale engineering works, geomorphic hazards prevailing in the channel itself and in riverine tract would be minimized. After some time that channel will also adjust itself with changed environment of the watershed. For better future scenario, the people of the area will have also to prove themselves as the best environmental managers.

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Spatio-temporal Changes in the Morphology of River Sai in and around Pratapgarh City

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Pratapgarh city in the Indian state of Uttar Pradesh is situated along River Sai, a 563 km long tributary of the River Gomti. However, in recent years, rapid urbanisation of the city has caused changes in morphology of the river. Moreover, vegetation along the bank and overbank zone of the river has been converted into agricultural land or encroached upon to build new settlements. This is creating a problem of water availability in a heavily agriculture dependent area. The present study attempts to quantify the changes in land use and land cover in and around Pratapgarh city. Landsat Images of 2000 and 2020 have been downloaded from USGS website and have been used to carry out change detection in the study area with the help of ArcGIS and ERDAS Imagine softwares. The study aims to find out the change in morphology of the river and the associated changes in vegetation cover of the city. A significant and remarkable change along the course of river has been identified in the study area.

28

Anthropo-Footprints and their Impact on Forms and Processes of the Mayurakshi River Basin, India

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In the era of Anthropocene, the evolutionary record of the rivers is largely altered by anthropogenic drivers across the world. The Mayurakshi River Basin (MRB) similarly exhibits different anthropogenic signatures including dams, barrages, check dams, sand mining, stone crushing, embankments, brick-fields, road-stream crossings, and changes of land use and land cover. For example, six dams and barrages i.e. Massanjore, Tilpara, Deucha, Brahmani, Bakreshewar, and Kopai installed over the different rivers of the MRB are found to alter the flow regime including a notable change in the flood event from high magnitude low frequency to low magnitude high frequency. Furthermore, bed scouring and channel bar formation are also observed in the downstream segments of the Tilpara barrage. Similarly, about 1625 check dams mainly concentrated in the upper MRB have a small-scale impact on channel morphology. Bedsides, the middle and lower MRB portray an abundance of in-stream sand mining with a continuous stretch of the Mayurakshi River of about 181 km extending from Kultore to Hijal having intensive sand mining. Bank failure due to sandmining is a common phenomenon in the MRB. Moreover, 56 stone quarrying and 42 stone crushing centers mainly concentrated in the upper MRB produce huge stone chips that alter natural river bed configuration. Similarly, embankments are found to constrict the valley and channel width. For example, in the upper stretch, the valley width is 795 m and the channel width is 350 m while in the lower stretch, they are 183 m and 51m respectively. Finally, the number of brick kilns have also magnified three times during 2006 (n=61) and 2019 (n=183) that also have important effects on the artificial earth movements in the basin thereby inducing changes in its form sand processes.

29

Causes and Consequences of Changes in the Morphology of River Majhuee in Phoolpur Tehsil of Azamgarh District

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This paper analyses the dynamics of conversion of the landscape along with the river Majhuee created by anthropogenic activities in the Phoolpur Tehsil of Azamgarh District. River Majhuee is tributary of the River Tamsa which itself is a tributary of the River Ganga. The river is presently at the verge of disappearance. The present deplorable state of river Majhuee is primarily attributed to the heavy encroachment in its bank zone. The government had distributed the land situated along the river to landless farmers in a haphazard manner that resulted in heavy deforestation, agricultural practices and soil mining in and around the course

of the river. The present study has been done in a GIS environment through quantitative morphometric analysis which has been carried out for linear aspects and relief aspects. During the study it was found that the Majhuee river is in the endangered condition the river bed is highly sedimented and the riverbank is eroded due to encroachment or agricultural activities.

30

Assessment of Groundwater Quality of Damodar Fan Delta using Fuzzy-AHP MCDM Technique

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In recent years, groundwater pollution has become increasingly a serious environmental problem throughout the world due to increasing dependency on it for various purposes. The Damodar Fan Delta is one of the agriculture-dominated areas in West Bengal especially for rice cultivation and it has a serious constrain regarding groundwater quality and quality. The present study aims to evaluate the spatio-temporal variation of groundwater quality for 2015 and 2019 using the Fuzzy –AHP method. The water quality parameters such as general parameters, major anions, and cations for the 13 sample wells of the study area were used for constructing the groundwater quality index. This study used the Fuzzy-AHP method to define the weights of the different parameters for the groundwater quality index. The value of the groundwater quality index was categorized into five classes such as very low, low, medium, high and very high. The results of the study illustrated that 83% of existing wells were located in the good and very good groundwater quality zone. Besides, the value of groundwater quality index has dwindled from 2015 to 2019. The understanding of the groundwater quality can help the policymakers for the proper management of water resource in the study area.

31

Assessment of Anthropogenic Impacts on Gomti River in Lucknow District, Uttar Pradesh

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Rivers and floodplains are an integral part of ecosystem services and deserve a holistic approach for their conservation and restoration. River Gomti, few years back, used to be the lifeline of Lucknow district but with the increase in the human induced activities the survivability of river Gomti is under threat. The methodology applied here can be categorized under three components which include the study of basin morphology, comparison of Landsat satellite data and study of flow pattern. The findings are intended to show that over the years, water source feeding the tributaries of the river Gomti is shrinking due to rapid developmental activities(land use land cover changes), the rivers and floodplains are getting fragmented, the wetlands and forest covers are decreasing.

32

Impact of Land-Use on Water Quality and its Evaluation in the Seasonal and Temporal Context in Damodar River Basin

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Assessment of seasonal water quality variation is an important aspect for evaluating the nature of water quality variation due to pollutants coming from point and non-point sources. Seven years' on 24 parameters collected at 11 monitoring stations have been used for the analysis of temporal variation of water quality along the Damodar River. Principal Component Analysis (PCA) technique has been used to evaluate seasonal variation in the correlation among the parameters and the rotated axis of PCA is used to extract the most important pollution contributing parameters in different seasons. We have considered a greater than 0.8 correlation value between components and parameters for extracting the important parameters. Cluster analysis has been performed to find out the spatial variation of water quality and how it is affected by land-use patterns is also analyzed.

SUB-THEME: GEOMORPHIC RESPONSE OF COASTAL SYSTEMS TO NATURAL AND ANTHROPOGENIC STRESSORS

01

Aila to Amphan: Legacies of Destruction, Case Studies from Indian Sundarban

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Natural and anthropogenic stresses often influence the coastal systems. Indian Sundarban, one of the dynamic ecosystems also responds to these changes. Indian Sundarban is physiographically a deltaic plain, intricately surrounded by creeks and rivers. Aila to Amphan, Sundarban has faced a legacy of destruction in a decade and every time the physical and social subsystems of Indian Sundarban have been hit hard. While the cyclones act as natural stresses influencing this coastal system, premature reclamation of Sundarban by raising embankments, massive deforestation of mangroves for preparing aquaculture farms are primarily the anthropogenic stresses influencing this coastal system. Cyclone Aila was the second tropical cyclone formed within north Indian Ocean in 2009. Vast areas of Sundarban were ravaged by cyclones Hudhud, Philin, Fani. Cyclone Matmo-Bulbul struck Sundarban as Severe Cyclonic Storm on 8th November 2019. Bulbul claimed much more loss than Aila. Amphan grew up to be a super cyclonic storm, a category 5 tropical cyclone having wind speed of 240 km/hr (3-minute sustenance) and 260 km/hr which sustained for 1 minute. Embankments, which are the lifelines of Sundarban as these protect the agricultural lands from inundation, get breached often resulting in saltwater inundation. However, measures of protection of embankments using gunny bags, brick-block pitching, concrete embankments, tetrapods and porcupine mesh have not been completely successful. Also, agriculture was massively disrupted after Aila. Mishaps like complete destruction of houses, resources, loss of income and livelihood, occupational shifts, human trafficking and man animal conflicts have come up after these disasters ruining the social subsystems of the tide country. This paper aims to address these issues through comparison of topographical maps and multidated satellite imageries, alongwith ground truth verification by field visits and recording oral history.

02

Assessment of Tourism Carrying Capacity for the Sustainable Tourism Development of South Andaman Coast, India

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Tourism is a most practiced activity in the coastal zone and it may vary from one location to another. The unique natural landscape, scenic beauty, and historical background make Andaman and Nicobar Islands India's one of the popular tourist destination. A huge number of domestic and foreign tourists visit these islands every year and the number is continuously growing year by year. The Andaman and Nicobar administrations have tried to promote high-value low-volume eco-friendly and environmentally sustainable tourism. In this situation, estimation of tourism carrying capacity (TCC) is particularly important in the coastal zone of South Andaman which is undergoing rapid change as a result of increasing anthropogenic pressure and over-tourism activities. The concepts of carrying capacities are related by the idea that each system has certain limits or thresholds and is not necessarily fixed in time. They are dependent on technology, preferences, and the structure of production and consumption. They are also varying with the changing nature of the interaction between the physical and biotic environment. The maximum permissible tourist limit of each studied beach of South Andaman has been determined by the tourism carrying capacity approach and the results indicating the present tourism status of the Island. This study reveals that the present tourism activity of South Andaman is less than its potential carrying capacity. Implementation of good infrastructure and management facilities will help South Andaman to reach its actual tourism carrying capacity shortly.

03

Shoreline Changes using Geospatial Technology: A Case Study of Ghoramara Island and Nayachar Isalnd at Hugli Estuary

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Shoreline is one of the rapidly changing linear landscapes of the coastal zone which is dynamic in nature. The study aimed to continuous sea level rise and coastal development which have led to considerable alarms on coastline changes along inhabitant island. Analysis of long-term coastline changes of islands were calculated according to Net Shoreline Movement (NSM) and End Point Reference (EPR). Data were extracted from Landsat Multi Spectral Scanner (MSS) and OLI 8 images having duration of 47 years (1973 to 2020) and topographic map (1954 and 1965) also collected to determine the coastline changes in the Ghoramara and Nayachar Island, Hugli estuary. The results of DSAS analysis using two shorelines (1973 and2020) indicated coastline changes with extreme erosion EPR of (-20.59) m/y and NSM of (-967.64) m at the Ghoramara point. In Nayachar Island extreme erosion (-22.1) m/y and NSM (1042.7) m and accretion rate EPR 164 m/y and NSM 7756.04 m. Two shorelines in different time shows the result in a more detailed and very clear way, so it can be known with certainty at the transect lines which indicate the presence of shoreline changes.

04

Coastal Erosion and Shoreline Change in Ganjam Coast along East Coast of India

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One of the rapidly changing coastal landforms is shoreline. It is very necessary to understand exact detection and frequent monitoring of shorelines through coastal processes and changing aspects of various coastal features. The present study aims towards an assessment and analysis of coastal erosion and shoreline change in Ganjam coast along east coast of India using open-source geo-spatial data, GIS based Digital Shoreline Analysis System (DSAS). The survey of India topographic maps and Landsat images were primarily used to extract shoreline features using software's like Erdas Imagine and Arc GIS. The present study area is the Ganjam coast which is located on the south coast of Odisha which is from Prayagi to Bahuda river mouth. The beach has been eroded particularly in the Ramayapatam and Podampeta coastal tract due to various coastal processes that has taken place; such variations in the coastal processes are recorded by Landsat images and true colour image (Google Earth) and by repetitive field survey at different coastal sectors. In last 20 years we have found that the Ramayapatam and Podampeta coastal tract has been eroded85 meters and 120 meters respectively. The nature and magnitude of erosion indicates the immediate effect of waves attacking the coast under the impact of the low-pressure systems over the sea and the long-term impact of the loss of equilibrium between the waves and the coastline under the impact of the regimes of changing climate and sea level rise.

05

Identification of Littoral Cells along Coastal Purba Medinipur, West Bengal: A Numerical Modelling Approach

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The continuity of the Purba Medinipur coastline is interrupted by three inlets, namely, Ramnagar, Jaldha, and Pichaboni dividing the coastline into four sectors. Each sector is characterised by severe coastal erosion, beach lowering and narrow beach segments. To bring such coastal areas under proper coastal management a detailed idea of the coastal cell configuration is required. The concept of coastal littoral cell plays an important role in coastal management issues and acts as a spatial unit for calculating the sediment budget. The formation of the coastal littoral cell is a complex interaction between the distribution of wave energy and longshore flow along the shoreline. The objective of this study is to identify the coastal cells along the western coastal stretch of West Bengal by using a set of numerical simulation models i.e., Mike 21 Hydrodynamics (HD), Spectral Waves (SW), and Sediment Transport (ST). The offshore bathymetry is generated from the GEBCO-08 grid with30 arc (~ 1 km) resolution and the nearshore bathymetry is obtained from chart no. 351of National Hydrographic Office NHO. and the depth condition of the mouth was derived by Echo-sounding from the detail sounding in the mouths of the tidal inlets. The other inputs such as wave climate and wind data provided in the model were collected from INCOIS (Indian National Centre for Ocean Information Services) and CAMS (Copernicus Atmosphere

Monitoring System) respectively. From the outcome of these models, it is possible to identify the dominant direction of longshore flow, which in this particular region is from west to east. The presence of the three tidal inlets and the local geomorphic configuration helps in recognizing four prominent coastal cells and several coastal sub-cells, often presenting a wide boundary variation according to the incoming angle of swell. After analysing the flow pattern of the coastal cells, it can be said that the introduction of some engineering structures may imply some positive impact on beach nourishment and sustainability of the tidal inlets. The analysis of the flow pattern of coast cells is expected to assess the viability of engineering structure in a better way.

06

Bio-Physical and Chemical Properties of Soil in the Mangrove Habitats of the Hypersaline Tracts: An Assessment in the Henry's Island of South-Western Sundarban, India

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Mangrove ecosystems are among the most vital ecosystems in terms of fragility, productivity and bio-diversity. The Sundarban, which contains some of the largest mangrove forests in the world, is also an endangered ecosystem. It is of importance to investigate the characteristics of soil in the mangrove habitats of the Sundarban, how they change over the seasons, and their association with the quality of the mangroves. Towards this, the Henry's Island situated in south-western Sundarban is selected, and soil samples are collected from different locations in hypersaline tracts based on elevation throughout the three seasons, pre-monsoon, monsoon and post-monsoon, over several years. The zonation of the mangroves is estimated from field survey and remote sensing techniques. Main aims of this investigation are (i) to study the changes in the physical and chemical properties of soil over different seasons within the same habitat, (ii) to investigate the relationship among the soil parameters through statistical analysis and to assess the impact of the soil characteristics on mangroves. Comparative boxplots and an analysis of variance procedure are used to investigate seasonal changes in the soil characteristics. Correlation plots are employed to study the relationships among the soil variables and the effect of the seasons over them. Results show considerable seasonal changes in the distributions of sand, silt and clay contents, organic carbon, organic matter, salinity and electrical conductivity of soil in the saltpan areas. The relationship between the quality of the mangroves and the soil variables over time is studied using regression analysis. It is found that electrical conductivity and salinity have considerable effects on the growth of mangroves.

07

Embankments and Local Economy: A Case Study of Occupational Transformation in Patharpratima C. D. Block of West Bengal

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Embankments in the Sundarban act as physical divides between water and land to protect human habitations and related land use practices in the estuarine and riverine low-lying areas as well as transport routes within the islands. These play significant roles in the riverine flood plains and coastal areas to safeguard not only the agricultural plots and habitations but also land area from being washed out by the recurrent tidal impacts, occasional flooding from storm surges, cyclonic hazards and sea-level changes. In this case study, Patharpratima Community Development Block, which has been experiencing continued embankment breaching, is studied in the light of land acquisition for reconstruction, agricultural. It is found that Patharpratima has gone through several phases of embankment reconstruction and as a result, the land-use pattern has been grossly affected. This paper tries to find the vulnerable points in different parts of Patharpratima and identify the change of land use pattern of those areas for that time period. The data used have been collected mainly through the extraction of information from relevant satellite images and topographical maps. It has been observed that the previously constructed embankments failed to protect land and in a number of areas, like Sitarampur, Krishnadaspur and Dakshin Surendragaung, the sea is advancing to destroy settlements and agricultural fields, the main livelihood support apart from fishing in the areas. Those land, in which new embankments have been constructed, agricultural lands are converted into either waterbody or earthen embankment. So, those land-owners who were involved in agriculture, they cannot gainfully utilize this land, because this land was used for embankment. For this case, the occupation of those landowners has been changed. But some people are getting benefits from different sides. The newly erected 'Aila bundh' is also failing in some parts, as in Sitarampur, due to poor quality of construction and strong waves. During high tides, and especially under violent winds usually generated by cyclonic storms, seawater is raised such a level that the settlements are found to be located below the water, and often breaching of the embankments created floods, washing way and inundation of the lands adjacent to the sea, causing huge loss of properties. The concerning authorities and indigenous practice may reduce the problem.

08

Structural Intervention into Estuarine-Fluvial Process – Study on Indian Sundarbans

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Natural ebb-dominated estuarine process of Indian part of Sundarbans is transferred into tide-dominated system by the reclamation through construction of embankment along the tidal channels and clearing of mangrove. Water and sediment get confined into narrow channel as they are excluded from larger inter-tidal tracts by the embankments. Tide dominated system pushes sediment load into the interior of channels which are not effectively drained by less powerful ebb. It results in the in-channel sedimentation. Once started, sedimentation continues and even attracts more and more sediment by positive feedback system. Channel bed rises which leads to frequent overtopping and embankment breaching. As more sediment

is trapped into the channels, the delta building process along estuarine front suffers from sediment shortage. After the eastward shift of the Ganga towards Bangladesh through Padma, delta building process in the western part of Ganga delta (Indian Sundarbans) largely depends on the water and sediment supply from its right-hand tributaries draining from Chotonagpur plateau and western margin of Bengal Basin. Numbers of large dams and reservoirs constructed in the river Damodar and Kangsaboti basin since1960s interrupted water and sediment supply into this western part of the Ganga Delta leading to sediment scarcity. Load deficient hungry tide erodes maximum portion of Indian part of Ganga delta especially along its southern front. Huge numbers of people were attracted to the newly reclaimed lands as they believed to be secured and protected by the embankments that are popularly known as 'life-line of Sundarbans'. Presently more than 1.44 million people (following 1991 census) reside in Indian part of Sundarbans. Life, livelihood and properties of these huge mass of population are at serious risk due to frequent embankment breaching and saline deluge triggered by alteration of internal estuarine factors coupled with external forcing of cyclone and sea level rise. Much reliance on structural approach for hazard management intensifies under development as it reinforces poverty, exploitation and discrimination.

09

Coastal Vulnerability Assessment of West Bengal Coast through Coastal Hazard Wheel

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Indian coasts are under threat and vulnerable due to multiple stresses like sea-level rise, erosion, frequent extreme events, saltwater encroachment, and human intervention. The present study was carried out to deliver an overview of the hazard profile and identify the hazard hotspots of the West Bengal coast through the Coastal Hazard Wheel (CHW) methods and techniques. The result shows that the entire coast is high to very highly vulnerable in gradual inundation, saltwater intrusion, erosion, and coastal flooding. Islands of Sundarban and mainland of East Midnapur district facing the coast are always prone to very high vulnerability. On the other hand, areas that are protected from open fetch of the ocean are less vulnerable to coastal hazards. We prepared five individual hazard profiles such as ecosystem disruption, gradual inundation, saltwater intrusion, erosion, and flooding. Coastal flooding and saltwater intrusion are in most vulnerable indicating a severe effect on the entire coast especially in the river mouths and tidal inlets. Sea level rise induced gradual inundation can damage major parts of the coast. Erosion produces a very high to moderate impact (63% to 37%). In the case of ecosystem disruption, 10.94% and68.86% of coastal land are under low inherent hazard and medium inherent hazard level respectively. Except the ecosystem disruption, all the hazards are very high at the southern tip of the coast due to its sensitivity to strong wave exposure, and storm surges. Based on the coastal classification code a management checklist covering 24 different management options has been developed.

10

Annual Sediment Budget Modelling of the Beach-Dune Sand Sharing System: A GIS and Statistics-Based Approach

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The beach-dune sediment exchange is indeed a complex process operating on a range of timescales. The available process-response based models often fail to estimate the integral pattern of changes in the beach-dune system. Therefore, an alternate method such as repeatedly measuring the topography with respect to a fixpoint/landmark to develop a comprehensive picture of the changes undergone has been suggested. The methodology of the present study combines five different steps. Step one incorporates dense elevation measurements during pre-monsoon, monsoon, and post-monsoon season using a laser total station. In step two, the raw data were adjusted and pre-processed before preliminary map production which constitutes step three. Step four involves the geostatistical analysis and DEM generation in the GIS environment, and finally, step five highlights the procedure of sediment budget modelling. The results were used to quantify the volumetric and areal change of the beach-dune system for the two sites: East Chandrabhaga Beach and Pearl Beach of the Puri district, Odisha. The elevation data points in X, Y, Z format became helpful in high-resolution DEM extraction (1m) thereby accurately quantifying the influence of seasonal changes on the sediment budget of the beach-dune complex. This study further outlined the importance of three-dimensional monitoring approaches over two-dimensional transect based studies for sediment budget modelling.

11

The Concerns of a Bar Built Estuary-A Case Study of the Chilka Lagoon of Odisha

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The bar-built estuary is a shallow water body, that is separated from the open ocean by sand bars that are deposited parallel to the coast by wave action. The lagoons like any other lakes are getting degraded due to multiple factors like siltation from the catchment and sand from the sea wave at the inlet. The physical, hydrological and biological character of the lagoon is getting modified. Large number of people depending for their livelihood are also affected as the fish population depletes. The lagoon is also rich in biodiversity both indigenous and migratory birds. The study area holds importance from tourism perspective also as large number of tourists visit the lagoon, thus boosting the socio-economy of the local people and revenue to the state. In this paper an attempt has been made to study the largest lagoon of the eastern India, the Chilka lagoon locally commonly known as the Chilka lake the most famous tourist destination. The lagoon is located at the coast partly enclosed by the Mahanadi delta. The lagoon is the life line of lakhs of people living in the vicinity of the lake. In course of

time the lagoon been losing its area, depth, salinity and rich biodiversity. In addition to the sediments deposited during river flooding in the southwest monsoon season, the chocking of the estuary mouth by sea waves reduces the salinity of the lagoon water, thus losing its brackish water character affecting the biodiversity including the fish population. The basic character of the lagoon is control by the sea waves as the lagoon is partially enclosed the sea (Bay of Bengal). The inlet of the estuary is controlling the entry and exist of the water of the lagoon. The paper focuses about the changing behaviour of the sand bar in its length and width leading to control the lagoon inlet. The sand bar is mostly affected by flood water of the river and storm wind originating from the Bay of Bengal. The changing nature of the bar is studied using 2005 to 2020satellite imagery of Landsat and Resourcesat. The change detection has been observed with suitable suggestions.

12

A Numerical Study of the Influence of Constructed Bridge on Sediment Transport along the Mumbri Creek of Sindhudurg District, Maharashtra State

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The south Konkan region is signified as a coastline of emergence with long stretched beaches, creeks, and estuaries. Since the last decade, the construction of bridges and flyovers over the rivers and creeks have increased manifold. Tremendous load of the population on transportation is common and thus infrastructural construction over the rivers and creeks have no alternatives. The study area includes the Mumbri bridge which connects the north Konkan with the south Konkan region. The banks of Mumbri creek have undergone spontaneous changes. During these constructions, the channel morphology and river bed bathymetry got adversely vulnerable along with tidal incursion, the recession of mangrove cover, changes in sediment characteristics, change in horizontal and vertical circulation pattern of the streamflow, etc. The present study is based on bathymetric mapping and sub-surface cross profiling along the bridge. The energy generated from tidal fluxes affects the sediment characteristics, hence the tidal data was collected manually as well as from the Maritime board. This can be sporadically identified by assessing sediment transport rates with the help of data derived from sediment and water sampling of either banks of the study areas during different phases of tidal energy, mainly during pre- and post-monsoon and dry seasons of the year. The study was carried out by using numerical simulations of hydrodynamic changes along the Mumbri Bridge. Estuarine, Coastal, and Ocean Modelling System with Sediments (ECOMSED) model was used to calculate the movement of water before and after the construction of the bridge. This model splits the mode of tidal currents according to high tide and low tide changes. The timestep of internal mode was set to 10 seconds and the external mode was set for 2 seconds respectively. The results show that a sediment belt, which was about 815 meters wide, has developed in the west of the bridge axis at ebbing time. However, numerical models definitely help to understand the trend of sediment transport along the bridge.

13

The Impact of Embankments on the Geomorphic and Ecological Evolution of the Deltaic Landscape of the Indo-Bangladesh Sundarbans

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The present-day deltaic landscape of the Ganga-Brahmaputra delta has evolved through a complex interplay of geomorphic processes, tidal dynamics and anthropogenic modifications, brought over in course of the reclamation of the islands. The earthen embankments are built along the tidal channels, coastal stretches and also within the deltaic plain to prevent flooding, salinity intrusion and land erosion. These engineered structures have altered the tidal inundation regimes, sediment accretion rates and consequent, geomorphic character of the deltaic inlets. Increasing in-channel flow velocity often cause bank erosion and invite risk of failure of the dykes in the protected areas. The hydro-geomorphic processes govern the structure and functions of the mangrove forests of the Sundarbans by controlling the physiological systems, chemical adaptations and metabolic parameters. Embankment, again, has its impact on the biodiversity and functionalities of mangroves with respect to substrate modification, habitat fragmentation and seedling establishment. Sustainability of the delta plain with respect to embankment and polder tract management could be feasible by bridging the gap between local knowledge and scientific knowledge and also through the application of cost-effective geo-engineering and bio-engineering methods.

14

Impact of Coastal Hydrodynamics and Engineering Structures on Beach Dynamics—A Study of Digha, Purba Medinipur, West Bengal

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Digha, one of the largest sea resorts in eastern India, extending for 5.45 km along the Medinipur coast of West Bengal has faced a long history of erosion. The study area can be divided into three sectors from west to east viz. New Digha, Old Digha, and Gangadharpur. The paper aims to quantify the spatio-temporal change in beach elevation from New Digha to Digha estuarine mouth, temporal shift of shoreline of Digha coast during 1973 to 2019 and relate it with nearshore hydrodynamics to identify the erosional and accretional do-mains along the beach and how it has been affected by the engineering structures. The study reveals that in the post-monsoon period the width of the breaker zone is about 1 km, which significantly increases to 3.5 km during the monsoon period and the estimated breaking wave energy is around 146197 Jm^{-1}, which is 7.5 times greater than the post-monsoon condition. It is apparent that orthogonal waves are effectively converging in the vicinity of New and Old Digha, but in the case of Gangadharpur, waves are refracted from the end of the old concrete

wall at Old Digha and erode the beach-dune area drastically, resulting in the high rate of coastal retreat at Gangadharpur sector than other two. Digital shoreline Analysis System (DSAS) has been incorporated in the study for the analysis of shoreline vulnerability by means of Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM) and End point Rate (EPR).Repeated survey along 14 beach profiles during 2011-2019helped to identify the erosion-accretion trend along the different sectors of the beach. To identify the possible interrelationship between sediment character and beach slope, the equilibrium profile has also been estimated. The SCE indicates that between 1973 and 2000, the coastline of New and Old Digha changed by 0-113 m and 157-213 m, respectively, but the Gangadharpur coastline changed by 281?334 m. According to the EPR, the coastal retreat rate of New and Old Digha is approximately 4.83 to 3.31 myr^{-1} and 3.30 to 1.90 myr^{-1}respectively, which depicts its erosive to moderately erosive character. The Gangadharpur sector on the other hand is being eroded at a rate of 6.28m to 4.84 myr^{-1}. In the areas near Subarnarekha delta, the EPR varies between +0.58 and +2.70myr^{-1} which de-notes its depositional character. Due to the construction of the concrete wall, the beach at New and Old Digha has lowered from the equilibrium beach profile by 2.15 mand 3.30 m along the low tide line (LTL) respectively. Although, Gangadharpur was in equilibrium till 2018, after the construction of a new concrete wall between Hotel Sea Hawk and the Digha estuarine mouth, the eastern part of the area is also facing a lowering along the LTL.

15

Geomorphic Analysis of Past and Present Dune Sequence: A Case Study of Digha Coastal Plain

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The coastal tract of the Digha region is characterized by the presence of parallel sand dune chains and interdunal depressions or dune slags. The dunes can be divided into beachfront dunes, remobilized dunes, and paleo-dunes. Considering the geomorphic significance of the coastal dunes the main objective of the study is to understand the geomorphic evolution of these coastal dunes under tropical monsoon conditions. This study aims to do a geomorphic classification of the dunes based on their height relative to the present highest high-water level (HHWL), sediment character, and vegetation type. The survey was done along five representative transects, covering the present beachfront dune to the paleo-dune by the side of the Champa riverbank, presently about 12 km from the present HHWL. Soil and vegetation samples collected from these coastal dunes helped to interpret the past and present geomorphological characteristics of the dunes. The beachfront dunes are 4 to 18 m high with steep slopes, characterized by the absence of clayey material and experiencing erosion during the monsoon season along the present HHWL. On the other hand, the palaeodune chains have elevation varying between 2 to 10 m with a thin layer of clay. These dune lines indicate the past shoreline positions before 6000 years (Chakrabarti 1991). Between the beachfront dune and palaeodune, the interdunal parts are covered with mud and remobilized sand, marked by several phases' retreat of the high tide level and storm tide level during the Holocene.

16

Cyclonic Hazard Evaluation and Mitigation Capacity in Sundarban Region of West Bengal

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Cyclone is considered as one of the most shocking hazards with large impact on both abiotic and biotic components of the environment. Sundarban region is world famous for its mangrove forest, coastal location and diversified ecosystem. Due to its geographical position, severe floods and cyclones hit this region with great loss on life and livelihood. It is really a challenging task to completely avoid the harmful impact of such la hazard. But the extent of loss of both life and livelihood can be mitigated through risk assessment and preparedness actions. On the basis of multi-criteria decision-making approach, the present study has shown vulnerable and exposure assessment, hazards mapping and risk mitigation capacity of cyclone hazards on Sundarban region. The efficiency of GIS and ranking method has been assessed to map the cyclone risk areas. The assessment factor layers were created in GIS environment using spatial analysis and spatial statistics. The data were collected from national and international online sources, offline data were also collected from Government authorities and also from field investigation. To evaluate the hazard, spatial hazard map in Sundarban region was generated by classifying the hazard index values into five categories. The result indicates that 15.77% of the study area comes under the very high hazard zones, 25.31% under high hazard zones, 26.40% under moderate hazard zones, 29.26%under low hazard zones and 3.23% under very low zones. The resulting mitigation capacity map shows that about 35% of the study area was categorized as having very high to high mitigation capacity zones and about 46% come under moderate mitigation capacity zones.

17

Violation of Coastal Regulation Zone and its Impact on Coastal Environment, A Study Along the Coastal Tract of Purba Medinipur, West Bengal

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Coastal Regulation Zone (CRZ) notification of 1991 was the first step taken by the Government of India towards sustainable coastal development and Integrated Coastal Zone Management (ICZM). The whole coastal stretch of India was classified into four zones and subzones on the basis of ecology, economy and environment (physical and cultural), and on the basis of this zonation, regulations and prohibitions were imposed on some activities. The original notification of 1991 was amended over 25 times between 1991 and 2009. Subsequently, new CRZ notifications superseding previous notifications were introduced in 2011 and 2019, respectively. Even after 30 years, CRZ notification is not fully implemented along the coastal stretch of India. A case study was done on the open coastal belt of Purba

Medinipur to understand the effectiveness of CRZ in sustainable coastal development. For that, the whole forefront coastal areas of Purba Medinipur were classified according to CRZ notification of 1991, and this CRZ map was considered as the base map. For understanding the changes within the CRZ areas, Land Use and Land Cover (LULC) classification was done for the years 1991, 2001, 2011 and 2020 and then those were superimposed on the base map, NDVI and MNDWI were also done to understand the changes in vegetation cover and water bodies. Detailed field survey was carried out in between 2018 and 2020 to understand the violating activities along the coast and also to understand the impact of violation on coastal environment. There are four coastal stretches, among these only Digha developed as an urban area and could be classified as CRZ II, and other areas could be classified as CRZ III where, up to 200metres from High Tide Line was No Development Zone (NDZ),but majority of the violation was observed along the coastal stretch of Mandarmani and within NDZ, on the other hand Junput being not so famous as a tourist destination witnessed a smaller number of violating activities.

18

Tidal Range and Asymmetry of the Hugli Estuary: An Analysis Based on Daily Records of Seven Gauging Observatories in 1985

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Tidal range is the average difference between the high and low water levels in the springs. Tidal asymmetry, on the other hand, is defined by the differences in the durations of the rising and falling water in a tidal cycle. The macrotidal Hugli is the largest estuary of eastern India. We used its 1985 tide gauge records, maintained by the Kolkata Port Trust, to bring out tidal characteristics of seven observatories along its length: Sagar Island (0 km from sea face), Gangra (31.4 km), Haldia (43.4 km), Diamond Harbour (70.1 km), Hugli Point (81.1 km), Garden Reach (142.1 km), and Tribeni (204.8 km). The data consisted of continuous records of tidal periods and elevations, which were analysed for station-specific tidal ranges and time-velocity asymmetry. The results show that the tidal range increases landward along the resonant lower part of the Hugli between Sagar (4.26 m) and Hugli Point (5.36 m) at 1.35 cm/km and decreases in the upper section between Hugli Point and Tribeni (2.56 m) at 2.26 cm/km. Conversely, all seven observatories of the Hugli are flood-dominated, and the tidal asymmetry increases landward, with the flood duration decreasing from 47% at Sagar to 28% at Tribeni at 0.92%/km (r=0.99). This makes the Hugli estuary a sediment sink, requiring constant maintenance of its navigational channels. Owing to its higher tidal range and greater tidal prism, this effect is more pronounced in the lower estuary.

19

Are We using Beaches as per their Carrying Capacity? An Appraisal of Beaches for Sustainable Tourism in Raigad District, Maharashtra

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Beaches attract the tourists throughout the world. In all the maritime countries, beaches are popular tourist destinations. Beaches of Western India are also popular destinations for the domestic and overseas tourists. The Raigad district is one of the major tourist destinations in Konkan region of Maharashtra, attracting huge number of international and domestic tourists. Among all the tourist destinations in the district, beaches are the most visited destinations and have a great potential for tourism as well. The present work is an attempt to understand the potential of the beaches by calculating physical and real carrying capacity, which will further help in better tourism management. Carrying capacity analysis is carried out through physical and real carrying capacity methods. The carrying capacity of beaches is calculated by demarcating the high and low tide levels. Exposed areas of beaches were also calculated by using the high and low tide levels and beach slopes. The results show that the beaches on the Raigad District coast are under used. The carrying capacity assessment can be used as an input into the local administrative process and will save the beaches from future deterioration.

GEOMORPHOLOGICAL RESPONSE TO URBAN DEVELOPMENT

01

Assessment of the Anthropogenic Interventions and Related Responses of Karala River, Jalpaiguri, India: A Multiple Indicator Based Analysis

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The sub-Himalayan foothill region is experiencing rapid landuse transformation over the last few decades resulting in decay of many rivers; Karala is one such river. Being known as the 'Thames' of Jalpaiguri, a small rain fed tributary of Teesta, the Karala river had almost decayed in recent years but no such significant assessment of its condition has been done till date. This study mainly aimed to measure the amount of human interventions and related responses of Karala river through a reach wise, multiple indicator based assessment system. Initially the reaches were delineated by segmenting the whole river into 10 equal assessment units. Afterwards, characterization in terms of landuse and land cover was done and a set of 14 indicators composed of hydro-morphology and water quality, along with related sub-index scoring systems were formed. Results showed that the built-up area in an around Jalpaiguri town had increased to nearly 600% during 1990 to 2020. It is evident that as the river approaches downstream, the upstream nature of forested landcover gets replaced by considerable human modification and in complete accordance to it, measured indices showed a steep gradient of human alteration from upstream to downstream. According to the measured reach wise mean (Rm) the highest and lowest Rm were 4.70 (R1) and 2.21 (R9) respectively. The need for restoration was also lowest in the upstream and highest in the downstream reaches (R9 and R8) since those areas portrayed massive deviation from least disturbed conditions (LDC). It was also revealed that the change in bar area (ID7), vegetation condition (ID3), non-point sources of pollution (NPSP) and change in channel widths (ID8) are in alarming condition. Although the hydro-morphology of Karala river is interpreted as to be under serious human alterations but in-situ measurements and West Bengal Pollution Control Board (WBPCB) provided water quality data revealed that the overall water quality was good enough to provide adequate support to river biota but not suitable for human use. We suggest that, regeneration of this river in terms of its hydro-morphology is a timely need in order to achieve sustainable use of its resources.

02

Geomorphological Responses to Changing Urban Development in Pune Municipal Corporation

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The progressive growth of population and excessive urbanisation in the major cities across the world has changed the development strategies since last two decades. The ever-increasing urban population leading to numerous challenges to the local administration in the million plus cities in India and the world. Pune is one of the important cities in the state of Maharashtra. Being an IT hub, it has a lot of employment opportunities that attracts the people from all over the State and other regions of India. The total population of PMC is 3124458 according to 2011 census and it has increased to 3371626 persons in 2017 as per the general election data. This increasing trend of population leading to change the landscapes creating demand for more housing and other infrastructural facilities. Mostly, the fringing areas are now being incorporated into the PMC limits and therefore increasing the urban population. The PMC was administering on the area of 243.84 sq.km. in 1981, where built up area was only 24.92sq.km, i.e., 10.24 % and the area under forest was 20.72 sq. km. In 2005, maximum area of city was captured by built up that accounted 143.80 sq.km area i.e., 58.97% and the forest cover area has drastically lowered to 5.71%. In 2011, PMC had78.92% built up area and less forest area i.e., 4.59% only. In2018, the total area governed by PMC is 343.19 sq.km. which has increased to approximately 100 sq.km. The present study seeks to understand the urban developmental practices and also tries to find out how the urban infrastructural development that has changed the geomorphology of the PMC and surrounding area. The study also incorporates the geomorphological responses that has been caused by urban development practices and have some environmental and social problems in the PMC.

03

Geomorphic Planning to Address the Urban Waste Challenges: Study in Landfill Site Selection

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Urbanization rate is faster in the current century and it is expected that nearly two-thirds of the global population will be urban by 2050. According to the UN DESA projection, India will add 416 million urban dwellers by 2050. Planning Commission Report (2014) reveals that urban areas generate 62 million tons of MSW per annum in the present decades and it is projected that by 2031, these urban centres will generate 165 million tons of waste annually and by 2050 it could reach 436 million tons. With this increasing population, the management of Municipal Solid Waste (MSW) in the country has emerged as a severe problem from the environmental and aesthetic concerns. Urban waste stream often ends up in dumps or landfills. Sometimes the wastes are collected and taken to legalised waste disposal sites but these are not always properly managed to protect environmental pollution. This can lead to the pollution of the surrounding biophysical component (water and land) of the environment. Urban or city landscape is an example of a climax phase of the human landscape. Geomorphic planning includes human landscape evaluation and helps to find the best solution for present land use problems and reduce the impact of environmental degradation. Site selection for

landfill is one of the most important task of municipal solid waste management system. That helps to achieve waste management goals and improve the quality of the urban environment. We have tried to choose the best place for landfill using geomorphological knowledge in Midnapore Municipality. The focus of this work is the application and the importance of geomorphic studies in urban planning. Overlay analysis of different geomorphic factors like slope, soil and geohydrology and other anthropogenic factors like land use, road network, settlements are performed by GIS software (ArcGIS, ENVIS and Erdas Imagine) to identify the most appropriate waste disposal site with the least ecological, social and economic threats.

04

A Study on Landscape of Krishnagar Municipality Area with a View to Sustain the Environment of the Urban Center

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Present era of civilization is in fact the era of urbanization especially for the developing world. The tradition of agriculture in countries like India influenced growth of urban centres mostly in riverside area following fertile plain lands with the actual facility of trade and transport following the river. The present study area is Krishnagar (23.3785°N-23.4259°N and 88.4642°E-88.5514°E), which also was setup as a settlement following the river Jalangi and played an important role in trade and commerce of this agricultural fore front region during 18th century. Presently the municipality is within Nadia District, West Bengal, India, and from Geomorphic point it is within the moribund portion of the great delta region. In last three centuries the settlement evidenced several changes in respect to total population, land-use and environmental quality. The urban centre started its journey as a capital city of its surrounding agriculturally advanced region and following years after years the unplanned growth of settlement produces the present scenario. The area evidenced human impact on river channels, filling of wetland and recently like any other urban center is covered with multistoried residential buildings. Present work wants to highlight on land-use changes of the area specially highlighting the changes those have encroached the palaeochannels, small wetlands within the urban area and dumping of urban wastes those are polluting the river Jalangi. Study of satellite images, ground level study, analysis of census data is done in quantitative and qualitative way. Present attempt highlights the thrust area for future planning to sustain the environment of this urban centre.

05

Urban Expansion and its Impact of Geomorphology: A Geospatial Techniques Based Study

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Topography, vegetation, climate, water table, and even the anthropogenic activities all are affected by urban growth through diverse mechanisms. The present study focuses on the

implications of urban expansion on geomorphology in the historical city of Prayagraj, India. The expansion of urban area has been quantified by deriving decadal data from the Landsat images. The results show that the urban built-up area has increased immensely. Overall, during the last 15 years, the growth of the urban built-up is nearly three times of the base year. The construction activities have affected important geomorphic features such as river beds and flood plains. It was concluded that, instead of short-sighted urban development, proper measures should be taken in accordance with scientific planning for the urban expansion of the city in the future.

06

Geomorphology of Bilaspur City - Its Impact on Urban Functions

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Complex interaction between the urbanization process and geomorphological factors of a location and its result impact on environment has been emerging as an important, exciting and growing area of research. Following this research tradition this study attempts to investigate the problems emanating out of the interactions of geomorphology and urbanization process in Bilaspur area, an ideal location for investigating this topic. Three major research objectives have been addressed. First, a systematic study has been carried out to identify the changes in the geomorphology in Bilaspur city due to urbanisation process. Second, the environmental problems, mainly water logging and the lowering of underground water table, arising out of the interactions of geomorphologic factors and urbanisation process in the city have been studied. Third, the city planners and administrators have been provided with some useful geomorphologic information and suggestions to aid better planning of the city in the future. Bilaspur was controlled by the Kalachuri dynasty of Ratanpur. The city, however, came into prominence around 1741, the year of the Maratha Empire rule. The Bilaspur city is approximately 400 years old and the name “Bilaspur” has been originated from the Fisher-woman named “Bilasa”. Bilaspur district is not only famous in Chhattisgarh state but also in India due to its unique characteristics like rice quality, Kosa industry and its cultural background. Bilaspur district has a major contribution in the naming “Dhan Ka Katora” for the entire Chhattisgarh region. Bilaspur has developed a lot. Bilaspur district is situated between 21.47° to 23.8° north latitudes and 81.14° to 83.15° east longitude. This study systematically demonstrates that haphazard growth and rapid urbanization combined with unfavourable geomorphological factors of the city have exerted tremendous stresses on groundwater regime and waterlogging problem in Bilaspur city.

07

Urbanization and its Impact on Deteriorating Drainage System: A Case Study

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Rapid growth of population and ever-increasing demand of land due to urban development coupled with the lack of planning creates many problems. Growths of cities occur in a haphazard way causing different environmental and social problems. One major problem of increasing urbanization results into significant modification in the surface runoff. Concrete construction work (buildings, road networks etc.) in urban areas reduces the infiltration of rain water drastically. This leads to increase in surface runoff volume and obviously its erosive power. Further, due to poor drainage the condition becomes worst and often creates flooding after rain. Jaunpur is an ancient city of eastern Uttar Pradesh. The unplanned development in recent past adversely affected the existing natural drainage system within the urban limits. The aim of present study is to determine the deteriorating natural drainage network in Jaunpur city and identify the problems related with the change in natural drainage. Further, remedial measures are pointed out to plan an obstacle free drainage network within the city. The methodology incorporates construction of the Digital Terrain Model (DTM) and digital surface model of different period of time in recent past. Surface runoff modelling of different periods has been compared with present condition to assess the changes. The result shows changes in the drainage system of the study area and a flood susceptibility map of the city has been prepared.

08

Ground Water Resource: A Case Study of Jaunpur District of Uttar Pradesh

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The ground water being a vital and dependable resource for irrigation, domestic, industrial and other needs. Ground water resource are gradually depleting due to haphazard and unplanned growth of various anthropogenic activity. Ground water resource in Jaunpur district is widely exploited for irrigation and other domestic purposes Jaunpur resident mainly depends on groundwater for their drinking and irrigation purpose. Irrational use of water has led to many problems like water logging, soil salinity and alkalinity and overexploitation of groundwater. The situation is getting alarming year after year. The quality of irrigation water is one of the major factors that affects the growth and development of any crops. Present study is based on secondary sources of data from various agencies. The quality of groundwater varies from place to place along with the depth to water table. Irrigation water quality of Jaunpur district of UP. were slightly alkaline to moderate alkaline. The present study revealed that some of the quality parameters do not conform to WHO guideline values. According to analyzed water samples indicated that the groundwater samples of some block and Jaunpur city were found unsuitable category for irrigation and requires proper water purification management.

09

Fluvial Responses to Urban Development: A Case Study of River Mahananda in Siliguri Region, West Bengal

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River system plays a significant role in the creation of any urban settlement. Almost all the large cities are grown on the bank of a large river, which is intensely influenced by human activities, especially through urbanization. As men enter any region, they change the land-use scenario, basin surface characteristics etc. which have a direct influence on the fluvial system. The removal of vegetation, creation of impervious layer by the construction of roads, parking lots, and other building greatly reduce infiltration and thus increases total runoff and peak flows and decrease groundwater level. The main aim of the paper is to analyse the impact of urbanisation on river Mahananda in Siliguri region. From the year 1990, the development of Siliguri has grown at an alarming rate, but a little attention has been paid on the development of its lifeline. As a result, the health, as well as morphology of the river Mahananda, has changed significantly. The channel width has reduced at a rate of 10-15m/yr. Rate of encroachment is very high at some region. At present, during non-monsoonal period, it looks like a dying water body. In order to identify the major changes of land use scenario, data derived from Topographical map, satellite imageries over the last thirty years have been incorporated with the context of urbanisation. Extensive field survey has been done to identify the major sources that are responsible for the deterioration of this fluvial system. The result can provide a reliable basis to determine reasonable management and conservation strategies of river Mahananda in Siliguri region.

10

Evaluation on the Condition of Urban Lakes and Water Bodies in and around Kolkata City

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Lately the scenario of water bodies and lakes of Kolkata are worst in terms of pollution, health, degrading ecosystem, diminishing or shrinkage of water bodies etc. Due to the expansion of the city the geographical importance of lakes, ponds and water bodies are questionable. According to a study of South Asian Forum for Environment (SAFE), Kolkata has lost 46% of water bodies since 2006. In urban areas, lakes and water bodies acts as lungs to maintain the ecological balance but loss and pollution of water bodies not only affect the ecosystem but also lead to urban flooding and several diseases during monsoon. The present study aims to highlight the present condition and the current scenario of the water bodies in and around Kolkata city. For the study emphasis was given on the analysis of satellite imageries, Google Earth data, field survey and peoples' observation to show the alarming state of water bodies and lakes and to seek some path to save the water bodies by implementing awareness for the betterment of urban future.

11

Spatio-Temporal Variation of Green Spaces in Urban Region: A Case Study of Pune and Pimpri Chinchwad Municipal Corporation

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In the recent times, there has been a huge impact of urbanization on the land use pattern, including green spaces. Urban green spaces play a crucial role in the ecological system of an urban environment. Regardless of the enormous advantages that urban green spaces provide, there is a serious lack of information about the quantum and quality of urban green spaces. Pimpri Chinchwad Municipal Corporation is a twin city of Pune Municipal Corporation. Both the areas have seen unique expansion of built up, urbanization and industrialization over the last few decades. Evaluating the progressive changes in urban green spaces and the amount of green space available per city dweller for the area will be helpful for urban planning and environmental management. In order to bring out the changes in green cover within study region, two satellite images with the difference of 20 years, were analyzed. The remotely sensed images are interpreted using digital techniques, such as Supervised classification. The Normalized Difference Vegetation Index (NDVI) is used to separate between green and non-green spaces in the images digitally. On the basis of NDVI analysis, categorization of greenspaces has been done. The analysis has discovered that there has been an increase in the green cover with substantially less amount of chlorophyll. However, there is a decrease in the percentage of green cover with mostly high chlorophyll content. Additionally, the growth in population has caused the decrease in available green space per person. Further, the results show urban green space per person is significantly less than the recommended value by World Health Organization. It can be concluded that the increased urbanization in Pune and Pimpri-Chinchwad Municipal region has resulted in the decrease of urban green cover and green space area per person.

12

The Impact of Urban Geomorphology in Changing Land Use and Land Cover in Baranagar Municipality of 24 Parganas North of West Bengal

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Urban geomorphology is the branch of geomorphology that describes urbanisation and its relation to natural environmental degradation due to anthropogenic activities. Urbanization is considered one of the important anthropogenic components in changing land use and land cover and environmental frame work in a region. It is the method of understanding the growth of urban areas, the increase of built-up area, change in density of population, and also transformation of the urban way of life of the population. Uncontrolled urbanization may alter the existing land use/ land cover change which might have both positive and negative impacts like unauthorized urban sprawl, loss of agricultural land, high land values, and other related problems. The present research work aims to analyze the changes that occurred in land use /land cover (LU/LC) over twenty-nine years (1990-2019) using modern technology like

remote sensing and Geographical Information System in Baranagar Municipality in North 24 Pargana District of West Bengal. There are 34 wards in Baranagar Municipality spreading in a 7.12 sq. km area with a population of 245213 (Census 2011). The land use and land cover change detection were carried out by using LANDSAT 5 TM and LANDSAT 8 OLI. Utilizing a hybrid classification method for interpretation and on-field validation, it has been found that the built-up area of Baranagar Municipality increased from 1991 to 2019 by 15 percent and also, the areas under water bodies and bare land have been decreased very significantly in the study period to accommodate the population and urban geomorphology has changed significantly. The research concludes that there is a need for systematic and comprehensive planning for sustainable development with a healthy urban environment and proper conservation of natural resources.

13

Analysing the Correlation between Imperviousness and Surface Runoff: A Case Study on Urbanizing Watershed of Bhima-Indrayani Basin, Pune, Maharashtra, India

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The altering land use due to rapid urbanization has recorded growth in impervious surfaces which has profound impact on the runoff in urbanizing watersheds. The spatial analysis in these watersheds is felt necessary for management of surface and subsurface water regimes. For the present research, the Bhima-Indrayani basin located in Western Maharashtra has been chosen because of a host of many upcoming industries and experiencing tremendous growth due to proximity of Pune and Pimpri-Chinchwad area. The built-up area has increased from5.64% in 1992 to 25.12% 2016 mainly along transportation routes (Mumbai-Pune Expressway, State highway-50). In 1992, this basin has relatively low imperviousness (15%) which was observed in case of Pimpri-Chinchwad and that too highly limited to a small parcel of land. On the contrary the same area shows a considerable sprawl along with the increase in imperviousness in 2008 (increase from 15 to 25%). Certain areas have also been increasing in 2008 which basically are the major settlements like Talegaon Dabhade, Vadgaon, Chakanand Khed which accounts for 23.67%. The similar growth pattern has continued for 2016 and it has reached up to 32% of imperviousness. Considering the surface runoff, in the entire watershed there is an increase of almost 8.4 MCM of runoff during the 1992 to 2016. Relationship between the runoff coefficient and imperviousness was attempted for eight different basins. As can be seen the runoff coefficient closely follows the percent IS, except at low levels where soils and slope factors become more important. In all basins there is a significant rise in the runoff amount with respect to increase in percent IS. For the Bhima-Indrayani basins in 1992 with lower values of percent IS the runoff produced is relatively lower, whereas within creased values of percent IS attributed to higher values of runoff in 2016. Thus, a strong and significant positive relationship is established between the imperviousness and the runoff for the present study area. The average runoff coefficients obtained for the gauged basins within the Bhima-Indrayani basin has a strong positive relation with imperviousness of basin with significance level of 0.5.

14

Geomorphology of Bilaspur City - Its Impact on Urban Functions

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Complex interaction between the urbanization process and geomorphological factors of a location and its result impact on environment has been emerging as an important, exciting and growing area of research. Following this research tradition this study attempts to investigate the problems emanating out of the interactions of geomorphology and urbanization process in Bilaspur area, an ideal location for investigating this topic. Three major research objectives have been addressed. First, a systematic study has been carried out to identify the changes in the geomorphology in Bilaspur city due to urbanisation process. Second, the environmental problems, mainly water logging and the lowering of underground water table, arising out of the interactions of geomorphologic factors and urbanisation process in the city have been studied. Third, the city planners and administrators have been provided with some useful geomorphologic information and suggestions to aid better planning of the city in the future. Bilaspur was controlled by the Kalachuri dynasty of Ratanpur. The city, however, came into prominence around 1741, the year of the Maratha Empire rule. The Bilaspur city is approximately 400 years old and the name “Bilaspur” has been originated from the Fisher-woman named “Bilasa”. Bilaspur district is not only famous in Chhattisgarh state but also in India due to its unique characteristics like rice quality, Kosa industry and its cultural background. Bilaspur district has a major contribution in the naming “Dhan Ka Katora” for the entire Chhattisgarh region. Bilaspur has developed a lot. Bilaspur district is situated between 21.47° to 23.8° north latitudes and 81.14° to 83.15° east longitude. This study systematically demonstrates that haphazard growth and rapid urbanization combined with unfavourable geomorphological factors of the city have exerted tremendous stresses on groundwater regime and waterlogging problem in Bilaspur city. It provides some useful guidelines to the city planners, engineers and administrators to facilitate decisions regarding the extent of urban growth in geomorphologically fragile areas of the city. It is emphasized that the city administrators and planners of Kolkata need to be aware of the importance of factoring the impact of complex interaction of city geomorphology and urbanisation process in city planning and administration for a better tomorrow.

15

Identification of Groundwater Potential Zones in Upper Karha River Basin using GIS

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The tremendous growth in population and urbanization has resulted in an irrational increase in groundwater demand in previous decades. The improper management of groundwater resources, lack of awareness related to the importance of groundwater, wrong agricultural and irrigation practices, uncontrolled overutilization of groundwater, monotonous crop pattern creates problems of Groundwater Scarcity. Because of inadequate knowledge about groundwater resources, their optimal use, and their management, the population, residing in

a study area, faces the problem of water scarcity for a long duration of time. The Upper Karha River Basin of Pune District is selected for the present study. The study area has optimum monsoon rainfall. There is a rapid growth in Urbanisation which results in increasing the demand for Groundwater. The main objective of the present paper is to study the availability of groundwater and identify the groundwater potential zones in the Upper Karha River Basin. To identify and to map the zones of groundwater potential, various geomorphological aspects have been taken into consideration. The various geomorphological aspects have a great impact on the underground occurrence, availability, and movement of groundwater. The tracing of groundwater underneath hard rock surfaces is such a vast and complicated task. To identify the groundwater potential zones, various geomorphological aspects like land-use, land-cover, lineaments, Morphometric properties, soils, and geology of the area have studied and a thematic map for each aspect has prepared using Arc GIS 10.3 software. The weights have been assigned to each thematic layer and a final map showing groundwater potential zones like High, Moderate, and Low groundwater potential has prepared. The final output map helps to understand the groundwater conditions in the study area.

16

Spatio-Temporal Variations in Creek Water Quality: A Case of Lower Reaches of Ulhas Estuary and Thane Creek from Maharashtra, India

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The present paper aims at understanding the spatio-temporal variations in the water quality along the lower reaches of Ulhas estuary and the Thane creek. Four distinct locations from the Ulhas Estuary and four locations over the Thane creek (flowing through Thane city) were fixed for the creek water samples. These locations were ascertained on the basis that the earlier years water quality parameter data was available for them. The recent water samples were collected from the same locations, analysed and WQI were computed for the same. Ten water quality parameters were taken in to consideration while the water quality index was determined based on four base parameters as suggested by CPCB. The water quality indices were computed for the various creek locations for a period of nine years (2010-2018). Water quality index during pre- and post-monsoon seasons, for all the years under consideration for all these five locations, ranges between 25 to 49. This indicates that during the assessment period the creek water is consistently in the bad or poor water quality state. During pre-monsoon, insignificant increasing trend of WQI is observed at Gaimukh, Retibunder and Kalwa while insignificant decreasing trend is noted at Kolshet. Kasheli on the other has a significantly increasing trend of WQI. The water quality index for post monsoon season depicts significant increasing trend especially at Gaimukh, Kolshet and Kalwa. Retibunder has an insignificant decreasing trend. Significant decreasing trend is observed at Kasheli bridge. Overall, it can be stated that the WQI during both the seasons consistently remains poor and pre-monsoon season WQI has insignificant trend.

17

Evaluation of the Determinants of Change of Land Use and their Implications on the Local Stream Network in the Fringe Areas of a City

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Environs of a region witness alteration in the landscape, as much as there is establishment of human institutions. As humans, from time immemorial have set their existence with the extraction of valuable resources from the immediate surroundings to quench their satisfaction of need. This quench of need for basic life support system is seen taking reverse side, as one the disastrous aspect of ever-increasing population is surpassing the renewal rate of some of the natural settings among them being the natural local canal or stream network specifically in the fringe areas of a city, where the mixed land use is taking up a toll on the stream network for the available farm land due to change in land use to mainly built-up. Geomorphic response of a stream network flowing in a locality in the vicinity of a city to existing land use is seen making drastic implications on the available farm land due to unprecedented irregular sprawl of the build-up on the available valuable farm lands. Going through the literature, an analytical method of research will be used to make an evaluation of the drivers of change of land use and their implications on the local stream network in the fringe areas of a city. Results of the study will be evaluated after carrying out literature survey of the problem under study.

MONITORING AND MAPPING GEOMORPHIC PROCESSES AND FORMS

01

Alluvial Fan Drainage Network Evolution and Development: An Example from Satpura -Purna Alluvial Plain, Western Vidharbha, India

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Alluvial fans are depositional landforms formed where a confined feeder channel emerges from a mountainous catchment to adjacent valley plain. Fan building is a result of complex interaction of climate and tectonics. It is expressed through hydrological and geological characters of watershed by erosional and depositional process. The present study aims to provide some insight into alluvial fan drainage network evolution and development, planform morphology modified by axial stream. Satpura-Purna alluvial plain in Western Vidarbha region of India contains sufficient number of alluvial fans to build drainage network development dataset and planform morphological analysis. Alluvial fan named as 'Akot' fan is one of the prominent fans located in the middle part of Satpura - Purna alluvial plain. A complete analysis has been carried out by integrating data from SOI topographical maps, DEM data, Google Earth images and geological maps. Compositionally, Akot alluvial fan shows wide variation in lithology from boulder bed formation in their upper (apex) portion to brown silt in the distal part. Analysis of Akot alluvial fan of Satpura - Purna plain reveals that geometry and morphology of fans is controlled by local relief and hydrological characteristics of axial stream. As the study area has similar conditions for tectonics, lithology and climate, it is clearly understood that geomorphology controls different processes occurring on alluvial fan, causing different type of fan surface morphologies. We suggest that, regeneration of this river in terms of its hydro-morphology is a timely need in order to achieve sustainable use of its resources.

02

Application of Data Envelopment Analysis (DEA) Method for Morphometry - Based Sub-Basin Prioritization of Kumari Watershed, Eastern India

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Drainage basin represents a fundamental geomorphic unit, being used for watershed management. One of the fundamental geomorphic processes operating within a basin is sub-aerial erosion, a complex interplay of a number of processes, operating in tandem. Exact

quantification of this process is difficult and therefore one has to depend on a number of morphometric variables for the estimation. One of the prerequisites for watershed management is to get an idea about the erosion susceptibility of the basin. Sub-basin prioritization implies the process of sub-dividing a basin (large areal unit) into smaller ones (sub-basins) and assigning priority on the basis of the susceptibility to erosion. In the domain of sub-basin prioritization, the multi criteria decision making tools (MCDM)have assumed greater importance in recent years. Amongst a number of popular MCDM methods, this paper has taken the Data Envelopment Analysis (DEA) for assigning priority values to the different sub-watersheds in the Kumari River Basin of Eastern India. The DEA, initially used for assessing the efficiency of different units in a business environment (called Decision Making Units or DMUs), has now been broadened toother disciplines. This method, which is based on the optimization principle in Linear Programming, is considered suitable as compared to other MCDM techniques, because not only does it assigns priorities, but it also makes a thorough h understanding of various causal factors of the dependent variable (in this case, erosion). This paper attempts to apply the DEA model for the exercise of sub-basin prioritization in the Kumari River Basin, Eastern India. IT also ranks the sub-watersheds (DMUs) on the basis of erosion susceptibility, which may be helpful in the domain of sub-basin prioritization for watershed management.

03

Near Real Time Flood Mapping and Monitoring Using the C band Synthetic Aperture Radar (SAR) Imagery: A Case Study of Assam Flood, 2020

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Flood appraisal for degree and seriousness is a pivotal contribution before, during, and after a flood event has happened. Even though the optical imageries have been broadly utilized for flood detection and planning, Synthetic Aperture Radar (SAR) imagery is favoured for identifying flooded areas and providing scientific information during a flood period because of its ability to work in all climatic conditions and also during the day/night time. The present study is an endeavour to utilize the C band Sentinel - 1A and 1B data for near real time flood monitoring for the state of Assam, India during monsoon, 2020. A total of 75 numbers pre-flood and 106 numbers post-flood images were processed in the Earth-Engine platform for developing the flood models. The Sentinel-1A and1B images were first mathematically aligned and geometrically rectified. After that, a refined Lee filter was applied to all the images to remove the speckles. Thereafter, water-based and slope-based threshold limits were applied to the SAR data to delineate the flood-affected regions. Moreover, the density slicing procedure was utilized to distinguish the open water from the non-water (land) zones. Finally, to identify the real inundated zone, fixed water bodies were separated from the open water. Different flood layers were overlaid to investigate the spatial extension flood, duration of the flood, and the spread of the floodwater with time. Three different flood phases were observed from the analysis. The first phase was in May, the second phase was from June to August, and the third phase was in September. Among the phases, the second phase has been experienced the most noticeably awful flooding scenarios. The study exhibits that 5.23 lakh

ha area was flooded in this region during the total span of 2020 monsoon. This investigation concludes that the SAR data in integration with the GIS analysis can be utilized adequately for flood water mapping, monitoring, planning, and, discovering courses for emergency actions during such events.

04

Integration of Geomorphological and Geological Data for Targeting Groundwater Prospects Zones in the Eastern Part of Boudh District, Odisha: A Geospatial Approach

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The goal of the present study to demarcate the ground water regime in the eastern part of Boudh district of Odisha, covering an area of 3098 sq. km is a drought prone area. The study area underlain by hard crystalline rocks, such as, charnockite, khondalite, granite and gneiss are the main rock types. Access to potable drinking water is a major challenge for the local population. Chronic droughts lead to annual emergency appeals to save the lives of the people. In this context, it is very much important to demarcate the groundwater regime for the better monitoring and conservation of these precious resources. Various thematic maps viz. lithological map, slope map, land-use/land cover map, lineament map and lineament density map, drainage map, soil map and geo-morphological map were integrated and incorporated in a GIS platform. These thematic layers were overlaid with ground-based hydro-geological data to map the groundwater prospects zones and identify the most suitable sites for borehole siting and drilling. Five different groundwater prospects zones namely 'very good' 'good', 'moderate', 'poor' and 'very poor' have been identified. The findings of this method have been validated with the field survey data on groundwater table position. The water table data was plotted on the groundwater prospect zones map to see the relationship between the groundwater prospects zones and status of water table position and validation report is satisfactory. Finding of this study are very encouraging and this approach used has proven its applicability in mapping groundwater prospect zones.

05

Morphometric Control on Settlement Distribution in Gandheswari River Basin of Bankura District, West Bengal

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In present era river is a most significant exogenous force. Most of the civilizations were established on the bank of the river. Bankura district is an extended part of Chottanagpur Plateau, which is characterized by numerous fluvial systems. Morphology of settlements on

the river basin is highly controlled by fluvial morphology such as – relief, slope, stream order, stream frequency, dissection index etc. The main focuses of this study are – to show the level of dependence of settlement morphology on fluvial system and to show the temporal changes of Gandheswari river health due to unusual settlement distribution within a very short time span. To formulate this paper, we have mainly used quantitative analysis based on primary and secondary data source. Extensive field survey has been used for deriving primary data source and various Governmental reports, journals, newspaper reports, SRTMDEM, LANDSAT images and Google Earth images has been used for secondary data source generation. Statistical and GIS software has been used for tabulation, computational and map generation. Present study is suggested that the selected river is progressing to reach its maturity level. Functional settlement morphology is highly diversified in upper catchment areas and monotonous traditional society based functional morphology is located in lower catchment of river basin. These studies are very useful for watershed management and maintaining the river health.

06

Analysis of Relief Aspects of Puran River Basin of Maharashtra, using Remote Sensing and GIS Technique

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Morphometric analysis involves the study of linear, areal, and relief aspects of the river basin. The relief aspect of the drainage basin is related to the study of three-dimensional features of the basin it involving area, volume, altitude and vertical dimension of landforms. In this research paper, an attempt has made to analysis relief factors of Purna river basin Maharashtra. For the better understanding, local relief characteristics author used different geomorphic parameters such as Absolute relief (AR), Relative Relief (RR), Dissection Index (DI), and Slope analysis. For preparation of base map and drainage map author used Survey of India toposheets at1:50,000 scale, and LISS III image. GIS and image processing techniques with DEM data is also used for the identification and analysis of geomorphic features of Purna river basin. The entire Purna river basin of Maharashtra is selected for the study. It lies between 20° 8' 31" to 21°28'30" North latitude to 75° 58' 25"to 77° 56' 20"' East longitude. Area of the basin is 1786.44 sq.km. Main objective of this study is to analysis relief and slope aspects of Purna basin. Absolute relief of the basin varies from 203 meters to 1162 meters. As per the calculation of Relative relief, it is 82.58 percent of area of the basin is low to very low relief. Dissection index of study area reveals that maximum area comes in rang of 0.00 to 0.20 and 0.20 to 0.40. Slope analysis indicates that the maximum area of the basin is a plain area with a gentle slope. The outcomes of this types of study provide significant knowledge and input that is essential in decision making for river basin planning and also for the development of the watershed.

07

Identification of the Bank Erosion - Signatures and its Sub-Types Factorizing Change in Channel Width of River Ganga in Malda District of West Bengal, India

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The study under pursuance has been carried out to view channel migration of River Ganga taking the eastern most channel-bank along Malda district, West Bengal i.e., the reach starting from Manikchak Ghat to Farakka as a major causative factor of bank erosion on spatio-temporal perspectives. Channel migration has been studied for specified years using the LANDSAT satellite images using geospatial technology under GIS platform. Google earth historical imageries have used and have consulted for the validation of ground reality. Photographic investigation and field measurements of geomorphic signatures of bank erosion and sub-types have done to document the phenomena location-wise. Cross section studies through satellite imageries explored that River Ganga received its highest average width out of the selected cross sections in the year 2000 amounting to 5.03 km, compared to 3.24 km in 1978and 4.43 km in 2019. Results also revealed that 11 villages are excessively affected by erosion which are jurisdictional to Manikchak, Kaliachak-I and Kaliachak-II blocks. Prominently the work has been corroborated to find out the dominant bank erosion sub-types in a location-wise manner and temporal change in channel width due to bank erosion.

08

Contribution of Mayurakshi River on the Downstream Planform Change of Bhagirathi River, West Bengal

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Mayurakshi is an important right bank tributary of Bhagirathi river which joins the Bhagirathi near Kalyanpur. Average annual rainfall over the basin varies between 765 and 1607 millimetre. This tributary discharges about 7591.2 MCM water and 3 million tons sediment annually into the Bhagirathi. This study emphasizes on the effect of Bhagirathi river downstream after the contribution of this huge amount of flow from Mayurakshi river. Contribution of this river on main stem has been evaluated by planform analysis of Bhagirathi. For this analysis, total 20 km reach of Bhagirathi river has been selected, taking 10 km upstream and rest 10 km on the downstream of the Mayurakshi confluence. Channel characteristics, confluence angle, sinuosity index (HSI, TSI & SSI) and bar morphometry (number and area of different type of bar) has been measured. Cross profiles are drawn on the river segment at specific interval for measuring width-depth ratio and hydraulic radius. Analysis has been done on the variation of flow pattern between the two reaches.

09

A RS-GIS Based Study on the Shifting Nature of River Raidak-1 of the Dooars Region, West Bengal

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The shifting behaviour of an alluvial river channel is a universal phenomenon. Originating from Mt. Akung Phu of Bhutan, the river Raidak (named as Wong Chu in Bhutan) flowed around 610 km in Bhutan and entered India near Bhutanghat. After entering into India, the River Raidak has bifurcated into two main branches named as Raidak 1 and Raidak 2. The present study is based on the Raidak 1 River which flows through the low-lying plane area of Dooars region to join with River Shil Torsa (Kaljani) near Balabhut, India. Like other alluvial plain rivers, Raidak 1 has also shifted its course throughout the time frame of 88 years. Due to various natural and anthropogenic factors; channel migration, bank erosion and bank failure is very common characteristics of the River Raidak 1, resulting frequent occurrence of flood; river capture; abundant river course in this region. This kind of instability in river bank has a huge impact on the bank dwellers of Raidak 1 River. The changes in bank lines position, center line movement of River Raidak 1 have been mapped and calculated by using Remote Sensing and Geographical Information System (RS- GIS). Different historical maps, Survey of India topographical sheets and LANDSAT Images have been used for the scrupulous work. The result shows that in four subsequent reaches, the river Raidak 1has total of 77.59 sq.km of Historical Migration Zone (HMZ) for the time span of 88 years (1930-2018).

10

Analysis of Land Use and Land Cover Dynamicity Using Geospatial Tools: A Study of the Gadadhar, Raidak and Shil Torsa Rivers Confluence Zone, Indo-Bangladesh

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Changes in Land use and Land cover (LULC) is a dynamic process. It is an important aspect in managing natural resources and monitoring environmental changes. The Rivers Gadadhar, Raidak, and Shil Torsa confluence around the Indo-Bangladesh border near the village of Balabhut, Cooch Behar. In the past few decades channel shifting makes a significant change in LULC in this area. Remote sensing data under the GIS domain were utilized to show the changes in LULC spanning over a period of 2001 to 2020. In this paper Landsat 7, ETM+ data for 2001 and 2010, and also Landsat 8OLI data have been used for 2020. Six different types of LULC were categorized and out of them, fallow land was evident as the most important LULC practices followed by agricultural land and built-up area in 2020. Significance rate of reduction in open forest area (-0.44%) to agricultural land and the built-up area was observed. The change rate of fellow land is -0.30%,agricultural land is 0.45% and built-up area is 0.48% which indicates the land use extension due to agriculture and human constructions. This entire work is done by Supervised image Classification, using Random Forest Algorithm. It is believed that the present study will help to contribute towards sustainable land use and land cover planning and management around the Indo-Bangladesh border.

11

Monitoring and Mapping of an Active Geomorphological Agent of Aeolian Sands Cause Desertification in the Semi-Arid Regions of Andhra Pradesh, India using Geospatial Techniques

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Desertification is one of the world's key environmental and social-economic issues. The primary objective for scientific and political organizations is therefore the observation and early detection of desertification, with geospatial techniques similar to the Remote Sensing and Geographical Information System is a candidate option for the enlargement of the monitoring system. The present study aims to evaluate the desertification caused by the deposits of aeolian sand near the Vedavathi River in the semi-arid area of the district of Anantapur, using temporal satellite image data. Active Aeolian geomorphological sand, sand dunes, sand sheets, and mounds occur in the study area along the eastern bank of the Hagari/ Vedavathi river. The migration of sand and sand dunes by the Aeolian process is the principal reason for the desertification of this region. It is necessary to monitor and mapping the Desertified areas in the study region to prevent the impact on the environment and society. The Desertification Status Maps (DSM) has been prepared by using the techniques Normalized Difference Vegetative Index (NDVI), Topsoil Grain Size Index (TGSI), and Geometric calculation methods in the Arc GIS 10.4 and ERDAS IMAGINE software.

12

Application of Multi-Criteria AHP Model in Morphometry-Based Terrain Erosion Potential in the Barakar Basin, Eastern India

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Exact quantification of the degree of fluvial erosion undergone by a basin is difficult. Under such circumstances, one has to depend on various proxies for determining erosion potential. Fluvial Morphometric parameters are used as proxies all over the world in order to ascertain the intensity of geomorphic processes operating in the basin. Since the advent of high-resolution Digital Elevation Models (DEMs), Morphometric attributes are quantitatively estimated for assessing erosion susceptibility of the fluvial systems. The Barakar River Basin in Eastern India has been selected as a case-study for the same. This study has used the Shuttle Radar Topographic Mission (SRTM) DEM of 30m resolution. Amongst a variety of MCDM techniques, the popular Analytical Hierarchy Process (AHP)was used. The primary difference between the traditional AHP techniques is that the relative importance of each parameter was ascertained on the basis of the multi-component Principal Component Analysis (PCA) technique. This implies that instead of taking only one PC, six PCs were considered with a cumulative explained variance of 96.624%. The relative importance of each parameter was determined on the basis of the loading ratios of the various parameters under multi-component PCA. Finally, AHP-based erosion susceptibility maps were weighed based on their explained

variances (obtained from PCA for individual component) and the final map was displayed on the basis of spatial variation of the erosion susceptibility in the Barakar Drainage Basin.

13

Lineament Extraction to Identify its Impact on Drainage Network in Upper Krishna River Basin, Maharashtra

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A linear Earth Surface feature associated with dislocation and deformation commonly known as lineament. The present study aims to identify the influence of lineaments on the drainage network in Upper Krishna River basin through the extraction of lineament using satellite images. Remote sensing techniques has boosted lineament studies since then the identification and mapping of lineaments becomes easy with the high-resolution satellite data. Remote sensing images can be use through enhancement techniques to identify linear features like lineaments. These could be useful and applicable in the fields of groundwater, mineral exploration and engineering geology. Lineaments are extracted by digital image processing (DIP)technique and final lineament map has been prepared using different GIS software, for the same Sentinel – 2 image data are used. In total 1314 lineaments are derived from the study area with the length of 3983.44 km. The lineament density is higher in the upper reaches of the basin where the undulating hilly regions of western ghat is located. Hence, these areas might have higher structural deformation, higher ground water infiltration potential because of the high density of the lineaments. About 1642.81 km (11.5%) of the total stream length is influenced by the lineaments and it is maximum in the source regions of the drainage network. With the significant findings, this study discussed the detailed structural control of the study area and it may be helpful in further studies of Geology, geomorphology, water resource management and related fields.

14

Flow Modelling for Bank Erosion Estimation of a Snow Fed River in Indo-Bhutan Region: A Case Study of Two Divergent Reaches of the Puthimari River

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The primary aim of this article was to compensate the heterogeneous flow velocities at divergent reaches of the same river. Two adjacent but with divergent sinuosity indices and planform geometry reaches were purposively selected to measure the flow velocities with a current meter across the channel in the downstream direction. The stream was traversed, taking velocity measurements in every 5m horizontal distance at the water surface, middle and near the bottom. The average velocity of each point was calculated based on surface, middle and near the bottom and then, flow modelling was done for both the reaches based on

these datasets. A model of flow velocities was developed by Kriging method in a GIS environment based on the measured dataset at random cross-sections in equal intervals across the channels of both the reaches. The eroded areas of both the reaches were calculated through overlay analyses of IRS 1D LISS III satellite images collected from NRSC (ISRO), Hyderabad. The relationship between near bank flow velocity and bank erosion of the river was established by the scatter plot method. It was proved that a strong positive correlation existed between flow velocity and bank erosion. The r^2 values for flow velocity and bank erosion of both the reaches ranged between 0.19 to 1.0 for a period of four years from 2011to 2014. In fact, it was empirically tested that strong positive correlations existed in most of the cases with r^2 values as high as 1. This study concluded that the near bank flow velocity exerted more pressure on bank material and eroded away by hydraulic actions resulting in bank erosion or lateral channel change.

15

Spatio-Temporal Anomaly of Glacial Lakes in the Changme Khangpu Basin, Sikkim, Eastern Himalaya

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The Changme Khangpu basin (CKB) in the Sikkim, a part of Eastern Himalaya has been investigated for glacial lake area variability. The Indian Summer Monsoon (ISM) and North-East Monsoon provide the precipitation in this N-S trending basin. The present study offers great potential to identify the nature of climate variability using the glacial lakes as a proxy. A sum of 49lakes has been delineated in the CKB covering an area of 3.37± 0.175 km2. Change detection analysis for the last 26 years (1988 – 2016) has been carried out for 48 lakes which existed in 1988 and had been partially free from shadow effect. Varying sizes of lakes exist as an ice-scoured trough, moraine-dammed lake, tarn, proglacial lake and supraglacial lake. The local topography such as aspects, altitude and surrounding geomorphology determine glacial lake distribution as well as lake area dynamics in the CKB. Total lake area had increased by 8% during 1988 – 2001 but decreased by 1% in post-2001.The most dynamic supraglacial and proglacial lakes such as the lake adjacent to Palochuthang-2 glacier and Lake of Tenbawa Kangse glacier made a significant contribution for such total glacial lake area anomaly.

16

Evolution and Decay of Wetlands (Bils) in the Moribund Deltaic Tract of Nadia and Purba Bardhhaman District, West Bengal, India

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The river Bhagirathi, flowing over centuries through the deltaic tract of Nadia (Krishnanagar, Nabadwip, Chapra, Santipur) and Purba Bardhhaman (Katwa I, Katwa II, Purbasthali I,Purbasthali II, Kalna I and Kalna II) show great metamorphosis in flow pattern. Morphologically the area is designated as moribund deltaic tract as the rivers Bhagirathi, Mathabhanga and Jalangi are in their decaying phase and have lost their connection with the parent streams. The entire flood plain of Bhagirathi being confined within high levees are not in a position to get inundated and land building processes have ceased. Due to absence of perceptible slope, Bhagirathi flowing through this moribund tract thus displays extremely intricate meandering courses. At some places the courses of a river have taken a complete turnaround. Detached length of old courses, meander cut-offs, oxbow lakes, inter-scroll swales, back swamp depressions, shallow depressions are scattered over the entire area indicating the extent of degeneration of the drainage condition. Detail study of defunct drainage channels, cut-offs, oxbow-lakes has been done based on Police station maps of 1921, Survey of India Topographical maps (79A/7) of1950 & 1967, Landsat MSS of 1977; Landsat TM of 1990, 1994& 2000, Landsat ETM 2009 , 2014 and 2019. The oxbow lakes (bils) once a rich zone of biodiversity are now in decaying condition and their rate and percentage of decay calculated over last 47-50 years is quite alarming viz. Ranipur bil (76%,),Santler bil (92%), Chander bil(74%), Bara bil(74%), Basaderbil(55%) in Purbasthali I and II block of Purba Bardhamandistrict Bachamari bil (61%), Moraganga (93%), Alokananda bil(68%), Hansadanga bil (61.5%) , Bhaluka Bil (84.98 %) in Nabadwip and Krishnanagar I block of Nadia district. Pakhir Char also known as Chupir Char in Purbasthali II block evolved during the early 90s from Bhagirathi meander have also decayed massively (78.79%) in last 26 years. The estimated decay is 3.03% per anum, after it got delinked from the main river course. Siltation, eutrophication, human colonization, agricultural practice, road construction, increasing domestic sewage, lack of government monitoring has led this surface water reserves gradually shrinking and they have begun to lose their natural functionability.

17

Drainage and Morphometric Indices of the Khowai Basin, India and Bangladesh, as Indicators of Active Tectonics

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The Chittagong–Tripura Fold Belt (CTFB), India and Bangladesh, uplifted due to the convergence of the Indian and Burmese plates in the Pleistocene and is characterised by six N–S aligned westerly convex anticlines and their intervening synclines. The Khowai (225 km), one of the major rivers of the CTFB, originates from the Longtarai range (310 m) of India, crosses the Atharamura range in the west, and then turns north to carve its way through an alluvial synclinal valley into the deltaic plains of Bangladesh. The main objective of this paper is to assess the effect of the upliftment of the CTFB on the Khowai using selected geomorphic indices. For change detection, we used datasets belonging to four years: 1932-33 (Survey of India 'inch' maps), 1962 (Corona photos), 1975 (Landsat-1 MSS data), and 2017 (Resourcesat-2 L4fmx data). Planform of the Khowai was extracted from these datasets and was divided into19 reaches based on the meander-belt axis direction to calculate sinuosity

index (SI). ALOS-PALSAR elevation data (pixel size: 12.5 m) of the region is utilised to bring out the river profile and basin perimeter. Morphometric indices like stream length-gradient index (SL Index), hypsometric integral (HI), valley floor width to valley height ratio (Vf), and basin elongation ratio (Re) were used to detect the drainage basin characteristics. The results show that between 1932-33 and2017 (85 yr), the Khowai changed its planform significantly in its alluvial stretch. Sinuosity of the Khowai mostly decreased in the alluvial reaches while increased slightly in the hilly stretches in the Longtarai and Atharamura. E.g., in the reach near Teliyamura, the SI decreased from 2.9 to 1.3 and the length of the reach decreased from 20.7 km to 9.3 km. The long profile has two discrete convexities which match the two anticlines. SL index is higher in the anticline area (122–442) than the alluvial plain (43–84), indicating tectonic activity in the Longtarai and Atharamura. HI (0.17) suggests that the Khowai basin is in senile stage although the valley floor width to valley height ratio suggests that the Atharamura (0.37) and the Longtarai anticlinal axes (0.62) are tectonically active regions. The R_e value (0.46) also suggests that the shape of the basin is elongated, and it is influenced by the tectonic activity of the CTFB. Decrease in sinuosity in the alluvial reaches may be the result of valley aggradation or the channel adjustment influenced by the tectonics, besides changes in rainfall and anthropogenic activity.

18

Structural Controls over the Evolution of Forms and Processes in the Baitarani River Basin, India

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Structural control plays a vital role in the evolution of form and processes in a river basin. Indian cratonic part is composed of different geological formations of different ages as old as Archaean. To identify the structural controls over the river basin, the Baitarani River Basin has been selected for the present study. The Baitarani River having originated from the Gonasiaka in the Gupta Ganga hills travels a distance of 360 km before joining the Bay of Bengal. The study has been carried out taking25 sub-basins of the Baitarani River. For computing morphometric indices such as hypsometric integral, asymmetry factor, standard sinuosity index, stream length gradient index, curvature index of long profile, and topographic symmetric index, Survey of India topographical maps (73F/6,73F/12,73G/6,73G/9,73G/13,73G/14,73K/2,73K/3,73K/4,73K/7, & 73K/8) and SRTM DEM (30m) have been used. To identify the structural control and gravity anomaly seismo tectonic map and GSI Geology map have been used. Hypsometric integral value of the Baitarani river basin showing 0.29 indicates old stage. In the river basin, several structural evidences such as structural axial trace of fold, dyke, joint, fracture and shear zone and morphometric lineaments are observed. The upper part of the Baitarani river is composed of Singbhum Craton and in this region several dykes are idenfied which strongly control the river direction. In Simlipal Folded area, two tectonic faults are located in Deo Nala sub-basin which control the channel direction. In the Musha nala sub-basin, confluence angle is guided by the structural lineament. Besides, in the Baitarani river basin negative Bougher anomaly (-30 to -60 mGal) is found and in lower part of the river basin a subsurface fault is found to guide river course.

19

Application of Topographic Wetness Index in the Groundwater Zonation Analysis

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Topography is often one of the main controls on the spatial distribution of saturated areas, which in turn is a key to understanding much of the variability in soil dynamics, geo-hydrological processes, and groundwater quality. The topographic wetness index (TWI) has become a widely used assessment to describe wetness conditions at the catchment and sub catchment scale. With this index, nonetheless, it is presumed that groundwater gradients always equal surface gradients. Topographic indices like the Topographic Wetness Index (TWI) have been used to predict spatial patterns of average groundwater levels and to model the dynamics of the saturated zone during events (e.g., TOPMODEL). However, the assumptions underlying the use of the TWI in hydrological models, of which the most important is that groundwater level variation can be approximated by a series of steady state situations, are rarely tested. It is also not clear how well findings from existing hill-slope studies on sites with transmissive soil can be transferred to entire catchments with less permeable soils. . The correlation between TWI and groundwater levels not being constant over time given the rainfall variability patterns and the subsequent groundwater changes over seasonal changes demands a comprehensive evaluation of topographic controls to be studied and evaluated. . This study focuses on finding the relevance of the topographic indices for effective and robust analysis for groundwater potential zonation.

20

Classification of Small Scale Land Forms, its Significance: A Case Study of the Middle Ichamati River, India

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The definition of landforms, their characterization and classification are the core subject of geomorphology. But it becomes complex and would be difficult for the identification of the landforms, especially when the landforms appeared upon the plain, highly modified by human activities. This paper has examined the landforms of the middle basin of the Ichamati river, and appears indeed to have undertaken as an important distributary in the district of North 24 Parganas, India. It has been primarily taken an attempt to classify the landforms with the help of the satellite image, IRS P6 LISS II and LISS III. The Digital Elevation Model (DEM) is not enough to identify the micro scale landform with utmost satisfactions. To overcome this intricacy a series of field works have been conducted (2004, 2009, 2012 and 2015) to collect primary data. Then the landforms have been classified as point bar, meander scroll, ripples, dappling the derivation (dy /dx) (second order:d^2y /dx^2, third order derivation: d^3y /dx^3) method and the ANOVA test (value = 5% for rejection the null hypothesis) stands for the aforesaid classification. The classified landforms are meander scroll (the lower one:

d^2z/dx^2>0.012, d^2z/dy^2 =0; the higher one: $d^3z/dx3$ >0.022 andd^3z/dy^3 =0.), and the F-statistics is 8>>>0.05 (ANOVA test), which strongly rejected the null hypothesis (meander scrolls are uniform in character); point bars (d^2z/dx^2 = 0.0001, d^2z/dy^2 =0.0001, F-statistics are 0.00017), ripples (large, medium and short) (d^2z/dx^2 >0, d^2z/dy^2 =0 as it is not applicable for such micro features) and F-statistics is 21.82 >>>0.05. The changing episode of the landforms indicates that the river is going to be decay gradually.

GEOMORPHOLOGY OF EXTREME EVENTS

01

Assessment of Agricultural Drought Vulnerability using Three Integrated Models in the Upper Dwarakeshwar River Basin in West Bengal, India

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Drought is one of natural hazards badly affecting the agricultural economy. One of the most significant aspects of disaster management and planning is to assess the agricultural drought vulnerability for sustainable agriculture and food security. Most of the studies on drought drew less attention to exposure, sensitivity, and adaptive capacity for vulnerability assessment. Hence, the present work deals with a comprehensive agricultural drought vulnerability assessment scheme integrated with exposure index, sensitivity index, and adaptive capacity index. At the upper Dwarakeswar river basin, 90% of rice cultivation is rain-fed and regularly encounters drought resulting in the low yields in this region. Exposure Index has been considered using six parameters. The sensitivity Index has been considered using eight parameters. The adaptive capacity index has been computed by combining the Physical Adaptive Capacity, Social Adaptive Capacity, and Environmental Adaptive Capacity Index. Each index has been assembled using the Analytic Hierarchy Process (AHP) technique. Then, the results were classified into five vulnerability zones. e.g., Very low, low, moderate, high, and very high. Finally, the results have been validated through the Yield Anomaly Index (YAI).

02

An Appraisal of Flood, the Fluvial Geomorphic Hazard of Torsa Basin, West Bengal

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Present paper is concerned with flood havoc, the fluvial geomorphic hazard of river Torsa (catchment area of 3419 sq, km) in lower Brahmaputra basin the river is notable for its fluvial and tectonic activities involving deepening widening and lengthening concomitantly. Most of the analysis of the study is based upon intensive field work data collection and empirical observation both qualitatively and quantitatively particularly in terms of (1) Pre field work (2) field work (3) Post field work (Mukhopadhyay 1980 1982) The researcher has adopted the modern methodology (including Remote Sensing and G.I.S). The maximum recorded discharge of the river is at Hashimara is 4071 cumecs and highest flood level 41.45 m. Excessive flood damages paddy cultivation. There seems to be urgent need to adjust the crop calendar

by increasing emphasize on rabi crops. The reserve forest and tea gardens are also affected by the ravages of flood. Peoples participation is necessary for balanced economic growth. Water harvesting afforestation in the catchment areas watershed management can abate miseries of basin dwellers.

03

Application of Persistent Scatterer Interferometric SAR (PSinSAR) for Monitoring Mining Subsidence in and around the Raniganj Coal Mine Area, West Bengal, India

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In the Raniganj coal mine area, ground subsidence is a serious and persistent problem that causes serious environmental issues, hamper local livelihood, and hinders infrastructural development. As land subsidence is a sudden and remote hazard, mapping, and monitoring of those events in a cost-effective way is a challenging job. Synthetic aperture radar (SAR) interferometry is a well-established technique that permits remote detection of deformation at the Earth surface and analysis of the time series of ground deformation providing detailed pattern and nature of subsidence. This study attempts to show the applicability of the Persistent Scatterer Interferometric Synthetic Aperture Radar (PS-InSAR) technique with C-band SAR data to investigate the slow surface deformation caused by the underground mining activities in Raniganj coalfield areas. A total of 160 numbers of Sentinel 1SLC (single look complex) data from both the ascending and descending orbit have been used for land deformation monitoring. In the preliminary steps, master data was selected considering the perpendicular baseline and the time of acquisition of the images. After that image to image, co-registration was performed using the precise orbit data of the Sentinel satellite. The atmospheric phase screen (APS) was applied to reduce the noise as well as to improve the quality of deformation value. The topographic influence was minimized using the SRTM DEM data. To find the Permanent Scatterer Candidates (PSC), the Amplitude stability index was used and only values having greater than 0.8 were selected as a threshold. The residual inversion method was applied to get the APS for each PSC. Finally, the displacement model was implemented to generate the deformation values for each PS candidates. The PS-InSAR technique has proven its ability to detect land subsidence over the vegetated and rural areas. It also resolves the low spatial density of permanent scatterers by considering partially correlated scatterers as permanent scatterers (PSs) and extracting deformation related information from these PSs. Active query areas were finally masked out from the final displacement maps to avoid the false alarm of subsidence as generated otherwise. The Time-series deformation rate suggests that land subsidence due to different modes of mining activities is dominant as well as a continuous problem for the Raniganj coal mine areas.

04

Mapping and Monitoring of Waterlogging Problem during Post-Cyclonic Period: A GIS Based Study in the Coastal Area of West Bengal

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Waterlogging and intrusion of saline water are very common environmental issue in the coastal area of West Bengal and it often get acceleration during tropical cyclone. Waterlogging and salinization caused land degradation and decrease productivity of the soil in this region. Satellite remote sensing along with Geographical Information Systems (GIS)offers an excellent alternative to conventional mapping techniques in monitoring and mapping of surface and sub-surface waterlogged areas. In following study an attempt has been made to mapping and monitoring of waterlogging condition during pre- and post-cyclonic period using RS and GIS techniques. For this, Costal area of West Bengal has been selected as the study area. Here, Survey of India topographical maps and Landsat 8 (2019 and 2020) image have been used to observe relief, slope, canal density, supervised classification, normalized difference vegetation index (NDVI), normalized difference water index (NDWI), normalized difference moisture index and wetness index. Image classification revealed that the water-logged area is around six percent during pre- cyclonic period and in the post cyclonic period it is around 22 percent. The study demonstrates utility of integration of remote sensing and GIS techniques for assessment of waterlogged areas particularly in regions where waterlogging conditions occur due to the extreme event or super cyclone Amphan.

05

Flash Flood Risk Assessment of Little Rangit Watershed in the Darjeeling Himalaya

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River catchment areas in the Darjeeling Himalayas experience several natural calamities such as earthquakes, landslides, heavy monsoonal rainfall etc. which causes rapid landcover and geomorphological changes and in-addition to this continuous modification of natural landscape by anthropogenic activities disturbs the natural equilibrium conditions thereby paving the way for the occurrences of flash flood (FF) and related hazards. Major rivers like the Mahananda or Teesta exhibit such changes in their large catchment areas and are widely studied, however similar research at sub-catchment scale in the region is scarce. Among the major incidents of FF in the regions, the event of1968 was denoted as the most disastrous and had occurred when a cyclonic depression initially formed in the Bay of Bengal caused heavy precipitation, triggering extreme meteorological events. Little Rangit watershed, a tributary of Rangit River is considered to be one of the prime affected watersheds by FF due to this event. Hence, the aim of this study is to investigate the possibility of the occurrences of such flash floods in the Little Rangit watershed and prediction of its spatial distribution based on present circumstances. For this, we have relied on a RS-GIS based approach supported by field observations. SOI Toposheet, declassified corona satellite image, SRTM DEM and Google Earth Pro imagery along with rainfall data collected from the Chongtong T.E office, soil map from NBSSLUP were used to generate different indices such as Landuse landcover, Geomorphology, Drainage density, Rainfall distribution etc. Finally, by incorporating these

indices, the flash flood potential (FFP) map was prepared in QGIS 2.14 Essen using the Cubic B-Spline interpolation algorithm. The FFP map shows that the watershed is dominated by the presence of medium zones of FF risk with pockets of high FF, largely due to the natural hilly terrain. We found that, as the extreme meteorological events causes rapid and widespread changes in the landscape of a region, the geomorphological features thus formed, can also affect the scale and intensity of future flash floods or landslides in the region. It should also be remembered that anthropologically driven landuse change in the regions concerned should be within permissible limit and undertaken sustainably.

06

Estimation of Rainfall Threshold for Forecasting of Shallow Landslides along the NH-10 in Darjeeling Himalayas

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Rainfall induced shallow landslides are common in Darjeeling Himalayas. During the monsoon season the region receives enormous amounts of rainfall, which triggers many shallow landslides along the NH-10, causing property damages and loss of human lives. Since landslides are a natural occurrence and hence it cannot be controlled but with the help of early warning systems its effects can be minimized to some extent. The present study aims to estimate rainfall threshold for initiation of shallow landslides. The intensity-duration model has been performed to establish the rainfall threshold. For that purpose, a dataset of 8 years (2011-2018) has been taken for analysis of the result. The required datasets, such as daily rainfall information was obtained from the India Meteorological Department (IMD) rain gauge stations and adjacent tea gardens along the NH-10, whereas landslide event-related information was obtained from the Public Works Department (PWD), newspapers, and earlier publications. During that period 288rainfall events resulted in 641 landslides that occurred along the road section. The rainfall threshold for the entire NH-10 has been estimated as I = (20.10 ± 1.84). D (0.45 ± 0.05), where I is the rainfall intensity (mm/d) and D is the event duration (d).Further, the role of antecedent rainfall (3, 5, 10, 15-days) over daily rainfall also been analyzed and it is found that about 17% landslides are biased towards daily rainfall when it plotted against 3-days antecedent rainfall. Finally, the effectiveness of the obtained threshold was validated using rainfall data of Tista valley, 2015.

07

Cyclone Amphan and its Impact on the Lower Deltaic West Bengal: An Assessment using Remote Sensing Sources

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'Amphan', the first Super Cyclone to form in the Bay of Bengal since the 1999 Odisha Super Cyclone, left a devastating impact on the Lower Deltaic West Bengal (LDWB), coastal districts of Odisha, and parts of Bangladesh. Despite the evacuation and other safety measures taken by the administration, it caused massive damages in the aforementioned regions. Cyclogenesis of the Amphan resulted with the formation of a convective low-pressure system in the south eastern Bay of Bengal on 13 May 2020, which rapidly strengthened into a Super Cyclonic Storm on 18 May 2020 at 11:30 IST with a sustained wind speed of 222 km/h. The Amphan made its landfall between 15:30 and 17:30 IST on 20 May 2020, and then continued as a Very Severe Cyclonic Storm for the next 6 hours. Because the Amphan's passage through the seafront occurred during low tide, the storm surge elevations were not exceptional, and saved the region from further damages. After landfall, the cyclone crossed the densely populated districts of South and North 24 Parganas, and Kolkata with a maximum sustained wind speed of 157 km/h. It then changed its direction toward northeast and caused devastation in the western districts of Bangladesh. Finally, after moving into the west of Meghalaya as a low-pressure, the system's life cycle ended on 22 May 2020. Synthetic-Aperture Radar (SAR) C-band data of 19 May 2020 (pre-event) and 22 May 2020 (post-event) were processed using Sentinel Application Platform for extraction of the storm-inundation zones. The district-wise inundated area statistics were generated by spatial analysis using vector overlay of pre-and post-inundation water areas. The results show that 12.3% of the study area was inundated by storm waters. Expanse-wise, 1,809 km2 (38.2% of the district area) and 622 km^2 (6.2%) areas in the Purba Medinipur and South 24 Parganas districts were inundated, respectively. Inundation amounts for the other districts were: North 24 Parganas (420 km^2, 10.3%), Hugli (298 km2, 9.5%), and Howrah (289 km^2, 19.7%). Maximum waterlogging can be identified around the Hugli Estuary region, and in the reclaimed areas of the Sundarban in North and South 24 Parganas districts. Some recovery of the flooded areas was seen during the weeks following the event, as the breached embankments were repaired and accumulated waters drained. The impacts of salt water incursion into the farmlands, however, are likely to remain for years.

08

Human Responses towards Flood Hazard in Noa – Mangaldai River Basin, Assam India

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Flood plains have been recognized as an ideal place for human settlement from times past due to the proximity to rivers, alluvial soils, ample water supplies and means of transport. Floods are the high low of water that overtops the natural channels and its role and importance in nature are diverse. Floods help in maintaining the natural function of river and source of fresh water and other natural resources, which bring the opportunity of livelihood. At the same time, it also causes hazard when people and their activities are exposed to flooding and can create severe loss and damages of people. The Noa-Mangaldai basin with 63.75% plain areas has the experience of recurring floods and associated hazards mainly in the middle and the lower reaches ranging from very high magnitudes to moderate magnitudes throughout its

history. About 58.57% area of the basin suffers from severe floods which receives 2 to 4 flood waves every year. The nature and extent of flood hazard and the modes of human responses and their adjustment in the study area have been analysed in this paper by using both primary and secondary data.

09

Natural Hazard with Reference to Mumbai Flooding: An Overview

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Natural disasters are Earthquakes, Landslides, Volcanic eruptions and Floods. out of these, floods are very common natural disasters, and it is dangerous to most of the villages and cities that are situated near the river bank. For the present study the flood aspect of natural disaster has been considered. Many cities in India facing this problem of flood during Monsoon. Some coastal cities experience the floods every year and heavy losses are incurred by the flood. The floods in the Mumbai area are consider for the present study. Mumbai is the financial capital of India, having area 603.4 sq. km., average annual rainfall 2,146.6 mm and 12,442,373 population as per 2011census. The floods occur in the Mumbai are due to Mithi river and its tributary. Flooding of the Mithi river is very common during monsoon, therefore, it is important to study the reasons of the floods in Mumbai. There are many causes of the flood in Mumbai. Few of them are consider for the present study, the water logging is one of the major causes discussed with respect to, Heavy Rains, Faulty Zoning and Drainage Systems Above discussed problems are studied with the help of obtained secondary data, Rainfall Statistics, GIS, Satellite imagery and topographical study. The study will helpful to find out the solution for runoff water to avoid the flooding condition in Mumbai.

10

Mapping Flash Flood Risk Zones and Analyzing its Sensitivity for Luni River Basin, India

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Aeolian conditions with fluvial interactions are typically characterized by the shifting sand dunes cut across by dwindling dry rivers with a continuous grapple of the either wind or water agents to curve out a unique geomorphic landscape. River character identification along with its expressive sensitivity can help to investigate the nature of geomorphic progression in the arid landscape which is already a water stressed region with unthinkable floods. But sometimes due to unusual rainfall events, water gushes down the sediment stacked dry river channels leading to a major flash flood event which has enough potential to expose the population at higher risk living along the river corridor. Channel diversions, bifurcations and avulsions engulfing the floodplains alter the land use practices of the area. Luni being the

"Maruganga" or the Ganges of the Indian Thar in Rajasthan has records of some major flash flood events during1979, 1990, 2017 and 2019 with the sudden onset of monsoon clouds passing by the Aravalli. The discharge and water level set an annual record indicating a peak flow event in the river fora short period of time lasting for not more than two days at a stretch. Hence flash flood sensitivity in dryland river basin is absolutely necessary to model and delineate the risk zones according to its severity helping us to plan and manage effectively for major settlement and land use alterations in the watershed. This study explains how the leeward slopes of Aravalli along with major rainfall dominant zones are prone to flash floods as the risk zones where carefully derived using various natural factors integrated using Analytical Hierarchical Process (AHP) and Composite Index formulae in GIS environment.

GEOMORPHOSITES AND GEOTOURISM

01

Geo-Environmental Settings of Bakarwal Habitat

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This paper studies the Geomorphological, climatic and environmental characteristics of the habitat of Bakarwal pastoral nomads. The research used both primary as well as secondary sources of data which include interviews, observation, field study, climatic data records, satellite images etc. The habitat of Bakarwals extends from 32º30' to 34º15' north latitude and74º to 76º15? east longitudes. These pastoralists migrate seasonally between three distinct geographical zones which include winter habitat (The Outer Himalayas and Dun valley) transit habitat (The Lesser/Middle Himalayas) and the summer habitat (The Great Himalayas). The results of study stated that geography of an area via its terrain, climate and land cover characteristics exerts influence over nomadic communities. The way nomads utilize and negotiate the space has distinct markers of geo-environmental character of a region. Pastoral communities occupy those territories where geo-environmental conditions limit the scope for a sedentary lifestyle and adaptation of Bakarwal pastoral nomads take place.

02

Geodiversity, Protected Area and Ecotourism: The Case of Tirthan Valley in Great Himalayan National Park Conservation Area

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Geodiversity forms an important component of the landscape characterisation. It can be defined as an assemblage of geomorphology, geology, soil, drainage, slope, and various operating physical processes in the area. The geodiversity characterisation helps in understanding the physical, chemical, and biological processes that occur within the landscape. The geodiversity has its bearing upon the biodiversity (flora, fauna, wildlife habitats, and ecosystems) of an area, which in turn, collectively attracts the human-cultural components (settlements, land use, and infrastructure) through resource purpose and the combination of these forms the modern landscapes. The geodiversity characterisation helps in identifying the landscape sensitivity thus raising awareness of the local distinctiveness or diversity and subsequent policies/decisions on protection of such landscapes and restoration and conservation strategies. In this paper, the geodiversity characterisation of Tirthan Valley under Great Himalayan National Park Conservation Area (GHNPCA) is done to understand the geodiversity and biodiversity of the area. The predominance of geodiversity and biodiversity with rich assemblage of flora and fauna having universal value has made it a part

of Himalayan biodiversity hotspot and giving the area outstanding significance for biodiversity conservation. The Tirthan Valley is a part of larger GHNPCA protected network established in the year 1999 and due to its outstanding conservational value; UNESCO has declared it as World Heritage Site in 2014. The indigenous communities of the surrounding Ecozone have traditional access to the resources which has been restricted due to the park's creation. Ecotourism has started as a major economic activity inside park and the surrounding Ecozone, thus providing alternative livelihood opportunities to these traditional communities and making them a stakeholder in the protection and management of the park area.

03

Bakkhali- A Well-Known Geotourism Site in West Bengal

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Today, tourism is not just for leisure or recreation, it became an important part of our life. Geo- tourism is a type of tourism, that highlights the geographical features of a place's unique environment, heritage, aesthetics, culture, etc. and plays a positive role in the welfare of the locals. Bakkhali (21°33'47"N 88°15'34"E) is a coastal village, within the jurisdiction of Namkhana CD block of the South 24 Parganas district, West Bengal. Bakkhali is unique in many ways. The windmills in Frasergunj serve as a power generating location. This small island juts out into the vast expense of the Bay of Bengal. The south-facing crescent-shaped beach of Bakkhali is one of the rare ones in the world that offer great views of both sunrise and sunset. Main Tourist attractions are Bakkhali watchtower, Crocodile project, Windmill, Fraserganj, etc. The present article has taken the help of Field observation and different secondary sources. This study is basically descriptive in nature.

04

Geo-Cultural Importance of Ajodhya Hill as a Geomorphosites of West Bengal

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Geomorphosites are characterized as those geomorphological landforms, which have scientific, cultural, social, and economic value based on human perception and use. Ajodhya hill, situated at the western part of West Bengal (eastern India) as an extended part of Chota Nagpur plateau covering an area of400 sq. km (approx.) plays an important role as Geomorphosites. The natural beauty of springs and waterfalls are considered as the main attraction of geo-tourism of this place. Springs over the Ajodhya hill play the main role as the water source for streams or rivers. Most of the Springs at Ajodhya hill are formed due to the presence of hard rock (granite or gneiss) under the sandy porous red soil. Waterfalls have appeared in different sizes and shapes at the sharp break of the slope with an average altitude of 430 m. Both geologically and geomorphologically, the Ajodhya hill is a significant landform of West Bengal as well as eastern India. It is the part of an uplifted plateau, which is particularly made of granite, gneiss, and migmatite rock of Archean age existing as an

extending part of 'Chota Nagpur Granite Gneissic Complex'(CGGC) which makes it one of the oldest landforms of India. The geomorphological composition of Ajodhya hill of Puruliya district favours the initiation of many springs even though it is a drought-prone area. The stored groundwater of the confined aquifer layer is forced to come out on the surface through an outlet (cracks, fissures, faults) as natural springs. The local tribal people worship many springs as God as it helps to sustain their livelihood year around. It is a perfect example of the geo-cultural relation of the particular physical set up on the culture of the community, which can be best observed in this drought-prone hilly region of West Bengal.

05

Modified Geosite Assessment Model: Importance of Tourist Perspective to Analyse the Geotourism Potential of Alipurduar District

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Geotourism refers to the travel of sites having geological significance that commonly uses the geological resources for the sustainable economic development. But, being a newly introduced sector in tourism and a new field of study especially in developing countries, it is not well recognized and promoted in the countries like India. Hence, even after having high potential for developing geotourism, with the existing exuberant sources of geological history along with diversified geomorphological features most of the regions lacks recognition as geotourism destinations. In this study, an effort has been made to evaluate the geotourism potential of Alipurduar district with some of its selected spots, where a modified version of Geosite Assessment Model (M-GAM) has been used. To consider a spot as a geotourism destination this modified version of this model includes the perspective of tourists along with the evaluation of experts based on some specific criteria. The study is based entirely on primary data which has been collected through the interview of experts and tourists. The study reveals that, for consideration of geotourism spot not only the judgement of experts but also the demands of tourists should also be taken into consideration. This will ultimately help to plan the possible ways of development in the field of tourism in the study area in order to bring socio-economic along with sustainable development.

06

Prospects of Geo-Tourism in and around Bihari Nath, West Bengal

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In recent day's geotourism add new aspects in tourism industry as well as geomorphological research. Geotourism is defined as tourism that sustains or enhances the geographical character of a place-its environment, culture, aesthetics, heritage, and the well-being of its residents. Different geomorphosites are becoming tourist's sites because of its own distinct natural and cultural diversities and open a new field of research. In this particular paper I try

to describe the geotourism perspective of Biharinath area and how this area becomes a focus of tourists and what are the future prospects of this area. Biharinath is a famous geomorphosite of West Bengal and it is also known as 'Araku Vally' of West Bengal. It is situated about 60 kilometres north-west of Bankura town and 14 kilometres north-east of Saltora town. With the discovery of Paleolithic tools in this area, the hill and the surrounding areas have come into focus of archaeologists and geomorphologists. Different tourist's spots like-Panchet dam, Maithon dam, Baranti, Susunia hill, Joychandi Pahar, Damodar river, different temples are representing the cultural and naturals importance of this area. The geotourism perspective of this area now enhance of cultural, adventure and ecotourism side as well. In future it can be expected that Biharinath become a famous spot for all tourists and researcher.

07

Anthropogenic Footprint across a Lateritic Badland Geomorphosite in West Bengal: Present Status and its Policy Implications

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The extensive lateritic badland surface near Garhbeta in Paschim Medinipur district of West Bengal is both an Indian geomorphosite due to its geodiversity and a popular tourist destination. However, its increasing attractiveness to tourists, mainly due to its ochre red hue and deep and narrow valleys has raised viability issues, via incremental changes in slope morphology, alterations of pedological attributes and gully-head expansion. Mapping of the hiking trails and gully field has been done from a 2 metre DTM, corroborated through a Total Station survey. Successive (2003-2020) very-high resolution satellite imageries are used to map trail development over time and associated vegetation changes, ratified through an along-trail GPS survey. Repetitive ground-based Structure-from-Motion imaging is used to capture even finer changes in the micro-slope facets, allowing accurate measurements of planform and volumetric changes between the original surface and the altered, trampled paths. Silver-Schmidt Hammer readings also attest to the lowered structural strength of these human trails. Constant hiking has accelerated erosion rates, with wood-fires for outdoor cooking during picnics, further charring and hollowing out the friable lateritic surface. Stairway construction has exposed scarp faces and the trails serve as newer pathways for runoff channelization. This walking-induced-erosion, besides modifying the slope facets along the trails, has also induced rilling along their edges by lowering their relative bed elevation compared to the adjacent gullies. This has precipitated minor slope failures and faster headward gully extension. Consequently, these have gnawed into the laterite, with the entire badland tract expanding by 16% in the last decade. Coeval with this expansion, the trail density has quadrupled, with simultaneous thinning of the scrub cover. If unchecked, this erosional trend will aggravate further in the future. Against this background, the work also highlights how the existing tourism policies in the area could be modified to address the abovementioned concerns.

08

Effect of the Covid on Ecotourism: A Case Study of Kumaon Region Uttarakhand

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Tourism is a industry and an important growth driver for a country, its economy and also for its social progress and monitoring. India has many geomorphological landscapes that attract tourists. The whole world has been affected by Covid epidemic since last one year and which has had the biggest impact on the tourism industry. Now what is the condition of geoturism and what is going to happen in the future, it is a serious question. The state of Uttarakhand, which attracts tourists from its geographical landscape, is now going through a crisis, in which Kumaon region is also particularly affected. It is bounded on the north by Tibet, on the east by Nepal, on the south by the state of Uttar Pradesh, and on the west by the Garhwal region. The people of Kumaon are known as Kumaonisand speak the Kumaonie language. During pre Covid period geomorphosites of region were center of tourist attraction. Uttarakhand has opened borders for inter-state and inter-district tourism activities under guidelines of unlock 2.0 from July 2020.In this paper, post-covid tourists' assessments of the geomorphological heritage of the region have been analyzed. The most interesting sites, from both the geomorphic and touristic points of view were chosen for the study. The scenario of tourists arrival was carried out by means of secondary data from various sources of Uttarakhand state government till December 15,2020. During visit of region authors made interaction with tourists and local people to analyze post covid impact on geotourism of the region. In this paper it is also tried to find out suggestion for minimizing impact of covid-19 impact on geotourism of the region.

09

Geomorphosites and Geotourism: A Case Study of Mehrangarh Fort Section

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Geological or Geomorphological elements of nature qualifies as geomorphosites, if they are worthy of being conserved as natural heritage. These sites of great value for us in terms of scientific, cultural, aesthetic, social and economic values and most of them are already being modified or damaged by human impact. This calls for their proper management and conservation which can be achieved through geotourism which promotes visit to location, conservation of geodiversity and an understanding of earth science through appreciation and learning. This article examines such geomorphosite, in the heart of Jodhpur city (Jodhpur District, Rajasthan) i.e., at the Mehrangarh fort. At the bottom of the famous Mehrangarh fort lies the Jodhpur group of Malani rocks which represent the last phase in the Precambrian age in the Indian subcontinent when the igneous activities were active. Mehrangarh fort section exposes the best Jodhpur Malani suit contact. This erosion contact is between the underlying youngest igneous suit of rocks of Precambrian age and overlying oldest sedimentary sequence of late Proterozoic to Eocene age. It is this geological significance that led to it being declared as a National geological monument. This article not only examines the geological and

geomorphological significance of the site but also explores the ways and means through which the economic and conservational potential of the site can be realised in a sustainable and eco-friendly manner.

10

Salkhan: An Unrecognised Heritage Value Site of Geomorphic Footprints

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A fossil park with geomorphic footprints estimated to be near 150 crores year old situated almost 15 km away from Robertsganj on state highway SH5A known as Salkhan Fossils Park on more formally, Sonbhadra Fossils Park. Algae and stromatolites types of fossil rings are scattered on boulders and it is located adjacent to Kaimur Wildlife Sanctuary extended over 25 hectares in Kaimur Range designated as land of Uttar Pradesh forest department. Sonbhadra is one among those districts in India where tourism potential as well as archaeological evidences are equally visible. Since, fossils available on this site are representative of oldest fossils of the world hence it is carrying a geological heritage value not only for India but also for the whole world. Now, the State Government has started focusing on development of this area after considering its tourism value. In this regard, issuance of a development fund of 1.25 Cr. is a step but a lot of efforts are needed to recognize its importance. This paper emphasizes on need of development this geological heritage to grab the opportunities of creating tourism value. This fossils park is still facing infrastructural bottlenecks e.g., Lack of proper road connectivity and transport facilities, lack of boarding and hospitality facilities are other major issues. If the Uttar Pradesh government is intended to attract different type of tourists like scientists, foreigners, women, children. Developing it as amusement park as well as archaeological site is a great challenge for the State Government. Therefore, this research paper will focus to suggest ways to strike a balance between preserving scientific value and creating tourism value in this park.

11

Assessment of Geotourism Potential of Singalila National Park, Eastern Himalaya, India

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Himalayan national parks provide ample tourism opportunities due to its diversified landforms, biodiversity and cultural characteristics. Singalila National Park (SNP) is located in the alpine landscape of Indian Himalaya and it has considerable potential for Geotourism development due to its tectonic history, landform characteristics, biodiversity and cultural characteristics. SNP provides generous geotourism attractions such as mountain valley, river, gorge, waterfall, river terrace, glacier lakes, dense forest, ecosystem, diversified plant and animal community. Besides these natural attractions, SNP has an interesting history of local communities and cultural heritage. Due to its diversified Geotourism value, this protected area

is highly suitable for geo-learning and Geotourism development. Trekking trails and metal roads provide access to this natural area. This article attempts to assess the Geotourism potential of SNP. For this analysis topographic maps, geological maps, geomorphic information, satellite imagery, cultural information, and GIS were used to evaluate geosites identification and geotourism potential in this protected area. Field surveys were carried out to evaluate Geotourism potentiality.

12

Landform Analysis of Ghatprabha and Markandeya Rivers with the Approach of Geomorphosites and Geotourism

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Landform analysis with reference to its application in various branches is important aspect of applied geomorphology. Geomorphosites are geomorphological landforms that have acquired a scientific, cultural/historical, aesthetic and/or social/economic value due to human perception or exploitation (Panizza, 2001). Karnataka Geologists' Association (KGA), Bengaluru had recorded the geomorphosites in south India. Kale V.S. (2014) has classified India's popular geomorphosites and geoheritage sites. There are several morphological landform sites in the State of Karnataka such as caves and stalagmites to inselbergs, bornhardts, nubbins, colourful badlands, waterfalls, beaches, caves etc. From historical times these landforms have acquired great value for cultural/ historical, defense, aesthetic, ecological, socioeconomic and/or scientific reasons. Such sites or areas are designated as ''geomorphosites'' (Panizza 2001; Reynard and Panizza 2005). For the present study, the Gokak waterfall and Godchinmalaki waterfall morphosites of Ghatprabha river and Markandeya river are selected. These both sites are located in Gokak tahsil of Belgaum district Karnataka State. In the view of tourism, both sites are approximately 70 km from Belgaum, near the river confluence, the Ghataprabha and the Markandeya. The main aim of this research is to assess the Gokak and Godchinmalaki geomorphosites and its potentiality to develop as geotourism site. To achieve these objectives the field visits, observation and interview methods are applied here. Besides this, secondary sources like SOI toposheet (47L/14), Mysore Gazetteer, Socio-economic abstract, official websites are applied to acquire the data. The empirical methodologies along with subsequent field surveys have been carried out to explore these sites as a geomorphosites research. It is observed that tourist places specifically landforms never considered in the perspective of conservation of landform with geomorphic research. Such geomorphosites should be studied by geomorphology researchers to protect from devastation.

13

Tourism Around Geomorphosites: One Week in Pokhara, Nepal

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Pokhara is located 200 km west to Kathmandu is the capital of the Gandaki Province, Nepal in the north-western corner of the Pokhara valley. The place is well known worldwide due to its majestic natural beauty. The Pokhara is also known as a city of ten lakes i.e. Phewa (The second largest lakes of Nepal), Begnas, Rupa, Khaste, Dipang, Maide, Gude, Niureni, Kashyap and Kamal located within the boundary of Pokhara Metropolitan city. The Devi's fall is a fascinating waterfall situated at Pokhara- 17, Chhorepatan, Siddhartha Highway is an important attraction for tourist. There are three limestone caves in Pokhara namely Mahendra Cave, Gupteshwor Cave,and Bat Cave. The breath-taking panoramic views of Annapurnarange, Dhaulgiri range and Mastapucha Horn enhance the beauty of Pokhara. Along with those Geomorphosites tourist can also enjoy adventure tourism, several holy temples, and museum in Pokhara. In 2018 I have an opportunity to visit Pokhara, Nepal for one week therefore, researcher observation, photographic documentation and secondary data is the main source of information for this paper. The Geomorphosites are very much important for sustainable Geotourism in Pokhara, Nepal. The main objective of the paper is to find out the importance of Geomorphosites to enhance geotourism in the context of Pokhara city development.

14

Dimension of Geo-Tourism: An Appraisal on the Attractions of Jainti River in Alipurduar District of West Bengal

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Geo-tourism is a new dimension of sustainable tourism which is associated with the enjoyment of aesthetic beauty, uniqueness sand attractions of other natural phenomena of a particular geomorphic site. This can significantly influence the economic growth at different scales and also preserves the environment and surrounding ecosystem through generating knowledge and sense of responsibility among the tourists. This paper attempts to examine the relationship between geo-tourism and micro-level benefits generated from this type of tourism at social and economic levels with the help of field observations and analyses in Jainti River valley of Alipurduar district in recent years. The study was conducted during the period of 2017-2019. Jainti River, originating from the Bhutan hills of the Eastern Himalaya is flowing through the Buxa Tiger Reserve of the Eastern Duars. The wide stretch of the riverbed, encircled by rich Tropical Rainforest, is the primary attraction for the tourists. In Jainti there is a rest house of the Forest Department in addition to several home stays and lodges in the nearby areas for accommodation for the tourists. The inhabitants of the Jainti village were earlier engaged as labours in dolomite mining activities on the hill slopes operated by some private concerns. After banning of this activity by the governments more than forty years the local inhabitants have now engaged themselves indifferent occupations associated with tourism. The people visiting Jainti now can observe the unique processes and resultant landform features around this river valley including the channel characteristics of the river, colourful sulphur water streams, stalactite-stalagmite caves and other geological forms. As

geo-tourism differs from other kind of tourism it requires specialist knowledge in presenting the sites to the tourists. The local people can be trained for this purpose. Therefore, the challenge remains in conserving and management of the geo-sites and, in addition preservation of the social and cultural heritages.

15

Geomorphological Assessment for Geo-Tourism Purposes: A Case Study of Tamilnadu Hills, India

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The tourist industry is one of the creating gathering of Industries on the planet. There are six gathering of geomorphological destinations in Tamilnadu plays major attraction spot for the tourists. In this study, vacationers' appraisals of the geomorphological highlights of elevation, slope, aspect and flow of the tourism industry of the area have been dissected utilizing geospatial innovation. The assessment by tourist flow was done by optional information sources. The primary inspiration for visiting the reviewed destinations was the stylish estimation of the scene. The respondents looked for data, chiefly on the Web, about nature, culture and vacation spots. The consequences of the overview show a requirement for additional advancement of the geo-touristic estimations of lesser-known destinations in Nilgiris and this will likewise empower the travel industry to be better overseen. At the point when the geographical locales are transformed into vacation destinations the inflow of the vacationer appearances are more which advances the travel industry and furthermore the financial improvement of the nation.

APPLIED GEOMORPHOLOGY

01

Challenges of Climate Refugees: A Case Study of Sagar Island of Sundarban, India

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The study explores the nature of livelihood vulnerability of the climate refugees from the coastal community of the Ghoramara, Lohachara, and Khasimara islands, migrated to the Sagar Block in Sundarban. We also emphasize the adaptive capacity of these vulnerable groups with the oscillating nature of climate change. To assess vulnerability and adaptive capacity of natives and migrants, a household survey (n= 352) was conducted and sample villages were taken from the Sagar where environmental migrants from the coastal community of the Ghoramara, Lohachara, and Khasimara islands, concentrated. In this connection, a Livelihood Asset Status Tracking (LAST)matrix based on financial capital, and a Sustainable livelihood Security Index (SLSI) based on eight related components including assets, nutritional status, education, community participation, water, sanitation, primary health and reproductive health were developed. Shannon's Crop Diversity Index, and forty-two years of monthly rainfall data of the Sagar centre were statistically analyzed to document how much climate change exerts mounting pressure on agriculture-dependent livelihoods. Quantitative analysis of livelihood of village Gangasagar Sagar Block showed quite a satisfactory performance (SLSI 0.369) as it is one of the important pilgrimages centres so that infrastructural facilities are available here. But an aggregated measure of SLSI of Bankimnagar, Gangasagar, and Kamalpur indicated that the villages were in distressed condition of the sustainable livelihood security including poor quality of life. The local administration adopted different social security measures for the Sagar Block but these are not upgrading the quality of life of environmental refugees. Only native residents were enjoying the benefit. This disparity in quality of life between native residents and migrants may be eradicated through adaptation with mechanized agricultural practices, and income generating alternative livelihood practices such as handicrafts, and micro-finance for the people engaged in unorganized sectors and through the expansion of Eco-tourism sector.

02

Long-term Temperature and Rainfall Variability at Agra, Uttar Pradesh

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This study focuses on climate variability in Agra in the twentieth century. Agra lies on the bank of River Yamuna in the northern fertile plains of Uttar Pradesh. Agra has a semi-arid

type of climate with hot and dry summers, a wet monsoon, and chilly winters. It is a significant agricultural, industrial, and tourist place with historical importance supporting a huge population. Thus, investigating climate variability at Agra becomes important for various aspects of policymaking or further management of this Mughal city. The objective of the study is to analyze the historical trends in temperature and rainfall data at Agra. Monthly maximum, minimum and mean temperature and total monthly rainfall data has been collected from the India Meteorological Department (IMD), Pune. Trend analysis is done by both parametric (Regression Analysis) and non-parametric methods (Mann-Kendal test and Sen Slope) for the period 1901to 1986 on an annual, seasonal, and monthly basis. The mean monthly temperature is declining in the first half of the century while it is significantly increasing in the latter half of the 20thcentury. The mean monthly minimum temperature is also showing a declining trend for all the months while during period1951-1986, it shows a significant increasing trend except for the monsoon season. However, the annual and seasonal mean monthly maximum temperature is showing a significant increasing trend. The total annual rainfall is increasing for the first half of the century but it is declining for the latter period1951-1997. There lies a lot of seasonal variation in rainfall trends and also the coefficient of variation is very high for winter and post-monsoon season.

03

Desertification and its Impact on Agriculture: A Study of Jaipur District of Rajasthan

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The study area comes under the Semi-arid Eastern Plains agro-climatic zone of Rajasthan. This zone is characterised with scanty and irregular rainfall, frequent drought, high temperature and evapotranspiration and paucity of water. Climate is the primary determinant of agricultural activities in this semi-arid region. In this zone the major Kharif crop are pearl millet, cluster bean and sorghum while major Rabi crops are wheat, mustard and gram. The objective of this study is to assess the impacts of desertification on agricultural pattern in the study area. Field survey was conducted for the assessment of impacts of desertification on agricultural pattern. A total of two hundred (200) respondents were interviewed using purposive sampling technique. For the analysis of data, the qualitative and descriptive statistical analysis such as tables, frequencies distributions and percentages techniques were used. The result shows a considerable decline in gross cropped (sown area) area and increase in fallow land in the area in recent years. Farmers have shown tendency to shift towards less water intensive crop instead of water intensive crops such as Taramira.

04

Physico-Social Barrier of Tribal Education in Jhargram Block, Jhargram District, West Bengal

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Scheduled tribes are socially, economically and geographically isolated and marginalised groups. They are lagging behind in terms of development. The development of a society depends on the balanced progress of all sections of the human community. Education is one of the essential tools for human resource development. It plays a major role in making ideas, behaviours, habits and attitudes towards life. Marginalised people of society are enabled to overcome the problems of deprivation with the help of education. The literacy rate of scheduled tribes is much lower than the mainstream groups of the country. Educational attainment of ST at a higher level is very low due to high dropout in the elementary and secondary levels of education. The present study aims to identify the constrains of education among the tribal population of Jhargram Block in the Jhargram district of West Bengal. Being situated along the margin of Chotanagpur plateau, this region shows undulating terrain with infertile lateritic soil. This is also one of the worst water scarcity regions of West Bengal. Presently this region experiences the problem of deforestation and soil erosion too. These difficult geomorphological and hydrological situations make the life and livelihood of tribal people harder. They have to struggle more to collect basic needs of life. They find less opportunity for leisure and thus attitude toward life is different from that of the mainstream population. They are indifferent towards attainment of education, and this apathy comes out of the difficulty in physical setup. Further, this difficulty is reinstated by political apathy towards infrastructural development. Study area has the least accessibility and connectivity because of the kuccha road and poor public transportation system. There is no higher secondary school and college in the study area within a buffer of 5-6 km. After completing primary level of education, they have to cover long distance for secondary schools and colleges through this difficult terrain along the forest roads. This restrains children especially the girls from higher education.

05

Geomorphic Constrain as well as Improper Afforestation Policy Limiting Livelihood Opportunity in the Forest Fringe Villages: Study on Kutusgerya Village of Jhargram District, West Bengal

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Undulating land, infertile soil and less availability of water set limitations in the prospect of agriculture in the forest fringe areas of Jungle Mahal. Landuse-landcover maps are compared with the Digital Elevation Model and it shows that the higher elevated and undulating areas are mostly covered by dense forest beingless affected by the human activities whereas, the low to moderately elevated zones are highly occupied by the different anthropogenic activities. These difficult terrains are occupied by the tribal population, whose life and livelihood heavily depend on forests. Geomorphic and hydrological constrains limit livelihood opportunity. Again, older Sal forests with heterogeneous composition are replaced by the younger homogeneous Eucalyptus species by recent forest management initiatives. It further restricts livelihood opportunity to the disadvantageous section of society. In Kutusgerya village of Jhargram C.D Block only 28% lands are arable. People face serious

difficulty in livelihood collection due to physical constrain and depletion of the quality of forest resulting from inappropriate forest management policy.

06

Analysis of Land Use and Land Cover (LULC) Change and their Impact on Land Surface Temperature (LST) of Cooch Behar-I Block, West Bengal, India

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Analysis of Land Surface Temperature (LST) is a crucial facto rfor determining the trend of global climatic changes. LST is continuously changing from global to regional scale, in response to the change of land use/land cover pattern. The present research aims to detect the changes, that takes place in land use/land cover pattern and its impact on the LST of Cooch Behar-I block of Cooch Behar district, West Bengal from 1999 to2019. For fulfilling that objective, the researchers have utilized Landsat 5 TM and Landsat 8 OLI images for assessing LST and Land use/Land cover (LULC) of the aforesaid region. In last 20years, declining trend was observed in the categories of vegetation, waterbodies, current fallow land and sand deposits, whereas rising trend was observed in case of agricultural land and built up area. Since 1999 to 2019, built up area expands its area by167% and area of agricultural land has increased 28%. Areal coverage of vegetation, waterbodies, current fallow land and sand deposits have decreased 16%, 40%, 57% and 70%respectively. In accordance to the changes of LULC, the Land Surface Temperature has gone under changes. In 1999, maximum Land surface temperature remained 28°C, which rises to 33°C in 2019; whereas minimum temperature was18°C in 1999, which becomes 20°C in 2019. The study will assist the land use planners to frame land use policy to restore environmental equilibrium, which will regulate the increase of LST.

07

Influence of Geomorphology on Population Density: A Case Study of Gangakhed Tahsil in Parbhani District, Maharashtra, India

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Geomorphology is an important aspect of all the living organisms. Human also used it for survival, settlement and completion of its daily need. The present research paper, Gangakhed tehsil in Parbhani district is selected for finds the influence of geomorphology on population density variation. It is come under draught prone area of Marathwada area, in central Maharashtra. Highest temperature during May is 45°C and minimum temperature is in January is 4°C; average annual rainfall in the study area is 888.5 mm. For this study, 105 village population data are taken from census book 2011. The present research paper, which is Based on geomorphology of the area, present villages are also classified and found that high population density occurs adjoining the river channel and very low density occurs in

denudational hill area. It is because of as compared to human daily need like drinking water supply, agriculture and survival facilities are easily available in the river channel area and this are very poor in denudational hill part. In this way, human also uses geomorphology indirectly for the settlement.

08

Time Series Trend Analysis of Rainfall over Konkan and Goa and Coastal Karnataka: Its Implications on Geomorphic Landscape

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The study area forms part of a rugged terrain consisting of hills, plateaus and plains and it is drained by many seasonal rivers which control the lineament of the area. This study is focused on the analysis of trends in rainfall variability over two meteorological sub-divisions demarcated by IMD and its impact on geomorphic landscape. These two meteorological sub-divisions lie in Western Ghats covering the states of Maharashtra, Goa and Karnataka between 74° to 76° E and 14° to 20° N. In recent decades, the frequency of extreme rainfall events has increased, which is the main cause of flash floods in the Western Ghats that has transformed the landscape of the study area. Due to high intensity rainfall, sediment supply in streams have also increased. Therefore, it is necessary to study the time series trend analysis of rainfall to observe the geomorphic landscape change. The study area is situated in humid and tropical climatic zone tempered by the proximity of the sea. Monthly rainfall data of 40 years for the period of 1977 to 2016 for annual, seasonal and monthly trends have been processed and used for the analysis. The parametric, Linear Regression analysis and student t-test have been used to identify the existence of trends and to know the changes in rainfall over the time period. An effort has been made to understand the relationship between ISMR (Indian Summer Monsoon Rainfall) and ENSO phenomenon whether rainfall over WG is influenced by ENSO phenomenon or not. Results revealed that although there is increased rainfall over Konkan and Goa, while declining over coastal Karnataka, the changes over both the sub-divisions were statistically significant. Considering rainfall in different seasons, there is a significant change in rainfall of monsoon season only, with increasing rainfall over Konkan and Goa and decreasing over coastal Karnataka. Furthermore, no statistically significant trend (positive or negative) was evident in any of the season. Results of this study may prove useful in the preparation of climate change mitigation and adaptation strategies in understanding the patterns of rainfall over the Western Ghats as well as to observe the geomorphic landscape transformation due to flash floods.

09

Application of Geospatial Techniques to Identify the Suitable Sites for Water Conservation Structures in Eastern Part of Pune district, Maharashtra

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The increasing water scarcity has been one of the common problem over a period of time with running days. On top of it, when the area is a part of rain shadow zone water conservation activities are must for overcome the issue of water scarcity. The study main aim is to demarcates potential sites for water conservation structures using geospatial techniques. A multi-thematic layer was created for understanding suitable sites for conservation structures. The thematic layer like slope, geology, geomorphology, soil texture, soil erosion, soil depth, stream density, lineament density and land use land cover have been produced from various data sources. Ranking weighted method were used for assign weights for each criterion. After assign weights weighted sum for analysis implemented within the ArcGIS which gave suitability zones area, this output shows the scope of sites for water conservation structures. The area already had a few existing structures and the study added to a few more sites to it.

This will contribute in increasing groundwater level thus, more irrigation to agriculture fields leading to well productivity as well as supply the water in areas with water scarcity.

10

Water Conservation Through Ponds – A Case Study in Dighirpar-Bakultala Gram Panchayat of Mathurapur-II, C. D. Block of Indian Sundarban Region

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In any area, occurrence and movement of groundwater mostly depends on geomorphological and hydro-geological factors such as elevation, slope, drainage, rock types, sedimentary depositions etc. Mathurapur –II is a Community Development block of Indian Sundarban which is located in the tide dominated active Ganga delta region. The average elevation of the area is 8 m and the general slope of land is towards the Bay of Bengal (BoB). The land is underlain by unconsolidated Holocene alluvium, and thus form high water potential in the aquifer, although under confined condition the aquifer appears with alternate sequence of coarse to fine grained sand and thick clay at the top that hinders water percolation and groundwater recharge. Fresh groundwater is found in between 160 to 360 mbgl, but shallow ground water in between 80 m to 150 m bgl is mostly saline water. Much of the surface water is contaminated and often saline, however, still used as domestic water because fresh water has to be collected from distant handpumps for drinking purpose only; and installation of deep tube well is very costly for the common people. Although some households have installed shallow tube well for domestic use, the water is saline and unsuitable; moreover, in summer most of the tube wells fail to lift water, and as pond water is reduced to worsen the situation. As the region receives huge rainfall of about 160 cm per annum, even if some part of it is allowed to run-off, rainwater harvesting in the household ponds can be immensely beneficial to tide over the water crises for both domestic and agriculture-pisciculture use. To understand the scope of water harvesting a field study of 30 household ponds were carried out for calculating the water storage capacity of the ponds. Data of depth and area of the ponds were measured along with their respective locations. The average area and depth of a pond is676m^2

and 3m, hence volume (Area*depth) of a pond is 2028meter3 which can store 2028000 liters of water (approx.). In ArcGIS 10.3 with integration of the coordinates of 30 ponds, volume was calculated using Triangulated Irregular Network (TIN) model, which produced almost the same results. So, in the block the scope of rainwater harvesting is massive, and the villagers should welcome the 'Jal Dharo Jal Bharo program' which is funded by the State Government of West Bengal to bear the expenses for excavation of new ponds and renovation of the old ones.

11

Organic Carbon in Mangrove Soil of Selected Stations in Indian Sundarbans

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In mangrove ecosystem, the organic carbon originates through various way like riverine, industrial and domestic wastes, agricultural, aquaculture and mining runoff, accidental spillages and decomposition debris from marine organism. Soil Organic Carbon (OC) level was monitored in four stations of Indian Sundarbans during June 2019. Sediment samples were collected from four stations of Indian Sundarbans. Total organic carbon was examined following a modified version of Walkley and Black method. The percentage of organic carbon differs significantly with stations and sectors. Among the four stations the order is Kachuberia > Sagar South > Sajnekhali > Haldibari. The result shows that the western sector of Indian Sundarbans which is anthropogenically stressed sector is the higher value of OC relatively central (protected zone) and eastern sector (control zone) of Indian Sundarbans. The main reasons behind the variation of OC may be attributed to a large extent by anthropogenic activities (fish landing, tourism and shrimp farms, and unplanned urban development), mangrove floral richness, forest age, the degree of tidal exchange and sedimentation. In all the selected stations, the soil organic carbon content decreased with depth.

12

Economic and Financial Feasibility Analysis of Apple Orchards across Physiographic Divisions in North-Western Himalayas- A Case Study of Kashmir Valley, India

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Financial investments in apple cultivation in valley of Kashmir are increasingly recognised as important factor of economic growth and poverty alleviation. Little is known, however, about the biophysical and land qualities that largely determine the success of investment in apple cultivation at micro-scale. To address this gap, this paper presents a comprehensive economic analysis across physiographic lines using precise economic indices that include cost-benefit analysis, project evaluation method and other socio-economic determinants. It relies on a primary survey of 866 farm-households, obtained across four physiographic divisions of the Kashmir valley viz-valley floor, Kerewas, Foothills and Side valleys. Results reveal that the

Kerewas fetch highest returns from an investment owing to its ideal geographical location which inhabit better financial prospects for apple industry. On the contrary, the non-Kerewa belt was found to be trailing in one or more economic indices, although, technically speaking, financial feasibility of an investment in apple cultivation was still found satisfactory. The study has a paramount significance since it demonstrates the effect of landform factor in relation to economic determinants of a financial investment. In other words, the study affirms a basic underlying premise that agriculture land-use decisions at micro-scale should be determined by the site-specific attributes and that, economic indices are largely dictated by physical characteristics of land itself. While demonstrating the utility of land-use decisions in light of geographical factors, our results can assist both farmers and policy-makers to design more adapted land-use strategy for fostering financial investments in apple cultivation in the Valley. The authors firmly believe that existing geo-physical and ecological conditions of an area should be realised in local decisions so that a healthy balance is ensured between socio-economic and environmental goals.

13

Assessment of Surface and Subsurface Irrigation System using the Multivariate Statistical Approach: A Study on Birbhum District, West Bengal

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Surface and subsurface water is one of the prime hydrological components which are mostly used in agriculture for their livelihood. A multivariate statistical approach has been used to identify irrigational patterns in Birbhum district. The result shows that canal and tube well irrigation are the main sources of irrigation. In the western part, tube well irrigation is very negligible due to proximity to plateau fringe. But the surface irrigation is high in this part, mainly irrigated by the canal, tank, and other irrigation. In the south eastern part, there is good availability of canal water as well as a moderate type of subsurface irrigation facility. In the northern part, the subsurface irrigation index is quite high. Almost 69% of the blocks of the district are characterized by the mono and double irrigation combination. The result of PCA reveals that canal and DTW are the main irrigational mode in the region which explains 31.78%of the data. The cluster analysis shows block wise homogeneous grouping of irrigation patterns. So, to achieve the sustainable development of irrigation and for the betterment of the region, such a study can open a new window.

14

Water Resource Crisis and Management: A Case Study of Jodhpur Districts

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From the beginning there was a tradition of participatory irrigation management in India. Farmers maintain and operate water resource under partnership. In Mughal's period irrigation

systems were planned and handed over to the farmers for management. Farmers co-operated in maintaining these schemes. Before independence because of some authoritarian policies farmers co-operation declined from water distribution sector. As the cooperation of farmers had gone down, participatory irrigation declined. These policies continued after independence also. Consequently, despite having so many dams in the country, there was a reduction in irrigated area. Farmer's thinking was that the water accumulated in the dam area is rain water and it should be free to everyone. Only few people got the benefits of dam water instead of entire region. Due to improper management and distribution of water only few people could get the benefits of irrigation water. There was no irrigation water available for the tail farmers and consequently government could not get proper revenue. Because of no revenue, government could not properly maintain the water distribution system. Therefore, national agriculture production decreased along with decreasing the economic and social level of farmers. On the other hand, due to fragmentation of land, changes in climate, less rainy days, with increasing population more demand of foods, more interest in cash crop, it became essential to take necessary steps to improve the irrigation distribution system. These improvements are not possible without the cooperation of the farmers. Food security is possible only with the proper distribution of water to the farmers by participating irrigation system. Water is the most valuable resource of the earth and we not only have to protect it for ourselves but also to preserve it for future generations. At present, when India as well as the whole world is facing water crisis, it is necessary to pay serious attention to it. Water management or conservation policies exist in India, but the problem lies in the level of implementation of those policies. Therefore, to eliminate the laxity in the implementation of policies, ensure their better implementation.

15

Impact of Climatic Variability and Spatiotemporal Changes in Conjunctive Sources of Irrigation on Rabi Crops of Bankura District, West Bengal

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Irrigation refers to the artificial way of providing water to plants to fulfil their water requirements. It offers soil moisture required for gemination, growth and development of crops and many other related functions. It is definitely one of the important inputs in modern agriculture as the crop production of any region directly depends on its existing irrigation systems. The Irrigation system of any region directly influence by the river geomorphology, drainage pattern, complex geological structure, slope and soil characteristics of that region. Bankura district, the present study area, is hydrologically a relatively dry region of West Bengal. Recent trend of climatic variability, erratic rainfall and absence of optimum irrigation support, the productivity of major food crops in this district remains insufficient to meet the needs. This paper attempts to find out the spatio-temporal pattern and changes of the major climatic parameters along with the changes of surface and ground water irrigation systems and its impacts on Rabi crops productivity in the district at C.D. Block level for the years of 1998-99 to 2014-15. Primary household survey data along with secondary data from India Meteorological Department and District Statistical Handbook, Bakura have been

incorporated, and different indices have been calculated using appropriate statistical techniques to know the temporal trend of climatic parameters and irrigation sources and their impact on productivity of Rabi crops. The result indicates significant increasing trend of the annual maximum temperature, non-significant increasing trend of the minimum temperature and rainfall, and increasing trend of inter-annual variability of rainfall. The result also indicates the significant reduction of surface irrigation, but ground water irrigation has increased significantly in during period. The overall reduction of total irrigated area remains the main reason for crop yield reduction and its variability among the different C.D. Blocks.

16

A Methodological Framework for Conjugate Management of Groundwater Drawdown and Aquifer Linked River Ecological Flow by Enforcing a Presumptive Standard Benchmark

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Since the initiation of human civilization, groundwater has been regarded as the most critically important source of water for rivers, lakes, wetlands and other terrestrial as well as aquatic ecosystems. However, most of the rivers ecological flow assessment frameworks have not been yet explicitly considers the potential impact of groundwater abstraction on riverine ecosystem. Thus, the major thrust of the present study is to manage the stream base flow by legislating a presumptive standard benchmark in the abstraction of groundwater resource. After assessing the complex surface-groundwater interplay and existing policies hindering the stream flow depletion from excessive groundwater pumping, it has been argued that a standard presumptive placeholder is crucial for proper maintenance of the river ecological flow. Thus, it is advisable to frame an appropriate placeholder to the groundwater overdraft, an indifferent but important driver of streamflow depletion. It is worth noting that an utmost ecological protection would require if groundwater overdraft causes monthly decline of base flow by less than 10 percent. The presumptive standard place holder would be highly critical for those areas where there will be a very little chance of detailed assessment of ecological flows in the coming days. The present study is intended to recommend a new metric i.e., ecological flow response time, that provide ample platform to the water resource managers to quantify the timescales of the implication of groundwater overdraft on the overall balance of the river ecological flows.

17

Assessment of Groundwater Quality using GIS-Based Water Quality Index and Human Health Risk Index

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Groundwater quality mainly depends upon geogenic structure and anthropogenic activities of any area. Quality of groundwater directly affects human body by consumption of it. Therefore, on the basis of its properties, groundwater quality and its risk to human health is very important in the present time on a spatial scale. Morphologically, undulating areas with basic granite-gneiss structure and various land use practice controls the availability of healthy groundwater very noticeably. Nituria block of Purulia district (W.B), India is such an area of Chotonagpur Plateau with high variation of agricultural and industrial activities. In this block groundwater quality is assessed for drinking purpose using standard Index method and GIS analysis. 52 groundwater samples were collected on pre-monsoon and post – monsoon season to analyse hydrochemical characteristics and drinking water suitability to health of local people. Multivariate analysis as hierarchical cluster analysis and principal component analysis as well as piper trilinear diagram identified groundwater quality is controlled by mainly interaction of anions and cations which are mainly occurred by geogenic condition of aquifer. Drinking water quality is assessed by using Water Quality Index (WQI) method based on standard limit of parameters published by Bureau of Indian Standards (BIS). Overall results of WQI show its value ranges from 59.40 to 171.43 in two seasons. During pre – monsoon 'Sabari' (171.43) indicates highest WQI value. In post –monsoon 'Purana Panchakot' (168.21) indicates highest WQI value. Spatial analysis of WQI using Arc GIS 10.4 software shows most of the region falls under 'good' to 'moderate' water quality zone. Fe and F- were used to assessment of human health risk of Nituria block followed by USEPA method. In the pre – monsoon period, Hazard Index (HI) of male shows88.46% GW sample and HI of female shows 94.23% GW sample are of non – carcinogenic health risk zone. During post– monsoon, HI shows 69.23% GW sample for male and 78.84%GW samples for female are of non – carcinogenic health risk zone. Remedial measurements of groundwater contamination on the hotspot zones will be helpful to check health hazard of this block as suggested in this paper.

18

Spatial Analysis of Land Use Concentration and Efficiency of Kakodonga River Basin, Assam

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The Kakodonga river originates from Naga Hills and flows in the course of Assam. It flows in the parts of the Jorhat and Golaghat districts of Assam, and the Wokha district of Nagaland. The Kakodonga river basin covered an area is about1,113 sq.km. The Kakodonga River basin is one of the important southern sub-tributaries of the mighty River Brahmaputra. It is geographically located between 26° 15'10" N to 26° 44' 48"N latitude and 93° 59' 10" E to 94° 21' 45" E longitude. The SOI topographic sheets on scale 1: 50,000 and IRS P6 LISS-III (23.5meter resolution) imageries of 2011 are geo-referenced and digitized through Arc GIS and ERDAS software. The present paper attempts to perform a spatial analysis of land use concentration that forest, area put under non-agricultural use, barren and uncultivable land, permanent pastures and other grazing lands, land under miscellaneous trees and groves, culturable wasteland, current fallow land, other fallow lands, and net area sown. The land use data has been collected for three years (2012-2014) at circle level and used the average area

of the Kakodonga basin for statistical purposes. The land use concentration, net area sown, and land-use efficiency of the basin worked out using Bhatia's (1965) method.

19

A Geographical Study of the Faunal Diversity of National Chambal Sanctuary

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The present research work provides an updated knowledge of the faunal diversity of National Chambal Sanctuary. As a research area, the faunal diversity of the National Chambal Sanctuary in Dholpur district of Rajasthan has been included. The research work consolidates information from field surveys, previous research works and a review of literature pertaining to this region. A total of 59 reptile,306 Bird and 56 mammal species are reported in the research area. The critically endangered Gharial and the Red-crowned roofed Turtle live here, and together with the endangered Ganges river Dolphin are the keystone species of the sanctuary. The National Chambal Sanctuary is listed as an Important Bird Area (IBA) IN122. Thus, the main aim and objective of this present paper is to high light the faunal diversity of National Chambal Sanctuary. It also suggests the conservation plan for faunal diversity of study area.

20

Surface Water Quality Assessment of Upper Catchment Area of Kangsabati River Basin, West Bengal

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The threat of surface water quality degradation is a sincere thought-provoking issue at the upper catchment area of Kangsabati river basin in Purulia district, West Bengal. The main objectives of this study are to investigate the spatio-temporal alteration of water quality status in the selective surface water structures throughout the above-said region and to highlight the triggering factors responsible for the changing water quality standard. Here, 24 water samples have been randomly collected from different surface water structures situated in the four blocks under the upper catchment area of Kangsabati river basin during the pre- and post-monsoon seasons within 2018-2020 and these samples have been tested in the laboratory to detect the levels of 12 selective water quality parameters. Multivariate statistical techniques e.g., hierarchical cluster analysis (HCA), principal component analysis (PCA), correlation matrix have been applied to examine the spatio-temporal changing trend of water quality. The result shows that the concentration of calcium, magnesium, nitrate, ammonia-nitrogen, total dissolved solids (TDS), electrical conductivity (EC), turbidity, total alkalinity, total hardness, biological oxygen demand (BOD), pH etc. have been magnified during 2020 compared with 2018 and 2019 and the mean value of pH, TDS, EC, magnesium and BOD exceeds the permissible limits according to BIS guidelines. The HCA groups 24 waterbodies into four

clusters where 17 waterbodies fall under moderately polluted category on the basis of similar water quality criteria. The PCA technique highlights that calcium, magnesium, nitrate, ammonia-nitrogen, TDS, turbidity, total alkalinity, total hardness, BOD have the immense impact in case of water pollution during the both seasons. The correlation matrix establishes positive correlation among all the parameters whereas DO is negatively correlated with other parameters. Mainly, unplanned agricultural expansion, excessive utilization of chemical fertilizers, disposal of urban sewage helps to ruin the health of the selective surface water resources. So, the adoption of sustainable agricultural practice, integrated irrigation schemes, renovation of sewage system are utmost significant remedial measures to promote the sustainable water resource management in the study area.

21

Morphometric Analysis and Prioritization of Neora Sub-Watersheds for Soil Erosion Vulnerability in the Neora Watershed, Kalimpong and Jalpaiguri Districts, West Bengal

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Soil erosion is one of the most significant environmental problems that pose serious threats to most socioeconomic productivities in a watershed. The present work is an attempt to carry out a detailed study of identifying the most erosion-prone sub-watersheds in the Neora watershed. Neora watershed is located between 26°40'N to 27°10'N latitudes and 88°40'E to88°50'E longitudes and covers an area of approximately 295sq.km. The vulnerability of the Neora Sub-watersheds to soil erosion was analyzed using GIS based Watershed Morphometric Analysis and Prioritization Approach. SOI Topographical maps (1:50,000), TM and ETM+ Images of better resolution, SRTM (DEM) images and other litho-tectonic and structural maps are consulted as an integrated part of intensive field study. Neora watershed has been classified into thirteen sub-watersheds with codes NSW1, NSW2, KSW2, KSW1, MSW1, MSW2, NSW5, MSW3, MSW4, KSW3, NSW6, NSW3and NSW4 having geographical area from 3.76 sq.km to 51.86sq.km. The morphometric parameters i.e., drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow, relief ratio, gradient ratio, dissection index, form factor, basin shape, circulatory factor, compactness coefficient and elongation ratio were calculated that have either direct or inverse relationships with soil erodibility and have been used for prioritization of sub-watersheds. The prioritization of the sub-watersheds with respect to soil erosion vulnerability was carried out by assigning ranks to the individual parameters and a Composite Rating (CR) value was calculated. Watersheds with highest CR value were of low priority while those with lowest CR value were of high priority. Results revealed that four sub-watersheds (NSW1, NSW2, MSW1 and NSW3) had high vulnerability tendencies to soil erosion, while KSW1, MSW2, MSW3, MSW4 and NSW4 had moderate vulnerability.

22

Climate Change, Agricultural Land Use and Ecological Vulnerability of Chambal Ravines

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Climate Change is an emerging challenge to agricultural land use and ecological sustainability of the Chambal Ravines. Chambal basin comprises a large geographical area of 1,43,219sq.km. Environmentally vulnerable, the semi-arid Chambal ravines extend over a sizeable area of more than 18,000 sq.km. Yamuna is the longest tributary of miraculous Ganga and Chambal is the largest tributary of Yamuna. Even though Chambal is a tributary of Yamuna it carries more water than her mistress. Most of the Chambal water, however, is detoured outside the ravines. Chambal is a little less than 1,000 km. long and has a large network of its tributaries. The total catchment area of Chambal sub-basin is 1,43,219 sq.km. Chambal has a unique characteristic of coarse deposits down up to its lower reaches. This renders its ecosystem highly vulnerable to erosion and degradation. The lower Chambal flows over the Proterozoic Vindhyan strata while its upper reaches drain the Cretaceous Basalt of the Deccan Trap which is geomorphologically more resistant to erosion. The geomorphic origin of Chambal ravines dates back to late Pleistocene period. Chambal ravines cover an extensive geographical area of1.8million hectares. Their largest extent is in Bhind, Morena, Shivpur, Gwalior, Ujjain and Mandsaur districts of Madhya Pradesh. Because of the topographic constraints the Public Sector Canal irrigation works are not feasible and due to the lingering poverty, the private sector tube well and jet pump provisions are also limited. As a result of it, there is wide spread water scarcity for a sustainable land use in the ravines. The government plans to undertake a massive agricultural expansion in the ravines. Because Chambal Ravines are made up of coarse-grained sandy soils, they are highly vulnerable to severe soil erosion and land degradation. A continued levelling of these vulnerable ravines for agricultural expansion is a growing challenge of water availability. The levelled irrigated lands remain initially productive. Subsequently, their maintenance becomes cost-intensive to the marginal farmers. A growing number of enterprising farmers from Punjab and Haryana have resorted to water-intensive cropping scheme. This is leading to uncontrolled water mining in the water scarcity areas along with the pressures of Climate Change. The study is an attempt to seek a relationship between agricultural expansion and the geomorphic vulnerability of the ravines to degradation.

23

Morphometric Analysis for Resource Potential Assessment of River Tawi Sub-Watershed, Jammu

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For the quantitative assessment of hydrological properties and resource evaluation of drainage basin of river Tawi, morphometric analysis and land use/ land cover (LU/LC) has been attempted using geospatial techniques. Geospatial techniques like Remote Sensing (RS) and Geographic Information System (GIS) have emerged as powerful tool in natural resource

management. With the help of RS and GIS, five sub-watersheds are delineated and morphometric analysis is being done by linear parameters such as stream order, stream frequency and drainage density, shape parameters such as bifurcation ratio, form factor, circulatory ratio and elongation ratio and relief parameters such as slope, relief ratio and compactness coefficient. Linear imaging self-scanning sensor-IV (LISS IV) data has been used for preparing of LU/LC maps. Prioritized score is prepared on the basis of erodibility for morphometric parameters and area covered for LU/LC classes for each sub-watershed. The results showed that drainage pattern is of dendritic type and stream order varies from 1 to 4. SW2 is given high priority with least composite prioritized score of 2.37 whereas SW5 occupies last position in the priority scale with composite score of 3.49.

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