31ST ANNUAL CONFERENCE OF THE INDIAN INSTITUTE OF GEOMORPHOLOGISTS (IGI)

AND

NATIONAL SEMINAR ON APPLICATIONS OF GEOSPATIAL TECHNOLOGY IN GEOMORPHOLOGY AND ENVIRONMENT

NOVEMBER 12 – 14, 2019

ABSTRACT AND SOUVENIR VOLUME

Organised by

DEPARTMENT OF GEOGRAPHY & APPLIED GEOGRAPHY

(UGC-SAP DRS-II)

UNIVERSITY OF NORTH BENGAL

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NOVEMBER 12 – 14, 2019

Convener
Professor D. K. Mandal

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Organising Secretary
Professor Ranjan Roy

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Siliguri Jalpaiguri Development Authority (SJDA), Siliguri
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Vice-Chancellor
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Date: 22nd October, 2019

MESSAGE

I am extremely pleased and happy to note that the Department of Geography & Applied Geography, University of North Bengal is going to host the 31st Conference of the Indian Institute of Geomorphologists (IGI) during November 12-14, 2019. It is also highly delighting to observe that an Abstract-cum-souvenir volume will be published to memorialize the Conference.

I am sure that this will be a great occasion for the teachers, students and research scholars to exchange their views. I also hope that the Conference will come up with worthwhile ideas and open newer vistas for advanced research and teaching as well.

I extend my heartiest congratulations and warm greetings to the participants and organizers of the Conference.

I wish the ensuing 31st IGI Conference a grand success.

Dr. Subires Bhattacharyya
Vice-Chancellor

Prof. Deepak Kumar Mandal
Convener, 31st IGI Conference &
National Seminar
Department of Geography & Applied Geography
University of North Bengal

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MESSAGE

It is a pleasure to note that the Department of Geography and Applied Geography, University of North Bengal, is organizing 31st Annual Conference of the Indian Institute of Geomorphologists (IGI) from 12 to 14th November, 2019 at the University of North Bengal..

It is known that the theme of the Conference is "Application of Geospatial Technology in Geomorphology and Environment" which is very much relevant to the present day context. Applications of Geospatial technology have been emerged as a new tool for Geoscientists to deal with various geo-environmental issues and challenges, understandably the Conference will address various aspects relating to the geomorphic processes as well as the changing environmental conditions.

The deliberations of this conference will help in understanding the changing dynamics of geomorphic aspects and environmental problems as well as their solutions for appropriate planning for sustainable development.

The Faculty Members, Research Scholars, Students and Staff of the Department must be appreciated for their initiatives for organizing the 31st Conference of the Indian Institute of Geomorphologists (IGI).

Registrar

University of North Bengal

University of North Bengal

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Professor B.C.Paul
Dean, Faculty of Science

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Ref No: .....

Date: October 24, 2019

Message from Dean

PG Faculty of Science, University of North Bengal

It is a great pleasure to know that the Department of Geography & Applied Geography, University of North Bengal is hosting the 31st Conference of the Indian Institute of Geomorphologists (IGI) during November 12-14, 2019. The Department of Geography & Applied Geography is always vibrant in organizing various lectures/seminars with eminent Geographer of international reputation. North Bengal University is situated in the lap of the Himalaya, an ideal place of learning and disseminating knowledge. The faculties and the research scholars of the department are deeply engaged themselves in research in various domains of natural activity by man and nature, environments in the sub-Himalayan Tarai region and many other places. I am proud to mention here that the first Educational Excellence 2018 award from Zee 24 Ghanta given to NBU added a new folk in its cap. I am proud to mention here that in two consecutive years S. S. Bhatnagar award 2018 and 2019 were given to Dr. Parthasarathi Chakraborty in Chemical Science and Dr. Shankar Ghosh in Physical Science, who belong to North Bengal University. I believe that there is potentiality among our students. The focal theme of the conference is **Application of Geospatial Technology in Geomorphology and Environment**. I strongly believe that the topics to be discussed in the seminar will give an ample opportunity to students and researchers a good exposure for their enhancement of knowledge.

I wish a grand success of the International Conference.

Prof. (Dr.) B. C. Paul
Dean
Faculty of Science, NBU

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31st Annual Conference of the
Indian Institute of Geomorphologists (IGI) &
NATIONAL SEMINAR ON APPLICATIONS OF GEOSPATIAL TECHNOLOGY IN GEOMORPHOLOGY AND ENVIRONMENT

November 12-14, 2019

Organised by

DEPARTMENT OF GEOGRAPHY & APPLIED GEOGRAPHY

UNIVERSITY OF NORTH BENGAL

Accredited by NAAC with Grade A

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	Sangita Karmakar, Tapan Debnath

The University

The University of North Bengal was established by an Act of the Legislature of West Bengal in 1962 with the mission "to encourage and provide for instruction for teaching, training and research in various branches of learning and course of study; to promote advancement and dissemination of knowledge and learning and to extend higher education to meet the growing needs of society."

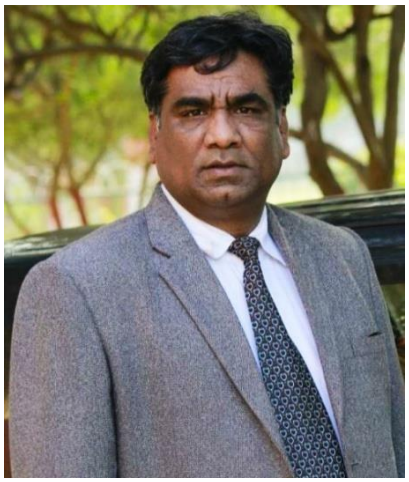
The University of North Bengal, since its inception in 1962, has been fulfilling the objectives of imparting higher education and research to the people of this socio-economically backward area of the country. With the global advancement and requirements in the arena of higher education and research, the University has shouldered the responsibility of dissemination of knowledge by judicious expansion of its role in advanced, non-conventional, applied and job-oriented fields keeping the quality of education at par with global standards at low cost. The University has taken initiatives in qualitative growth by way of achieving excellence. The Departments are well equipped with research programmes from various agencies and have received academic distinctions and recognitions. The University has been re-accredited by the National Assessment and Accreditation Council (NAAC) as an 'A' grade University in 2017.

The Department

The Department of Geography & Applied Geography North Bengal University started its journey in the year 1962 along with the University under the Headship of Prof. Sujon Bandhab Chatterjee. The Department offers Post Graduate, M. Phil and Ph. D Courses and offers specializations on Applied Pedology, Cartography, Fluvial Geomorphology, Population Geography and Urban Geography. The subject is also offered in the Jalpaiguri Campus since 2013-2014 session. The Department has paid due attention to different emerging & application oriented subjects like Geographical Information System, Remote Sensing & Disaster Management. Semester System has been introduced in 2008-09 session and CBCS in 2017-18 session. The Department has a Centre for Studies in Climate Change, which has been recording daily weather information since 2000 and providing the society need-based services as the data is disseminated to students, research scholars, government and private agencies. The Department of Geography & Applied Geography, NBU has successfully completed UGC-SAP DRS-I programme (2009-2013) and is now carrying out UGC-SAP DRS-II programme (2016-2021). The faculties are actively involved in a number of research and consultative research projects. Presently the department is running with 4 Professors, 1 Associate Professor and 7 Assistant Professors under the Headship of Prof. Subir Sarkar.

ANNUAL REPORT

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 convenership in the Department of Geography, University of Allahabad wherein more than 200 delegates from European Countries and India participated and presented their research papers. After long discussion for two days regarding the name and logo of the association, its goals and objectives, mode of formation, constitution etc. were finally decided to call a general house meeting of all the delegates on January 19, 1987 to finalise the modalities. Ultimately the general house agreed that the name and logo should be Indian Institute of Geomorphologists and IGI respectively. The following objectives were formulated-

1. To bring the entire earth scientist dealing with geomorphology and allied disciplines on a common platform under the banner of IGI.
2. To hold annual conferences in different places of the country.
3. To publish a research journal entitled Indian Journal of Geomorphology now it is Journal of Indian Geomorphology.
4. To coordinate research being carried out on geomorphology and allied disciplines in different universities and laboratories in the country,
5. To encourage young research scholars doing research in geomorphology by giving awards and certificates.
6. 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 29th annual conferences of IGI with different focal themes have been organised at different places important being Andhra University, Waltare (First, 1988); Rajasthan University, Jaipur (twice); Poona University (twice); North Eastern Hill University Shillong (twice), North Bengal University, Darjeeling (2000); 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 Vigyan 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 in 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, fourthone 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 researchfindings 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 of 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, Convener, 9th ICG and Professor V. S. Kale, Professor Sunando Bandopadhyay and entire IGI family for making the event successful. The 30th conference of IGI was held in the Department of Geography, Jamia Millia Islamia University, Delhi during 03-05 October,2018

The publication of Journal of Indian Geomorphology is smooth and updated. The last volume was releasedin the 30th IGI conference. The family of IGI has grown rapidly with its life members exceeded to 585. It has been observed that young geomorphologists are coming very fast and they are doing quality research in the field of geomorphology. All the life members have contributed much in the growth and progress of this organization.I wish the 31st IGI conference a grand success under the dynamic leadership of Professor Deepak Kumar Mandal(Convener) and Professor Ranjan Roy (Organizing Secretary), and all the faculties and the students ofDepartment of Geography and Applied Geography, North Bengal University. I take this opportunity to extenda very warm welcome to all the delegates coming from various parts of the country.

I wish the conference a grand success.

Prof. A. R. Siddiqui
Secretary
GeneralIndian Institute of
Geomorphologists (IGI)
Department of
GeographyUniversity
of Allahabad

PRESIDENTIAL ADDRESS AT THE 31ST ANNUAL CONFERENCE OF THE INDIAN INSTITUTE OF GEOMORPHOLOGISTS (IGI) & NATIONAL SEMINAR ON 'GEOSPATIAL TECHNOLOGY IN GEOMORPHOLOGY AND ENVIRONMENT' HELD DURING 12-14 NOVEMBER, 2019 AT THE UNIVERSITY OF NORTH BENGAL, DARJEELING

Subir SARKAR
President, IGI

Respected Dr. Subires Bhattacharya, Hon'ble Vice Chancellor, University of North Bengal; Prof. Bikash Chandra Paul, Dean, Faculty of Sciences, Dr. Dilip Kumar Sarkar, Registrar, University of North Bengal; Executive Council and life members of the Indian Institute of Geomorphologists, colleagues, scholars, students, ladies and gentlemen.

At the outset, I would like to thank the Executive Committee and members of the Indian Institute of Geomorphologists who elected me as the President, IGI for 2018-19. It is indeed a matter of great honor for me to work for the Institute during the last one year. I am very glad to see three generations of Geomorphologists who have gathered in this conference to share their scientific achievements.

The IGI has been working since 1987 to promote research and development in the field of Indian Geomorphology. This is the only organization of the country of such kind. A group of Indian Geomorphologists formed this Organization in Allahabad University leaving responsibility on Prof. Savindra Singh to materialize the activities of the Organization. On its journey for past three decades the Indian Institute of Geomorphologists has organized the 9th International Conference on Geomorphology in November, 2017 at the Vigyan Bhavan, New Delhi, Geomorphologists from 47 countries had participated the conference.

Presently, Indian Institute of Geomorphologists (IGI) is an affiliating organization of the International Association of Geomorphologists. We are very happy that one of the Vice Presidents of the International Association of Geomorphologists is from our country and is in our midst today. I am happy to note that today Indian Institute of Geomorphologists is well established in the International platform. The responsibility of our future generation is to carry forward these activities.

To share a few of my observations over the decades, however, I am a bit apprehensive that the subject is gradually being polarized in few pockets of the country. I know many researchers are doing their research work individually, publishing their research papers, bypassing the Indian platform and journal as well. I firmly believe that it should start from our own organization where the knowledge and input given by the senior Geomorhologists of the country would help in improving the quality of our research work. The reason why I am making such a comment is because I personally feel the face of the IGI is the Journal of Indian Geomorphology which is suffering from lack of good papers and timely reviews.

Traditionally, Geomorphologists used to present their views and theories based on their theoretical ideas supplemented by field observations. This was continued till 1950s and Geomorphologists used to follow cyclic or non-cyclic concepts. The content of the subject have been shifted from cyclic to physically based models and quantitative mechanistic models. Geomorphologists have become more inclined to process geomorphology and detailed field investigation. Since 1970's the trends have changed from process geomorphology to applied geomorphology. Intensive field investigations had been more important in this phase.

Traditional equipments used in geomorphic field investigation normally take long time to prepare the map and get results. Gradually through aerial photographs we started to prepare the detailed base map, followed by satellite images, computers, remote sensing and GIS tools, GPS, Total Station, LIDER, UAV and so on. Every moment, the technology is improving to enhance accuracy and minimize physical labor to achieve the desire goals. Based on these technologies modern geomorphological research is becoming more application oriented.

Today, geomorphological research is inextricably linked with geospatial technology. Driven by rapid technological advances of remote sensing, geodesy, photogrammetry, computer science, and GIS, the application of analysis tools using digital information on the land surface have revolutionized quantitative geomorphological research. In the last three decades, geospatial technology has increasingly influenced various fields of geomorphology.

GIS tools support and enable many upfront research fields from the quantitative analysis of landforms to process modeling, the investigation of form–process interrelations and linkages to climate and environmental conditions. Furthermore, process and form modeling, statistical analysis and regionalization of field data as well as graphical visualization and map creation are key features of geospatial technology applied in geomorphology.

Since the late 1990s, there has been a shift to increasing use of GIS in geomorphological studies. This development is strongly related to advances in computer science, remote sensing and photogrammetric techniques. In particular, the availability of global digital terrain datasets has boosted applications of geospatial technology in research of land surface and process analysis. As a consequence, the use of GIS tools in geomorphological analysis is becoming increasingly popular.

Applications of GIS in geomorphology span from pure visualization approaches, landform classification, land surface and hydrological analysis, process and erosion modeling, topographic change detection to hazard susceptibility modeling. While many applications focusing on land surface analysis, change detection, or hazard modeling are performed within the specific GIS software, some approaches use statistical software, or special modeling software to perform geospatial analysis. Many useful GIS modeling approaches have been developed in the field of natural hazards, rock-falls, landslides, hydro-models, floods, avalanches, or soil erosion share inherent characteristics of hazards such as magnitude or spatial extension and depend strongly on slope angle, aspect, or other parameters which can be ideally integrated and displayed in GIS environments.

Following the large scale application of geospatial technologies the present trend shows that many Geomorphologists are concentrating more on computers instead of paying attention to geomorphic knowledge domain and field measurements. Geospatial technology can help us to produce almost accurate maps and features, but for understanding the evolutionary and deformation processes and further implications, intensive field investigation and verification is necessary. I would therefore request the young geomorphologist to do extensive field based study as it is the true core of the subject. Please do not base your research based only on such technology; but let the technology be a tool to enhance your findings in the field.

Otherwise, the real danger is geospatial technology will not only begin to modify the conceptual frame of geomorphic research as can be perceived today, but it will also started to take control over the domain knowledge. I hope and request the young Geomorphologists to come up to take the challenge of promoting Geomorphology using geospatial technologies judiciously.

With these few words I would like to thank the Hon'ble Vice Chancellor and Dean, Faculty of Sciences, Registrar, University of North Bengal, dignitaries, Executive Council and other Members of the IGI, participants in this august gathering to have given me an opportunity to share my ideas and listen to me patiently. I thank my colleagues; research scholars, office staffs and students of the Department of Geography & Applied Geography, University of North Bengal who have worked hard to organize this conference.

Thank you.

Professor S. R. Basu Memorial Lecture,

2019MAPPING OF THE SARASWATI RIVER SYSTEM: A SHORT OVERVIEW AND NEW FINDINGS

Amal KAR

Kolkata
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Saraswati River is mentioned in the Rig Veda as the best of rivers (Naditame), and the most powerful among the rivers (Nadinam asurya), having seven major tributaries from the Himalayas, and flowing independently to the ocean. Subsequently, the Yadurveda mentioned it as having five major tributaries and five major distributaries.The Mahabharata mentioned the river as having disappeared at Vinasana in the desert, and then reappearing at Chamasodbheda, Sirodbheda and Nagodbheda. The Ramayana mentioned three Saraswati rivers as one crossedthe Yamuna towards the Sutlej: the Prachi Saraswati (the Sursooti in the Rennell's 1788 map), the Saradanda Saraswati (or the Markanda) and the Ikshumati Saraswati (or the Ghaggar; O.P. Bharadwaj, 1986). Modern scientific studies to map the Saraswati as flowing independent of the Indus into the Arabian Sea, began in the 18th Century. Our scrutiny of available old maps now reveals that such a river was first mapped by Herman Mollin 1715. Subsequent editions of the map and its copies by other map-makers named the river as the Chaul, Sitmegus, Dena, Diemad, etc., which refer to the Sutlej. The first map of a Himalayan river, the 'Sursooty', joined by the 'Gaggar'/'Kenkar' River in the Sub-Himalayan Plains, and then getting obliterated but leaving traces as a 'supposed course of the Gaggar River' through the western part of Thar Desert to the Arabian Sea, was published in 1788 by James Rennell, the first Surveyor General of the East India Company, and his team of unknown route surveyors. All such maps, however, suffered from high inaccuracy of coordinates. Since the early19th Century the Survey of India (SoI) started publishing systematically a series of detailed maps of western India, which not only depicted the dry bed of the Ghaggar, Chautang and Naiwal, but also many abandoned and shifted courses of the rivers between the Yamuna and the Indus. A summarised view is available in their 1885 Canal Map of India. Based on those detailed maps and field observations, C.F. Oldham (1874, 1893), a medicalSurgeon, first prepared a map of the Vedic Saraswati River through the dry valley of the Ghaggar, and then through the disjointed segments of the Wahind, the Hakra and the Nara to the Great Rann, and then to the ArabianSea through the Kori Creek. The name, Saraswati, for the flow path through the Ghaggar valley was earlier suggested by a French Geographer, Vivien Saint Martin (1855) in his book describing the Vedic river system, but his map (1857) wrongly depicted the river joining the Indus above Sukkur. Oldham's findings have led to many exciting research on the Saraswati river system.

The first satellite-based map of the palaeochannels of the Saraswati River system in the Punjab Plains and Thar Desert was prepared by Ghose, Kar and Husain (1979), which interpreted the signatures on the then- available ERTS-1 satellite images. This map and another by Kar and Ghose (1984), based on Landsat TM and other remote sensing data, showed several very old south-flowing courses of the proto-Saraswati and the proto- Drishadvati through Thar Desert, as well as many former courses of the Sutlej on its alluvial fan. The studies were based on the premises that a large stream would leave imprints as alluvium with relatively shallow aquifer and vegetation banding, or as carbonate- and sulphate-rich evaporites along narrow bands, all of which could bevisually interpreted from the different satellite wavelength bands with adequate ground-truthing. The Ghose et al. map (1979) was followed immediately by a map by ISRO (Yashpal et al., 1980), which unfortunately did not provide any new information. Remote sensing studies since then provided many finer details of palaeochannels along the desert margin.

Recently the author carried out band ratio analysis of the ASTER data of Thar Desert to map the distributionof evaporites as sulfates and carbonates, and thermal index mapping for moist area discrimination. Additionally, the DEM data from SRTM, ALOS-World3D and CartoDEM sensors were analysed to filter out the remnants ofpalaeo-valleys in the dune-infested areas. The mapped details were verified from standard FCCs of the large- scale Sentinel-2 and Landsat ETM+ bands. The DEM data for the vast Punjab Plains and adjoining desert margin areas were processed to identify the alluvial scarps and major lineaments, as well as to distinguish the palaeochannels from the modern canals.

The results not only confirmed our previously-drawn south- and southwest-flowing courses of the Himalayan river system, but also revealed some hitherto-unmarked Saraswati palaeochannels through the desert. Despite the thick aeolian sand cover some palaeo-valleys could be found to control the dune morphologies. The alluvium, the evaporites and the groundwater left by the river system are now the precious resources that the inhabitants are using for millennia. n the Punjab Plains most palaeochannels occur on an old terrace surface (the Bangar), with a gentle southward slope. The lower surface (Khadar), at 2-5 m below the Bangar, contains the present-day channels of the large streams. As the streams meander across the Khadar and cut back the Bangar scarp in the Doabs, the palaeochannels become the victims. Presently the Sutlej Fan has the best-preserved palaeochannels because the river, on reaching the sub-Himalayan plain, takes a sharp westward turn and lies in an incised valley. The other fan surfaces have been mostly cut down to the level of the Khadar. The terracing was possibly triggered by high water influxes after the Last Glacial Maximum, especially during the early Holocene monsoon strengthening (~10-8 ka), which not only led to several channel shifting but also incision of some valleys that left many palaeochannels' confluences with the new incised valleys as 'hanging'. During the Harappan period the Ghaggar was reduced to a small misfit stream in a wide valley, as the Sutlej had already shifted away. This helped hundreds of ancient settlements to flourish in the valley. Provided the Rig Veda was composed around 6 Ka, its description of a vast, ocean-like expanse of the Saraswati River was probably meant for a segment of the Ghaggar-Hakra valley downstream of Anupgarh-Marot, roughly in the vicinity of Ganweriwala-Uch, where the Sutlej might have its erstwhile confluence with the Ravi, Beas and Chenab, receiving the additional snow-fed discharge from the Jhelum, and the combined flow getting chennelised through the Hakra that was still receiving the perennial flow from the Ghaggar, Chautang, etc., in the east. In other words, the Satadru of the Rig Veda played a crucial role in the maintenance of the Saraswati River valley. As and when the Satadru shifted away from a segment of the Saraswati valley through a Naiwal (Marudvriddha in the Veda), that segment became a misfit stream in a wide valley. The process continued over a long period of time and in different time steps, till the Satadru totally abandoned the Ghaggar-Hakra valley of the Saraswati, but the river survived as the Nara. Given the swinging behaviour of the Himalayan streams on their alluvial fans that allows re-occupation of the old courses, there is every chance that the Ghaggar dry valley along the Sutlej Fan margin will again get the Sutlej discharge sometime in the future. After all, the periods of one civilization or two are but some small time-steps in the eternity of a river system's life span!

Plenary Lecture 1

CLIMATE CHANGE WITH REFERENCE TO INDIA: ARE WE PREPARED FOR IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL?

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The biggest story in Environmental Science today is Global Warming and Climate Change. Newspapers, Media and various reports have been creating a great deal of anxiety about our future because of global warming and the resultant climate change. It is being projected that climate is changing at a rapid pace because of human activities. However, supremacy of Nature is still evident. Global temperature is increasing that is likely to cause devastation.

Climate change is a dynamic phenomenon. It has been changing ever since the Earth was born about 4.5 billion years ago. Sometimes the change has evolved time periods of tens of thousands years to a few thousand or even hundred years. There are also records of climate change at a much faster rate in a few decades Climate changes during the last two centuries are evident that over the last century the average temperature has increased about 0.60^{o}C around the world. A Closer look at 19th and 20th century temperature record shows three distinct trends.

1. Warming trend – Late 19th century till 1940
2. Cooling trend – 1940 until 1970's
3. Warming trend – 1976 onwards

The paper has the following objectives:

1. To analysis the trend of climate change at the National Level
2. The study of Temporal variation and rainfall variation in Rajasthan
3. To analysis at what extent this change in climate effect the agriculture

India experienced severe drought during 1987, 2002 and 2009 with deficient monsoon rainfall. Heat wave condition was experience in coastal areas of Andhra Pradesh in 2003. In 2005 India experienced very heat wave conditions in June over northern eastern parts. Mumbai experienced unprecedented rainfall of 94 cm within a period of 8 hours on 26 July, 2005. Heavy flooding is also recorded in Gujarat. India experienced heavy rainfall in August 2006 over north-west India specially Barmer in Rajasthan desert but in 2015 monsoon has been very weak throughout India. However in 2016, there is experienced normal, below normal and heavy rain in western Rajasthan. 2019 monsoon in India prolonged for usually a longer period till the end of October.

Climate change projections made for India indicate an overall increase in temperature by 1^{o} to 4^{o}C and precipitation by 9-16% towards 2050s (Krishna Kumar et al., 2011). However, different regions are expected to experience differential change in the amount of rainfall that is likely to be received in the coming decades. Another significant aspect of climate change is the increase in the frequency of occurrence of extreme events such as droughts, floods and cyclones.

All of these expected changes will have adverse impacts on climate sensitive sectors such as agriculture, forest and coastal ecosystems and also on availability of water for different uses and on human health. Historical trends also show a noticeable increase in mean temperature in the country though there is no discernible trend in the rainfall during the last several decades. However, regional variation in behaviour of monsoon rainfall was observed over the years.

Among India's population of 1.25 billion people, about 68% are directly or indirectly involved in the agricultural sector. This sector is particularly vulnerable to present day climate variability, including multiple years of low and erratic rainfall. Scenario generated by Global Circulation Models (GCM) shows that India could experience warms and wetter conditions as a result of climate change particularly, if the summer monsoon becomes more intense. Increase rates of evapotranspiration due to higher temperatures may offset the increased precipitation, fading to negative impacts on soil moistures. ICAR launched a Network on climate change and agriculture in 2004 to study impact assessment, adaptation and mitigation options in India. A 1^{o}C increase many reduce yields of wheat, soybean, mustard, ground nut and potato by 3-7%. Productivity of most crops are likely to decrease only marginally by 2020 but 10-40% by 2100. Milk production in India is declining.

Climate change is likely to reduce yields of most crops in long-term. In short term effects may be small (preliminary results, better field data and models needed). Increased climatic variability could cause significant fluctuations in production even in short-terms. Adaptation strategies can help minimize negative impacts. These need greater research, policy and financial support. Costs of adaptation are less understood but likely to be high; cost of inaction could be even higher. Adaptation practices take time to become effective. A crop variety, e.g. takes 10-20 yrs. to develop. Need to act now effectively. The present paper shows the change in climate in term of rainfall, flood and drought condition and their effect on the agricultural development in India specially in Rajasthan

lenary Lecture 2

A COMPRESSED GLOBE: EASE IN MEASUREMENT, ANALYSIS AND VISUALIZATION

Milap C. Sharma

CSRD, JNU, New Delhi

with: Ishwar Singh, Rakesh Arya, Sanjay Deswal, Syed Umer Latief, Pritam Chand, Rakesh Saini, Parvindra Kumar, Pawan Kumar, Satya Prakash, Suresh Das, Sandeep Tanu Mandal, Ishita Manna, Manasi Devnath, Elora Chakraborty, Preeti Singh

The World has shrunk!!! It has shrunk to a size that it fits into our palm today. Each feature is on our finger tips. Everything is measurable and manageable, to zoom into, to glace through, and to quantify. Geography has reached the living rooms, believe it or not. You can peep into the bedrooms as well. Each tree is my spatial data. Each canopy is a new vista to detect miniscule changes. Geography has blossomed, of late!!! Difficulties in gathering spatial data thus has become a child's play. Terrain analysis using topographical maps has been one of the tedious and time consuming exercise that we all know of. A linear analysis using the basic geographical tool was a month's work!!! Terrain took few more months not so long ago. But here is the boon; the DEM from better than 1:50,000 scale, at 15 to 30 meters resolution. And the resolutions are improving by each day, and getting better. Thanks to internet and our *Google Maharaj*!!! The Change detection of the world landscape and atmosphere is just a click of effort. MODIS or GRAS, satellite data has revolutionized the global surface temperature analysis. Same is true with hydrosphere now. In our opinion, ground knowledge and control is not only Important but Paramount while attempting to use other tools. Therefore, a Geographer is fully equipped with Such a Knowledge and Control, having competence in measurement of space and time.

It is in this context, we provide a comprehensive analysis of the Himalayan Cryosphere, terrain and climatic parameters using variety of field and geomatic tools for spatial analysis. The immense areal extent and highly inaccessible terrain makes it difficult to carryout field based studies of the Himalayan cryosphere. To make it perceptible and applied, contemporary global warming, climate variability, and associated societal impacts and for a better assessment of regional and global forcing factors, it is important to characterize and quantify past glacial changes. We have accomplished this exercise by limited field mapping, and processing remotely sensed data. We have assessed the glaciers of Sikkim in the East, Uttarakhand and Himachal in the west, and Karakoram in the Trans-Himalaya. This has been further strengthened using climatic elements as well as evaluation of the related hazards. In a nutshell, our studies using variety of techniques, reveal a perceptible decrease in the glacier cover, spanning over last few centuries and millennial. This presentation would cover the geospatial analysis, with elaborate field records of the cryosphere.

Plenary Lecture 3

LAND FORMS AND EQUIVALENCE STUDY IN GEOMORPHOLOGY - A CASE STUDY
THE LAKE DISTRICT AND NORTH WALES LOOK LIKE AMBOOTIA VALLEY, KURSEONG, WEST BENGAL OR VICE VERSA

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Nature is known to be supreme and man has realized that from the early age of human civilization. The society has accepted natural phenomenon and happenings with great awe. Now Art is describing the Nature through various forms whereas Science is trying to interpret the various processes and Technology at the crossroad, is trying to improve the quality of human achievements through Man-Machine interactions. In this context "Application of Geospatial Technology in Geomorphology and Environment" may be an example.

The word Uncertainty synonymous in spirit with Nature is fascinating and need long hours of debate, argument and arriving at a general agreement on the products and the processes that happened long before(may be in prehistoric time) or going to happen in future. This has a very negative impact too on the society which often tries to mask the scientific outlook and leading to unfounded predictions and exploitations. Science by definition is intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through Observation and Experiment. Some describe it a branch of Knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws of the physical or material world gained through observation and experimentation. Science is also described as the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence. Scientific methodology that follows the pathway i.e. Evidence through Experiment and/or Observation as benchmarks for testing hypotheses and ultimate acceptance. Thus Observation leading to Interpretation and establishing a phenomenon called Prediction is almost a mirror image of the procedural approach where Description leading towards Diagnosis and Prescription mode at the end steers almost all the scientific investigations and acts. Repeatability and reproducibility are the fundamental conditions of Science where reasoning and logic is the frame and Canvas is the experimental arena. Many of the age old natural processes cannot be exactly reproduced but can be authenticated with modern equivalents.

Geospatial Technology has basically evolved from Remote Sensing concept and is a tool or set of tools with which GPS and Imagery Data can be pulled, processed and presented in an interactive and interpretative manner. Once data generated through remote sensing techniques can be turned into required format and processing and visual presentation is accurate, fast and without any bias. But this is one side of the coin. Can Geomorphologic studies survive without hand on field studies? Geomorphology is a concept and embedded domain knowledge which needs to be structured, validated and upgraded through reasoning and by means of Comparative Analyses, Multiple Simulations and Equivalence Studies at the cost of rigorous field studies. Later, it could be Visual and Pattern Matching, Statistical Weightage and determining susceptibility factors including Heuristics. A heuristic technique, often called simply a heuristic, is any approach to problem solving, learning, or discovery that employs a practical method not guaranteed to be optimal or perfect, but sufficient for the immediate goals. While working for last few years in Snowdonia and Lake District areas of United Kingdom, and also spending long months of the decade in our local home close to Ambootia Valley in Kurseong, India, a few interesting observations on three distant locations were evident. A natural quest in mind arose and in many ways, a few striking similarities between genetically established geomorphology of valleys of undoubted glacial and periglacial origin in UK and debatable landslide origin of Ambootia valley of Kurseong became an issue. So the venture of pursuing studies on Land forms and Equivalence Study in Geomorphology - a case study started. Searching possible literatures and remarkable works of eminent geomorphologists of our country and abroad on the Ambootia valley area, it is noted where they opined "Here, broad valley with ten-aces have also been identified which is perhaps the product of massive aggradations due to major landslide in and around Ambootia (Starkel et al, 2000). Accordingly "The Ambootia landslide developed as a result of linear erosion and was called a "landslide valley" (Starkel, 2017)". They further described "The Ambootia landslide developed at the southern edge of the Ambootia TE on the left side of the Balasan River Valley, dissecting the W-E marginal ridge rising 1200–1800 m above sea level.

The Polish researchers observing Ambootia (Froehlich et al. 1991, 1992) called it a "landslide valley" because it not only has the shape of a valley but its evolution is also the product of gravitational slope processes acting in conjunction with linear down cutting. The surrounding area is formed of the Darjeeling group of metamorphic rocks comprising Gneiss, Mica Schist and Chlorite Schist of various resistance, inclined 30–50º NNW. The regolith is 1–5 m thick in the vicinity of the landslide, with one exception.

The loose deposits are up to 30 m thick within the wide colluvial fan zone (elevation: 900–950 m) and consist of gravel and stony layers, which alternate with impermeable Silt and even Clay horizons. Wide valleys are found along the extreme southern part of the study area."(Starkel, 2017). If Ambootia landslide valley is a common phenomenon then the equivalence study must have found such feature elsewhere, otherwise it shall be regarded as the solo example so far. "Massive aggradations due to major landslide in and around Ambootia" (op. Cit.2000) needs strong perception since aggradations (or alluviation) is the term used for the increase in land elevation, typically in a river system and due to the deposition of sediment. "The geomorphic configuration of this hilly tract is the joint product of geologic foundation and fluvial processes; although slope-wash, in particular mass-movements and related phenomena play a significant role in the final shaping of the landform. The region is characterized by a myriad of ridges and valleys because of the spurs ramifying into lateral spurs which give off lesser ones and these in turn cut the terrain into ridges and valleys, creating a mosaic of micro-topographical units" (Cajee, 2018). If we agree that the majority of the land forms in this region are product of ephemeral gully erosion and mass wasting by fluvial processes, then occurrence of flat valleys or shape like Ambootia is an enigma. Could the flat valley floor be created by landslide dynamics? One might question the spatial scale of the form and the answer is possibly lying with the eminent Geomorphologists.

The question of lookalike valleys of North Wales and Scotland and Ambootia valley of Darjeeling Himalayas has a few striking features of a possible inherent and concealed genetic linkage. The Ambootia valley situated on the upper reaches is cut across at its toe by a river (Balasan) with a notch like valley floor several hundred meters below and there are a few remnant and sporadic landslide scars on the north and north-north east side like a dissected girdle. The accountability of such a nearly flat floor with pedestal blocks of stone masses and abundant talus or scree like deposits of mound or hummocky shape occurring especially on the northern fringe and almost throughout the elongation of the valley and exhibiting asymmetric wavy topography which is now unique site of tea plantation, remain untold. The observations made by the earlier workers can be substantially accepted but there are a few more issues which need to be explored like "What the valley floor is made up of (either bore hole data and or cutting section mapping can answer); Why there are large boulders and faceted pebbles strewed around; Can bedrock be hit in the middle of the valley and at what depth etc. We believe the present land forms are the outcome of geomorphic processes operating since latest Pleistocene (~70,000-11,600 years ago) and Holocene (last 11,600 years) and precise age dating with the advent of Optically Stimulated Luminescence (OSL) and Terrestrial Cosmogenic Nuclide (TCN) surface exposure dating, it has been made possible to establish the chronological status of some of the successive valley deposits of Tibet and Nepal (Owen, 2010 and Owen et al., 2014). Now the most pragmatic approach is to employ a team of scientific soldiers, amply equipped with sound geological knowledge and who can undertake the rigorous field work and comparative analysis of parts of mountainous terrain and can also exercise the intellectual freedom through keen Observations and Experimentations and solve the riddle of the past.

Plenary Lecture 4

A POSTMODERNIST VIEW ON PARADIGM SHIFT AND FASHION IN GEOMORPHOLOGY

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Geomorphology and its related disciplines are complex composites of the basic sciences - physics, chemistry, and biology that have certainly developed through paradigm definition and replacement. As a distinctive discipline, geomorphology emerged quite recently. Hence, domination by observationalists was short but observation has extended into succeeding periods. Most pre-Darwinian examples of geomorphic observationalists are best distinguished as geologists, geographers, or naturalists. Geomorphology is a philosophically sedate discipline representing the progression of Kuhn's 'normal' science. Sperber (1990) applied the concept of 'fashion change' to explain one means of controlling the developments and directions of geomorphology. He contends that changes in the goals, subjects, methods, philosophies, or its practice can be attributed to the emergence of an opinion (or fashion) leader, pointing toward a different path - setting out the new fashion. Thus, the fashion process relies upon the fashion dudes to advance their disciplines.

Aristotle (384-322 BC), the Greek philosopher and polymath was the first to propose the concept of 'hydrological cycle': *the rivers derive their discharge in part from the rain soaking into the ground*, only to be proved by Perrault (1674) who measured the discharge of the Seine and showed it was comparable to the rainfall over the watershed. Perhaps, it was Ibn-Sina (980-1037), the Arabian Scholar who was the first to explain the origin of the mountains of two distinct classes as:

1. those produced by '*the uplifting of the ground by earthquakes*' and
2. those resulting from '*the effects of running water and wind in hollowing out valleys in soft rocks*'.

In the 4 - volume magnum opus, *The Discourses of the Brothers of Purity* by a group of unknown Arabian scholars, we find reference to what we call erosion and transportation by streams and wind, weathering and even the idea of peneplanation (Said, 1950). During the period between15th-17th Century, landforms were explained largely in terms of the prevailing philosophy of *catastrophism*, i.e., the surface features of the earth are the results of '*violent cataclysms*' that produced sudden and marked changes on the earth's surface. It was the *earliest paradigm* in earth science that prevailed for a long long period.

Leonardo da Vinci (1452-1519) noted the disastrous action of rivers in the Alps and, from observations in a glass flume and of natural rivers, he discussed eddies, variable velocity distribution and the relation of depth and width to velocity that led to the foundation of the *concept of resistance* and the *principle of continuity*. Gugleimini (1655-1710) was the pioneer in founding the science of hydraulics of rivers: *the relation of slope and depth of flow to scour and deposition in rivers and espoused the concept of equilibrium of force and resistance in river action*. The other notable thinkers in the 18th Century were the Frenchmen Buffon (1707-1788), Guetthard (1715-1786) and Desmarest (172-1815), the Italian, Targione Tozetti (1712-1784) and the Swiss De Saussure (1740-1799). Their works paved the way for the development of the *2nd paradigm* in earth science: *present is the key to the past* and the doctrine of *uniformitarianism* that replaced *catastrophism*. It was probably the first *paradigm shift* that happened in earth science. Uniformitarianism was, in fact enunciated by Hutton (1785), beautifully restated by John Playfair (1802) in his book *'Illustrations of the Huttonan Theory of the Earth'* and popularised by Sir Charles Lyell (1797-1875) in the numerous editions of this book, *Principles of Geology* (1830-33). The concept of a river system and its geomorphic significance has never ever been better explained than by John Playfair. The impact was enormous and still going strong.

As a distinctive discipline, geomorphology emerged quite recently. Hence, domination by the observationalists was for a brief period. In the pre-Darwinian period, the geomorphic observationalists are best distinguished as geologists, geographers, or naturalists. The first example is Alexander von Humboldt (1769 – 1859), a Prussian explorer with interests in geology, mineralogy, geophysics, climatology, and botany, who helped found *physical geography* and was a major stimulus for explorations of the American West. Another is Louis Agassiz (1840), a dedicated follower of Humboldt, was a Swiss zoologist and paleontologist – and later was an antievolutionist, who, in 1837, proposed that *'a great ice period'* had occurred prior to the uplift of the Alps. In 1846 he joined Harvard University and studied glacial landscape development, and founded the subdisciplines of glacial and quaternary geology and glacial geomorphology.

John Wesley Powell (1875), the 2nd Director of USGS recognized structural control on stream courses, stating that folded structures tend to divert water around them. He classified landforms and differentiated between valleys that trend perpendicular to the strike and those that trend parallel to rock layers. Based on the Colorado River expeditions, he defined *consequent, antecedent,* and *superimposed* channels. Clarence E Dutton (1841-1912), a companion of Powell, extended his ideas, such as the deduction that the levelling of the landscape is a product of river-bottom corrasion and slope weathering and attributed the origin of the Colorado plateau through the epoch of the great denudation applying the concept of base level. The great heroes of the American 'school of geomorphology' during the period 1875-1900 were Major J. W. Powell (1834-1902), G. K. Gilbert (1843-1918) and C. E. Dutton (1841- 1912). They, in fact, collectively laid the groundwork upon which W. M. Davis (1915) built his '*concept of a geomorphic cycle*', the 1st *paradigm in geomorphology*.

Identity for geomorphology actually occurred with William Morris Davis, a disciple of Darwin. He wrote papers, best expressed in '*The geographical cycle*' (Davis 1899), that treated landforms as evolutionary and time-dependent landscape features. He patterned his model after Darwin's concept of evolution, and therefore subscribed to uniformitarianism. The *'sequence in the developmental changes of landforms is, in its own way, as systematic as the sequence of changes found in the more evident development of organic forms*'. Earlier, Davis (1883) suggested that the 'many pre-existent streams in each (Appalachian) river-basin concentrated their water in a single channel of overflow, and that this one channel survives - a fine example of '*natural selection*'. Interestingly, Davis's idea was vaguely glimpsed by Desmarest in the 18th Century and was most appealing due to its *simplicity, seeming applicability to prediction and interpretation, presentation,* and *rationality*.

Davis – the great definer, analyst and systematizer, was responsible for establishment of the Association of American Geographers in 1904 (Chorley et al. 1973). The impact on geomorphology of W. M. Davis (1850-1934) was greater than any other single man. The Davisian Cycle of Erosion gained rapid favour as the dominant *paradigm* of the early 20th Century. In the introduction to his stylish book on geomorphology in 1942, O.D. von Engeln of Cornell University presented a portrait of W.M. Davis above a caption entitled ''The Master.'' On the facing page was a portrait of Walther Penck, ''The Challenger.'' It represented in the most beautiful way possible to recognize the geomorphology's then dominant paradigm, and of the controversy raging over whether Davisian peneplanation or Penckian slope retreat was responsible for landscape denudation. However, the impact of uniformitarianism was so deep and comprehensive a concept that it was more than just a paradigm; rather it was a '*superparadigm*' and it was not replaced by this Davisian cycle of erosion. Hence, this cannot be regarded as a *paradigm shift*.

Through the mid-20th Century, most geomorphologists practiced 'normal science' of Davis's cycle of erosion, but alternative viewpoints in a context of time-dependency were expressed by Walther Penck (1924) and by Lester King in the 1950s and 1960s. Penck in his '*Die Morphologische Analyse*' approached the study of landforms from 'geologist's perspective' and described knickpunkte and piedmont treppen within a system of noncyclic slope retreat and crustal movement. He conceptualized the associated processes of *gleichformige entwicklung, absteigende entwicklung, and aufsteigende entwicklung, steilwand* and *haldenhang* and eventually, the 'parallel retreat of slope'. His visualization of primarrumpf and endrumpf is just technically distinctive from those of Davis. King, however, modified Davis's concept of peneplain formation by suggesting that landscapes form through 'integration of pediments that are enlarged by headward recession of scarps' (Higgins 1975).

Kirk Bryan (1888-1950) was among the last of the acclaimed geomorphic observationalists. He replaced Davis at Harvard in 1926 and was mentor there to J.T. Hack (1913-1991). He was a field-oriented generalist who contributed important papers on channel changes, soil phenomena, erosion and sedimentation, alluvial chronology in the southwest United States, terraces, slope retreat, and gully gravure. He was supportive of an evolutionary approach to geomorphology, especially that of Walther Penck, but scorned emerging quantitative techniques (Higgins 1975). His idea of 'dynamic equilibrium' was first proposed for landforms by G.K. Gilbert (1877) in 'Geology of the Henry Mountains (Utah)'. He was also influenced strongly by Powell, presented his ideas of geomorphic equilibrium prior to publication of Davis's system, but the popularity of evolution relegated this part of his classic paper to relative obscurity.

Harbingers of *methodological shift* were the 'research articles' by R. E. Horton (1945), describing morphometric approaches to drainage basins, and A. N. Strahler (1950, 1952, 1954, 1957), who anticipated the application of equilibrium to landscapes through quantitative techniques. Horton was insistent on the application of quantified data and mathematical techniques to investigate process. Strahler (1954), on the other hand, stressed process and incorporated mechanics, fluid dynamics, and quantitative techniques into geomorphic studies, although he was inclined to blend the erosion cycle into an equilibrium format. It was not until J.T. Hack (1960) revived Gilbert's concepts of geomorphic equilibria that doubts of the Davisian system presented a suitable climate for paradigm replacement.

Equilibrium conditions are quickly attained and then maintained as a graded system that is essentially independent of time. Any change in the existing conditions is accompanied by rapid adjustment of landforms to the new conditions. Although Hack's paper was the catalyst, change occurred more through a consensus of uneasiness through the subtle changes in ideas (fashion changes) in the 1960s and 1970s: emphasis on equilibrium-related topics such as allometry, topology, and a variety of statistical techniques.

Hack completed his doctorate at Harvard under Kirk Bryan in 1940. After two years, he joined the USGS and served with its Military Geology Unit. Following World War 11, Hack began pursuing research interests along the Maryland coastal plain and in the Appalachian Ridge and Valley Province where Davis had developed many of his ideas. Hack joined a group of scientists working in the Shenandoah Valley; others were C. C. Nikiforoff, C. B. Hunt, and Harvard graduate-student friends M. G. Wolman, C. S. Denny, J. C. Goodlett and L. B. Leopold. Hunt, Wolman, Denny, and Leopold were geomorphologists/hydrologists, whereas Nikiforoff was a Russian soil scientist and Goodlett a plant ecologist. Members of this unique band of equilibrists interacted, reinforcing equilibrium concepts expressed in numerous papers on geomorphology, ecology, pedology, and hydrology (Osterkamp 1989).

Among Hack's products were reports on longitudinal stream profiles (Hack 1957), entrenched meanders (Hack and Young 1959), and the geomorphology and plant ecology of an Appalachian watershed (Hack and Goodlett 1960). These studies revealed conflicts with erosion-cycle concepts and led to 'Interpretation of erosional topography in humid temperate regions' (Hack 1960), which explicitly offered time-independent equilibrium as an alternative to the Davisian system. Although detractors such as J. Hoover Mackin were antagonistic, acceptance occurred rapidly, and it became fashionable to be critical of Davis.

Dominance of equilibrium was short because many geomorphologists realized the futility of discarding time. Thus, integrationists tried to reconcile systems of evolution and equilibrium and offered explanations of compatibility, that a system is applicable depending on scales of space and time. Richard Chorley (1962) preferred open-system dynamic equilibrium. Other milestones in geomorphic approach include Chorley's *interrelated model-based approach and systems analysis* under the *general systems theory* to deal with the problem of evolution of landforms (Chorley and Haggett, 1967 and Chorley and Kennedy, 1971). Both were presented by the authors as paradigms, but failed to stand as one, for the lack of greater applicability and complete acceptance (Hart, 1986). However, both the approaches have widened the horizon of geomorphic enquiry and analysis. In fact, the Davisian Cycle of Erosion is a model better explained in terms of a closed system while Hack's Dynamic Equilibrium represents a soulful expression of an open system. In contradistinction to this, concepts of 'uniform flow' and 'slope stability', confirmed in the 18th Century, waited for almost 200 years for incorporation into geomorphology texts sensu stricto, although they had long been available in books on hydraulics and soil mechanics. Schumm and Lichty (1965) presented objective-dependent guidelines for applying the conceptual models to landscapes. Efforts to reconcile the extremes of geomorphic systems have yielded recently to models of integration including *geomorphic thresholds* (e.g. Schumm 1973, 1979), *complex response* (Schumm 1973), *nonlinear dynamics* (Middleton 1990), and renewed recognition of a *systems approach* (Ritter 1978).

Thus, g*eomorphic fashions of* Sperber (1990) *have swung from the qualitative statements of early observers to the highly mathematical treatments and back again to inductive studies derived from field measurement* (Carson and Kirkby, 1972). The current geomorphic fashion is the *perfect landscape* concept of Turkington and Paradise's (2005) that circumscribes a geomorphological worldview as:

1. *Landscapes are strongly influenced by laws, principles, relationships and rules that are independent of place and time, and that operate within their domains everywhere and always (global factors).*
2. *Landscapes are strongly influenced by historically and geographically contingent factors that are particular to place and time and thus idiosyncratic (local factors).*
3. *The probability of encountering any specific set of applicable global and local factors is extremely low; thus, landscapes have elements of uniqueness.*
4. *The key to increasing the generality of models, concepts and research results is to reduce the number of variables and factors considered.*

Probably, the latest fashion is the 'fractal geomorphology' based on the 3rd definition of fractal: *a set or pattern is fractal if the scaling of far more small things than large ones recurs multiple times*. All geomorphological features are fractal or living, given the right perspective and scope (Bin Jiang, 2019).

These are visualized with infinite and previously unknown stunning perspectives using geospatial technology. Its artistic aspect arises from the underlying scaling or fractal or living structure rather than something subjective or idiosyncratic (Griffin 2017). Thus, it can evoke a sense of beauty – structural beauty that can be measured quantitatively, as well as sensed by human beings (Jiang and Sui 2014, Jiang 2015, Wu 2015). A beautiful geomorphological map reflects the underlying living structure, which accounts for a majority of beauty, while aspects of surface beauty such as colour and design account for a minority.

N.B. Details of the references and other articles avoided in this abstract.

Contents

HILLSLOPE AND GRAVITATIONAL PROCESSES

GLACIAL PROCESSES

FLUVIAL PROCESSES

AEOLIAN PROCESSES

COASTAL PROCESSES

TECTONIC GEOMORPHOLOGY

GEOMORPHOLOGICAL HAZARDS AND RISK MANAGEMENT

GEOMORPHOSITES

URBAN GEOMORPHOLOGY

HUMAN IMPACT ON ENVIRONMENT

GEOSPATIAL TECHNOLOGY FOR HUMAN WELFARE

YOUNG GEOMORPHOLOGISTS COMPETITION

HILLSLOPE AND GRAVITATIONAL PROCESSES

SOIL GEOMORPHOLOGY OF PLATEAU FRINGE REGION AND ITS INFLUENCE ON LAND USE AND LAND COVER: A STUDY ON THE AJODHYA HILL, PURULIA, WEST BENGAL

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Attribute of LULC are dependent on soil and geomorphological character of the area. The prime objective of the present work is to find out relationship between the attributes of soil geomorphology and land use and land cover of the study area. SRTM and ALOS data are used to prepare accurate DEM for analysis of morphology and topography of this region. LULC map is prepared from Landsat 8 satellite imagery. Ajodhya Hill is situated in the Purulia district of the state of West Bengal. Maximum elevation of the hill is about 698m from the msl and is composed of older Archaeanrock mainly granite. Ajodhya hill is associated with five residual hill, with undulating surface, having the maximum slope in the northern side while the slope is gentle in the southern side. Foot hill area of Ajodhya hill has gentle slope varying between 0˚-5˚ with moderately thick soil layer. Scattered vegetation, fallow land and agricultural activity are found in the foothill pediment area. Sandy loam is the principal soil texture having neutral soil pH. Majority of soil samples having salinity level of 32-95 μƨ/cm. Surface soils are dry in character having 1-3 percent of soil moisture. Percentage of organic matter is very low. Concentration of nitrate nitrogen is very high, while ammonical nitrogen is medium to low. Elevation of foothill pediment region is less than 300 m. This area is very dry and only feeded by the rain fall during monsoon season. Local people stores water by creating artificial reservoir for use of agriculture and household purpose. Sustainable management of resource is very useful for that region.

Keywords: Agriculture, soil, geomorphology, scattered, forest.

SHAPE ANALYSIS OF THE PLANAR SURFACE IN SLOPE MORPHOMETRY

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Slopes are very much common in the natural world, and in the built environment. There are many techniques which are already been used to understand the nature and the properties of the slopes. It can be analysed in many ways. In three dimensions, the slopes may be considered as a combination of infinite number of horizontal and vertical planes. Sometimes two dimensional representation of the points on the planes are also beneficial to understand the changes or the variations in the shape of the planar surface in (X, Y), (X, Z) and (Y, Z) planes, where X, Y, and Z are used in different perspectives. The first step to understand the shapes of the planes are to find a mathematically natural way to describe them. Now to understand any kind of variability in the shape, it is better to estimate the deformation of the points on the plane.

Keywords: Planar Surface, Deformation.

GLACIAL PROCESSES

QUATERNARY GEOMORPHOLOGICAL ENVIRONMENT AND LANDFORMS IN THE EAST SIKKIM HIMALAYA

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The paper bears an account of the Quaternary Geomorphological Environment and landforms in the East Sikkim Himalayan region. A wide variety of the associated landform features occur over the high altitude mountainous terrain in this part of the Himalaya. Among them, Glacial and Periglacial features are most common. The glacial features, mostly in the form of morainic drift limits (mainly lateral and terminal moraine), glacier-washed valley floors, corrie lakes and melt-water channels are ubiquitous; while most of the periglacial features are in the form of frost-shattered debris type (block slopes and scree), gelifluction lobes and lobate sheets, stone garlands and pro-talus ramparts. Utmost endeavour has been given to identify and classify these features according to the process of origin and the condition in which they are now preserved (relict or active). The entire work is based on thorough and systemic field investigation by traversing the area on foot and instrumental measurements on the size of the features and the slope gradient upon which they occur. It has been assessed that all the glacial landforms were formed during the Late-glacial and the periglacial features have been formed in both Late-glacial and early Post-glacial periods under the substantially harsher cold climatic condition, and after the cessation of harsher climatic condition the landform features are by and large preserved in the relict form. Only the limited number of minor periglacial features remain active in the present day.

Keywords: Quaternary, Glacial, Periglacial, Late-glacial, Post-glacial.

FLUVIAL PROCESSES

CAUSES AND CONSEQUENCES OF CHANGES IN THE MORPHOLOGY OF SASUR KHADERI RIVER IN ITS LOWER COURSE WITH REFERENCE TO OCCURRENCES OF FLOOD IN YAMUNA RIVER

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Morphological changes of river due to excessive rain and floods are a very common phenomenon. A flood caused by heavy rains and release of water from the dams during the period of excessive rain in the monsoon season is a serious issue particularly in the lower plain areas where a large population has been concentrated especially along the banks of the river. In this paper an attempt has been made to assess the causes and consequences of changes in the morphology of the lower course of Sasur Khaderi River, a tributary of river Yamuna originating from Tithora Village, Kaushambi and flowing towards the main Yamuna River in Prayagraj District. An attempt has been made to observe the causes and consequences of changes in the morphology of riverine landscape, channel migration and shifting, land loss, sediment discharge and mixing. A significant and remarkable change along the river bank has been identified in the study area.

Keywords: Morphological, flood, river bank, population, riverine landscape, channel migration, sediment discharge.

SEMI-QUANTITATIVE APPROACH ON MORPHOLOGICAL SUSCEPTIBILITY ASSESSMENT OF THE MAYURAKSHI RIVER OF EASTERN INDIA

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The present research determines the channel Susceptibility Index of the Mayurakshi river of Eastern India whose channel configuration has been considerably altered by the natural hydro-geomorphic changes and extensively regulated by human interventions. The Channel Susceptibility Index incorporates morphological components of the channel in connection with eco-geomorphic quality of the adjacent area, anthropogenic artificiality and temporal channel adjustment. A semi-quantitative ranking method has been adopted in this research. Individual ranks have been assigned for each sub-component depending on their functional relation with channel sensitivity. The composite Channel Susceptibility Index was prepared by compiling the ranks of each and individual susceptibility classes. The analysis concluded that the Channel Susceptibility Index is very high in lower and middle reaches due to its hydro-geomorphic set-up and repetitive human interventions. Thus, the composite Channel Susceptibility Index can be treated as a relevant and effective tool for channel sensitivity assessment and management. Hence, it will help the policymakers to seek for appropriate channel design and management schemes.

Keywords: Channel Susceptibility Index. Morphological dynamics. Anthropogenic artificiality. Channel adjustment. Mayurakshi River.

AN ASSESSMENT ON THE NATURE OF CHANNEL MIGRATION OF RIVER JORDA OF JALPAIGURI DISTRICT, WEST BENGAL USING GIS TECHNIQUES

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Lateral movement of river channel within its valley with time is a common phenomenon. Various processes of fluvio-geomorphological environment such as rapid valley fill deposition due to decrease of channel gradient and resultant migration of active channel, bank failure and bank line shifting, frequent occurrence of floods, capturing of lower courses of the tributaries by the trunk streams, and abandonment of tracks and avulsion are the most prominent factors behind channel dynamics in the sub-Himalayan part of Jalpaiguri District, West Bengal. Moreover, human interventions in the form of engineering constructions (bridges, flood embankments, etc.), tea plantation, mining and quarrying, and agricultural encroachment have emerged as another leading issue which is pulverizing the ways of natural channel adjustment as well as also the channel behaviours. Both these processes are carrying significant messages of immense vulnerability for the study area known for its geomorphological instabilities. The study mainly focuses on bank line shifting, river channel bar change and river course shifting. For this study the author has used secondary (topographical map, Land sat image) and primary data (field visit). The result shows that the channel of Jorda River has changed over time due to human interference like sand mining, land use change etc.

Keywords: Channel, bank line shifting, Centreline, GIS, Remote Sensing.

BEDROCK CHANNEL INCISION AND DEVELOPMENT OF MENDHA GORGE OVER GEOLOGIC TIME SCALE DETERMINED BY OSL DATING

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In order to understand and evaluate rate of incision of the modern channel at Mendha Gorge, a sample has been collected for optically stimulated luminescence (OSL) dating from a palaeochannel. The OSL age is 19.577 ± 0.958 ka. It indicates that the palaeochannel was active during Tarantian period. Furthermore, elevation difference between palaeochannel and modern channel has been measured with the help of auto level. The analysis reveals that the modern channel has been incised for 32 m at calculated incision rate of 1.2 mm/yr. This is an extraordinary high rate of incision as compared to rates of incision in the other parts of the world. This hypothesis is further supported by the vertically incised modern Mendha Gorge into bedrock for 59 m. It is attributed to infrequent large magnitude floods in the geological past as well as modern floods with an immense competence to erode the bedrock and transport huge boulders. For instance, an extraordinary flood event had occurred in 1968 which resulted into plucking and transportation of the huge boulder with an intermediate axis of 6200 mm from the gorge. The theoretical values of mean velocity, unit stream power and bed shear stress required for entrainment of this boulder are 5.12 m/s, 5176 W/m^2 and 1054 N/m^2 respectively. The estimated values of these variables are several orders magnitude higher for the 1968 mega event. The analysis further shows that the cavitation had occurred at this site during 1968 flood. It is, therefore, reasonable to conclude that a palaeoflood had occurred in the Tarantian period. The formation of modern Mendha Gorge was initiated and only infrequent large magnitude floods are responsible for an extraordinary higher rate of incision, transportation of very coarse sediment and formation of an excellent vertically cut Mendha Gorge in a short period of time.

EVALUATING SEDIMENT TRANSPORT CONDITION THROUGH THE MODEL IN THE SUB-CATCHMENT BASIN IN THE GANGA-BRAHMAPUTRA-MEGHNA ALLUVIAL SYSTEM

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Rivers would be the most crucial water supplies and analysing conditions of hydraulic parameters. Perhaps one of the studies within this field is erosion and sediment transport. Estimating of transfer capacity in rivers is a necessary part in planning and designing of river training and watershed therapy, soil conservation, flooding control and structures. A bathymetric shift, widening valley and deposition is the central part in Ganga-Brahmaputra-Meghna (GBM) meandering system. Due to the increasing rate of sedimentation and individual interference, the problems of flooding increase in the present day. MIKE 11 mathematical model can be utilised to study the simulation of their river. Manning roughness coefficient believes for its sub-catchment basin of computational results and GBM system called by observed data, assessed and compared. Ackers-White, Meyer-Peter-Muller and also Barry's equations offered better forecasts of changes. A lateral and upper bed level change of the analysis area anticipated from upstream to downstream. MIKE 11 Model could be appropriate software for predicting sediment transport of meandering mature river. Based on the outcome of the study, it demonstrates that the GBM meandering system's region has rapidly changed by the period. It's caused by sedimentation, human hindrance and also un-scientific bridge formation over the river that contributes to river scouring. The amount of river bank erosion accelerates due to the changing depositional pattern throughout the river and seasonal variation of river's discharge amount. The local populace's sustainable behaviours changes with the changing nature of their stream and shortly the water accessibility condition of the river could decrease.

Keywords: Ganga-Bhra maputra-Meghna (GBM) meandering system; MIKE 11; Sediment transport; Bathymetric change; Bed load transport.

SPATIO-TEMPORAL STUDY OF CHANGING LOCATION PATTERN OF SANGAM DUE TO CHANNEL SHIFTING OF RIVER GANGA IN ALLAHABAD CITY

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A channel is a type of landform consisting of the outline of a path of relatively shallow and narrow body fluid, most commonly the confine of a river. A channel is typically outlined in terms of its beds and banks. The proposed work is an effort to study spatio-temporal changes in location of Sangam due to shifting of channel of river Ganga. Its confluence with River Yamuna in Allahabad city is known as Sangam. Every year a religio-cultural event called Magh Mela is being organized at the bank of River Ganga in which masses take essentially a holy dip at and near Sangam. Because of variable discharge, gentle slope and sedimentation, Ganga keeps changing its flow direction due to shifting of its channel in the basin at Allahabad. This very geomorphological character of Ganga flowing through the city of Allahabad need to be studied in order to plan the socio-cultural and economic activities of the city with special reference to organize Magh-Mela on yearly basis and Kumbh and Mahakumbh every sixth and twelfth year, respectively. Due to channel shifting of River Ganga, the location of Sangam also shifts every year. This shifting has induced many geomorphological changes in the flood plain of River Ganga which in turn has also lead to many problems in carrying out the agricultural activities as well as in land-allotment to stakeholders e.g., Akharas, Devotees for Magh-Mela, etc in the vicinity of River Ganga. To present a spatio-temporal accounts of channel shifting of River Ganga and consequently the Sangam, GIS

techniques have been used. In the present study satellite imageries and SOI Topo-sheets revealed the spatio-temporal shifting of river channel.

Keywords: Ganga, Shifting of Channel, Sangam, Spatio-Temporal, Magh-Mela.

A STUDY ON TERRAIN CLASSIFICATION OF THE SANKA RIVER BASIN

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Land is a dynamic element and experiences continuous transformation of its physical condition by its external and internal factors. Terrain can be defined as the expression of the assemblage of geological structure, the geometry of surface and the soil of the earth's crust. The main purpose of evaluation of terrain is concerned with meteorology and climatology, hydrology, geological and mineral survey, soil survey, agriculture and forestry, civil engineering, military activities, archaeology, resource evaluation etc. The classification of the terrain involves – analysis, quantification and assessment. The broad variety of topographical order of Sanka Basin has attained a dynamic geomorphic entity. The landforms originated in different altitudes represent various micro environments and diverse geomorphic especially fluvial processes. The main purpose is to identify different terrain classes based on the physiographic, lithological, and morphometric attributes using the simple principles of map algebra that combines different attributes to produce the classified attributes of a terrain. The present study is a focus on the pattern of terrain using SRTM DEM, SOI topographical maps, GSI district resource maps, temporal satellite data from USGS free sourced site and field investigations. It will help to the formulation of different development strategies within the basin area.

Keywords: Terrain, structure, morphometric attribute, fluvial process.

MANSAITA RIVER ORDERING AND ITS GEOGRAPHICAL IMPORTANCE, PRAYAGRAJ, UP, INDIA

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River is valuable natural gift for man. Its play an important role in human life, hence the study about river is very important. The present study is related to the Mansaita River. Mansaita River is the tributary of holy River Ganga. It meets to the left bank of River Ganga in the east side of Curzon Bridge in Phaphamau, Prayagraj. Mansaita River extends from 25˚30′ N to 25˚40′30"N latitude and 81˚53′ E to 82˚00′ E longitude. The basin length of Mansaita River is 24.4 km. The catchment area of the river is 165.37 km^2. It flows in Soraon and Bahariya blocks of Prayagraj district. It is a seasonal river. This study included stream ordering of Mansaita River and its geographical importance. Stream ordering is based on mainly two approaches; top-down and bottom-up approach. Top-down approach refers to the Hack's method of stream ordering and bottom-up approach included the method of Horton, Shrive and Strahler.The geographical importance is the importance to the contest of ordering. It includes the ordering impact on river processes like; erosion, transportation and deposition and its impact. Further study included the impact of processes on human activities like; agriculture and settlement.

Keywords: Mansaita River, Prayagraj, ordering, importance.

CHANNEL MIGRATION ASSESSMENT ALONG LOWER DWARAKESWAR RIVER, WEST BENGAL

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Lateral movement of river and bank line migration are very common natural phenomenon but the study on channel dynamics is important for delineating the channel migration zone of a river. Various geomorphological processes such as valley aggradation due to severe soil erosion and very gentle channel gradient, frequent occurrence of flash flood over the floodplain, tidal propagation in the lower part of the river and detachment of tributaries play the dominant role controlling the magnitude of channel movement in Dwarkeswar river. Consequent events are the channel migration, avulsion and bank failure. Moreover human intervention in the form of bridge and embankment construction, sand mining and river-bed agriculture makes the channel instable. A spatiotemporal analysis has done along the lower Dwarkeswar river to demarcate its migration character .The study has done on the basis of multi-dated maps and satellite images for the last 100 years (1920- 2019) with the aid of geo-spatial techniques (RS & GIS) and field investigation. Some representative reference sites have been selected from lateritic upper part, alluvial middle part and fluvio-tidal lower part of the channel. Valley morphology and mechanism of bank line movement have been assessed on the basis of cross profile variation,measured during field work. Two important geomorphological outcome of this study are a)from the spatial point of view the rate of migration is very high in the middle part of the study reach due to meandering tendencies as compared to the upper and lower part of the channel b) from temporal point of view, rate of migration is less after 1980s due to the construction of embankment along the river.

GEOMORPHOLOGY AND DRAINAGE BASIN CHARACTORISITICS OF THE HILLY TERRAIN

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Knowledge of drainage basin characteristics becomes an important pre-requisite to evaluate basin hydrology. Drainage basins one of the most fundamental geomorphic units. It occupies nodal position in geomorphic studies. So the study of various properties of river and drainage basin is quite pertinent. Such a study is useful in ascertaining the stage of geomorphic evolution of different basins, topographic characteristics and hydrological condition of the concerned area, which in turn will provide essential input for watershed/ catchment management strategies. Keeping these fact in view in the present paper tries to evaluate quantitatively the drainage analysis of the Una district (H.P.) and covering three aspects namely linear, areal, and relief. Physiographically the Una district is situated Himalaya Himachal of Mandi-Beas region and covers a total area of 1540 km^2(including 42 km^2 Govind Sagar).The study reveals that out of twelve basins eight moderately well drained. So for the stage of basin development is concerned, six early youth, four middle youth and remaining two are in late youthful stage.

Keywords: Una district, Morphometric evaluation, Drainage basin, Drainage Density, Drainage Frequency, Elongation Ratio, Hypsometric Integral, geomorphic unit.

EFFECT OF RAINFALL ON FLUVIAL PROCESSES: A CASE STUDY OF AMBIKAPUR REGION

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Ambikapur region experiences seasonal variation in rainfall and is an inseparable part of Vindhyachal, Baghelkhand region which is situated between $20^0$32'30" to $23^0$57'25" N latitudes and $81^0$2'10" E to $83^0$42'15" E longitudes and its total geographical area is 13851.58 km^2. Ambikapur region is characterized by moderate winter, hot and dry summer whereas hot humid monsoonal climatic conditions in rainy season. In this way all three major seasons have opposite characteristics to each other. Winter season is not phenomenon to the view of erosion but summer season produces weathered material for turbulent streams in rainy season. Present study region represents the view of semi-arid region during summer season, while in rainy season it represents the different picture of hot-humid climate. During the intensive field work researchers observed that numerous first to fourth order stream look helpless in dry months of summer and have least contribution in erosion, transportation and deposition but these helpless streams of dry season become powerful in rainfall season and become able to displace even big boulders remaining in valley beds and valley sides. Present study region receives its maximum rainfall during wet months of June, July, August, September and October. In this way region receives 84.23% rainfall only in rainfall season. Although slope gradient plays very vital role in determining erosion capacity of river, this also proves its significance with increased amount of water in rainy season. Perimeter zone of the region is eroded by increased volume and velocity of streams in rainy season. These streams involve themselves in deposition in the middle part of the region because central part of study region is in the form of peneplain or basin which is surrounded by perimeter highlands or plateau. The streams of this region have fresh water in winter season whereas these have huge amount of sediments in rainy season. This proves that erosional, transportation and depositional work of stream in fully influenced by rainfall season.

THE STUDY OF THE MEANDER CUT-OFF MECHANISM AND FORMATION OF ABANDONED CHANNELS OF SANKOSH RIVER IN INDIA

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Sankosh River in its lower course is seen to have a tendency to meander over floodplains to balance the transport of water and sediments. As a result, both the neck and chute cut offs occur as considered the main mechanism of abandoned channel formation. The neck cut off occurs due to deposition of sediments continuously on the convex bank and sediment which is eroded from the concave bend. As a result, the sinuosity of the meander is increased and forms a narrow neck. The torturous meander bend at the neck remains in instability threshold unless naturally, the neck disappears due to threshold exceedance and a straight channel is formed, creating a cut-off. When the cut off is sealed from the main channel by sediment deposition, an ox-bow lake is formed and left as abandoned channel. On the other hand, chute cut-off usually occurs when successive high water flows develop a chute across the inside of a point bar which starts to flow as straight channel decreasing the sinuosity of the main river course on that part. Thus, the former sinuous course becomes detached as an abandoned channel. In this regard, it is to be mentioned that such channels reduce sinuosity and increase velocity gradient in flow and discharge through chute and neck leaving cut-offs which lead to the development of abandoned channels.

Keywords: Abandoned Channels, Neck cut off, Chute cut off, Point bar.

LITHO-STRUCTURAL CONTROL ON DRAINAGE SYSTEM OF KUMARI RIVER BASIN, WEST BENGAL

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Underlying lithology and structure play a vital role for development of landform and drainage system. Fluvial process not only controlled by any single factor but significantly affected by underlying litho structure. It influence flow characteristics, erosional process and sediment transportation .The Kumari river is a monsoon influenced river system, covering an area of 1961km^2.The river flow through Precambrian landscape situated largely on western part of West Bengal. The area is mainly composed by Chotonagpur Granitic Gnissic Complex (CGGC) in north and Singbhum groups of rocks in south .The entire area characterised by extensive bedrock outcrops, numerous fractures and lineaments. South Purulia Shear Zone (SPSZ) passes through the central part of the basin. Here an attempt has been made to study the litho structural influence on drainage system of Kumari river basin. The work has been carried out by using geospatial techniques and detail field study. Quantitative geomorphic approach has been applied in this study. Analytical result shows that drainage system of Kumari River fall under the category of straight channel and controlled by topographic determinants. Development of drainage network in the study area is largely affected by lineaments. Majority of the streams display disequilibrium condition of longitudinal profile marked by a series of small knick points at structural and lithological boundaries.

Keywords: Litho-structural control, drainage network, lineaments, longitudinal profile.

HUMAN INDUCED PLANFORM DYNAMICS ALONG THE KANGSABATI RIVER, WEST BENGAL

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The rivers of the south western part of West Bengal and eastern India have evolved through complex interaction between natural as well as anthropogenic forces. In the present case of river Kangsabati neotectonic activities, hydro- meteorological fluctuation and anthropogenic interventions are modifying this river at various spatio-temporal scale. Kangsabati River, whose channel form have been subjected to large scale adjustment to repetitive intervention in resent past. Hence, the paper attempts to highlight the temporal trend of planform characters at different reaches with help of multi- temporal maps and images since 1926- 2018 in GIS environment. The analysis shows that the channel sinuosity and braiding index have been amplified due to construction of dam. Lastly, the study concluded that haphazard sand mining leads to transform the shallow wide channel into deep narrow channel in resent past.

Keywords: Sand mining, Sinuosity index, braiding index.

SEDIMENT CHARACTERISTICS OF ELEVATED SECTIONS OF A SUBTERRANEAN CHANNEL: A PRELIMINARY STUDY OF KREM DAM, MAWSYNRAM, MEGHALAYA

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Krem Dam was once thought by people as a haunted place. It is a geomorphic feature of great interest as the channel is now flowing underneath a relict stream. The inlet is large and wide while the outlet is restricted leading to a pooling effect after and during heavy rain. Preliminary sampling of sediments from the elevated sections of the subterranean channel, drying and sieving them after which particle segregation was done for sizes from 32µm to 2mm. From the percentage available in each category, it was found that the open channel upstream retained the larger particles. While stream velocity decreased, the smaller particles are transported and deposited at different locations in the sub-terranean channel.The peak sizes of the sediments over the elevated sections are concentrated around 63 µm and 125 µm while those in the open channel are around 500 µm to 250 µm. The sediments in the main subterranenan channel are observed to be highly varied but are yet to be sampled.

ANALYSIS OF FLOOD CAUSES AND ASSOCIATED SOCIO-ECONOMIC DAMAGES IN DOWNSTREAM AREA OF DIBANG RIVER, ARUNACHAL PRADESH, INDIA

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North-east region of India is exposed to numerous hazards but the problem of the recurrent floods has been causing massive losses to lives and other properties. The downstream region of the Dibang River in Arunachal Pradesh is no exception to it. In this paper, an attempt has been made to analyse the causes and associated socio-economic impacts on the region. Paglam circle of Dambuk sub division, Lower Dibang valley district is being falls under the downstream area of the Dibang River.The area has been studied with special reference to Physical setting, recurrent of floods and impacts of flood on socio-economic. Similarly seven sample villages were selected randomly from the active floodplain area. The sample include the Anpum-I, Anpum-II,Anpum-III,Loklung,Paglam-I,Paglam-II and Paglam-III. This is located in the downstream area of the Dibang River. Both primary and secondary have been applied. The analysis revealed that in the study area,floods occur during summer season, which is mainly caused by heavy rainfall as well as rapid melting of the snow. Besides there are some floods, intensifying factors which accelerate intensity of floods and enhance resultant damages in the region. It was found that in 2014 &2015 floods more than 350 houses were washout by Dibang and Sinkin Rivers in the area apart from that tremendous loss to cropland,govt.properties etc.The government have yet not implemented any major flood protection strategies in the area. However in addition to structural measures, land use zoning and flood abatement strategies would largely help in reducing the adverse consequences of this recurrent phenomena.

AN ASSESSMENT OF GULLY BASIN MORPHOMETRY: A CASE STUDY OF KHOAI

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Development of a drainage system and the flowing pattern of a river over space and time are influenced by several variables, such as geology, geomorphology, rock structure, soil and vegetation of the area through which it flows. Basin morphometry is the measurement and mathematical analysis of drainage form, its characteristics, shape and network. The basic objective of the study includes the critical evaluation and assessment of morphometric parameters and prioritization of the watershed area, through linear, areal and relief aspects. The study also aims for the quantitative and qualitative description of geometry and nature of the basin area. A systematic methodology has been followed for conducting the present work. Data has been collected from both primary and secondary sources. The basin covers an area of 37.994 sq. metre. The number of 1st order streams are identified to be forty-nine, followed by ten 2rd order streams and one major stream of 3rd order. The present paper is an attempt to study the Khoai and analyse the morphometric aspect of the drainage basin.

Keywords: Linear parameters, relief parameters, aerial parameters, Khoai Sub watershed.

IMPACT OF RIVER BANK EROSION ON LAND USE AND LAND COVER ALONG THE LOWER REACH OF THE BALASAN RIVER, WEST BENGAL

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River bank erosion is frequently observed along the lower reach of the Balasan River due to loose unsorted bank material, lateral adjustment of the river caused by highly fluctuating discharge, braided channel pattern with frequent flow diversion and human interference in terms of boulder extraction from river bed and bank. The present study attempts to assess the impact of river bank erosion on landuse/landcover along the lower reach of the Balasan River, West Bengal. Bankline shifting method and supervised classification using Landsat TM (1990), ETM+ (2000), LISS-III (2008) and Google Earth (2017) have been carried out to quantify the amount of river bank erosion and to detect associated landuse/ landcover change in surrounding flood plain area. A perception study on flood plain dwellers has also been conducted through in-depth interviews and focus group discussions. From the shifting of river banks it is evident that the lower reach of the river is unstable and a large portion of land has been lost due to frequent lateral channel migration. Landuse/ landcover change detection indicates that area affected by channel shifting primarily comprises the agricultural land although it is also evident in area under settlement. Almost 87% of land under agriculture has been reduced during these 28 years of period. A noticeable amount of land has been converted from agriculture and settlement to waste land after some recurrent floods and associated river bank erosion.

Keywords: River bank erosion, Landuse/landcover change, supervised classification, Balasan River.

TREND ANALYSIS OF WATER LEVEL AND DISCHARGE IN RESPONSE TO RAINFALL AND LAND USE/ LAND COVER PATTERNS IN SUBARNAREKHA RIVER BASIN, INDIA: A HYDROCLIMATIC AND ENVIRONMENTAL APPROACH

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Regeneration of ground water, surface and sub surface water resources is hampered with climatic variations and changes in Land-Use and Land-Cover (LULC) patterns. Recharge and discharge of an area can be monitored through water-table fluctuations. Present study deals with an analysis of spatiotemporal distribution of rainfall, temperature in relation with water-table and discharge variability applying the Mann–Kendall (MK) and Sen's Slope statistical test over Subarnarekha River basin. The relationship assessment between the variables followed Pearson's Coefficient Correlation. Changes in LUL Chave also been identified in Land satellite imageries and are mapped through GIS approaches. Meteorological data are collected from Regional Meteorological Centre, IMD, Kolkata and the discharge and water-table data are compiled from India-WRIS. Statistical illustrations of rainfall trend shows significant downward trend at Jamshedpur, Ghatsila and Medinipur and upward trend at Ranchi and Balasore whereas discharged epicts a decreasing trend at Muri, Adityapur, Ghatsila, Fekoghat and Rajghat and only increases at Jamshedpur. Moreover the LULC changes over the basin indicate large-scale alteration of land and forest cover into cultivation and settlements. Assessment on a time span of 25 years from1994 to 2018 the basin experiences decline in rainfall, water-table and discharge and hence indicate towards a process of gradual drying. For a better understanding between rainfall-water table relations apart from FGDs a GPS survey of 37 wells were sampled with their physical parameters of elevation, well depth, depth to water and well diameter around the origin site of the river in it supper reach. Static water-level, ground water flow direction, surface profile and 3-Delevation model of the are a were also produced in GIS platform. The study calls for proper use and management of water resources, check in its overuse, laying stress on rainwater-harvesting and recommendations on suitable ground water recharge.

Keywords: Groundwater, Climatic variation, Land-use Land-cover, Rainfall, Water-table, Discharge, Mann–Kendall test, Static water-level, Groundwater flow

CHANNEL BAR DYNAMICITY IN THREE REACHES AT FOOTHILL RIVERS OF DARJEELING HIMALAYAN PIEDMONT ZONE, INDIA

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Channel bars are common, striking fluvio-geomorphic depositional features of alluvial rivers. The study of this article has aimed to investigate the morphodynamic behaviour of channel bars (n=50) in three reaches of Darjeeling Himalayan Piedmont zone. Dynamics of micro to meso bars is mainly accomplished by the channel gradient, variation of discharge and amount of sediment. Spatiotemporal variation of the areal extension and maximum width of the bars of three reaches have studied on the basis of satellite and Google Earth images since 2000s. Changing hydro-morphological character of these channel bars of three reaches has analysed based on field data (2016-2019) and has explained with the aid of Multi Criteria Analysis (MCA) methods. Grain size analysis and open facies analysis have done to provide the information on the variation of sedimentological nature of these channel bars. Paleohydrological characteristics can also be detected following Wilson and Willims' methods. On the basis of these analytical procedures character and magnitude of the mobility and stability properties of the channel bars have been ascertained through Union and Intersection methods of geostatistics. The dynamicity in the areal extension (Δ_A) of the bars in upper, middle and lower piedmont reaches varies from 0.12-0.71 sq.km, 0.12-2.83 sq.km and 0.10-5.43 sq.km respectively. Stability of channel bars in the respective reaches are 58-72%, 26-42 % and 14-29%.

AN APPRAISAL OF DYNAMICS OF BANKLINES OF THE LOWER COURSE OF HOOGLY RIVER, WEST BENGAL

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River is the main agent in sculpturing the landscape broadly. The age old channel changing behavior of river Hoogly, main river of Bengal basin, has its impact on the morphological modification of the landscape. In the present study a stretch of Hoogly River with a length of 80 km has been selected for determining the shifting nature of the river. The corridor extends from The Gouranga setu in Nadia district to Chandrahati Gram Panchayat. Channel changing has been analyzed on the basis of the satellite image for the year 1973, 1986, 2000, and 2018. Results denote that maximum shifting have occurred along the left bank of the channel where the maximum value is 2.21 near Palpara. On the other hand the right bank has the highest shifting of 1.81 km. The geological structure and neo tectonic evolution are the causes behind such shifting. This type of micro level study is helpful for determining the channel migration zone.

PALAEOFLOOD RECORDS OF THE MAHI RIVER OF LATE PLEISTOCENE AND HOLOCENE PERIODS

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The palaeoflood analysis of vertically-stacked sequences of the slack water deposit (SWD) was carried out at mouth of a tributary of the upper Mahi River. The SWD exposed 37 flood units representing successive floods of increasing magnitude. The thickness of the section was 9.7 m and the thicknesses of the flood units varied between 0.1 and 0.7 m. The highest flood deposit was observed at 15.37 m whereas, the lowest was at 6.37 m from thalweg. Fourteen samples were collected for optically stimulated luminescence (OSL) dating, out of them 6 samples of high-resolution flood units of the deposit are dated to 16.98 ka (kiloannum), 7.13 ka, 6.52 ka, 2.57 ka, 1.76 ka and 1.48 ka. These dates represent that the deposits are associated with floods of Late Pleistocene to Late Holocene periods. The hydraulic modelling has been used to calculate water-surface profiles and representing the palaeo and modern flood levels. The modern flood had occurred in 2006 due to heavy rainfall associated with upper air circulation and its estimated discharge is 25770 m^3/s. The palaeoflood discharges ranging from 3500 m^3/s to 10600 m^3/s of Mid Holocene (7.13 ka) and Late Holocene (1.48 ka) periods respectively. The lowest flood deposit was dated 16.98 ka of Late Pleistocene period located at 6.37 m from the thalweg with calculated discharge of 2072 m^3/s. On the basis above studies regarding the modern and palaeoflood on the Mahi River, it is concluded that there is a good temporal correlation between the occurrences of floods of Late Pleistocene to Late Holocene periods. Another important finding is that the magnitude of floods increased gradually from Late Pleistocene to Mid Holocene. The magnitude of floods further increased from mid to late Holocene. Moreover, the modern flood was of much higher magnitude than palaeoflood.

STUDY ON TOPOGRAPHICAL CONDITION AND MEANDERING LOWER COURSE AND ITS IMPACT OF THE RAIDAK-I AND TURTURI INTERFLUVES

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Topographical characteristics of any region affected on the drainage networks and its evolution. Topographical aspects like relief, slope, aspect, etc. of any river basin have their prominent influences on the hydrological character of the river. The hydro-geomorphic conditions of the Duars region of West Bengal are characterised by river bank failure, flash floods, rise in river bed levels, shifting of river courses, channel widening and loss of land, loss of forest resources and biodiversity, loss of tea gardens, arable lands and settlement, deterioration of soil quality, water quality, deforestation, etc. The Raidak-I River is characterized by the presence of flooding events in nature. The River Raidak-I have been witnessing the problem of rising of the river bed, bank erosion and lateral changes of the lower courses which consequently contributed to the gradual decay of the river regime. In the rainy season the Raidak-I and Turturi received a huge amount of water and as a result lower part of the river valley often floods in the surrounding areas and frequency of flooding in low lying areas is very high. Meander formation and highly sinuousness is resulted to flood in the lower part of the basin. In the present study an attempt has been made to evaluate the existing topographical condition and lower course meandering of interfluves area and its impact on the surrounding environment by using suitable remote sensing and GIS techniques.

Keywords: Interfluves, topography, meandering channel, flood, GIS.

THE MANDAWARIYA HILLS: A MORPHOMETRIC STUDYOF DISSECTION INDEX

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Dissection index is an important indicator to ascertain the nature and magnitude of dissection of a terrain. This is dimensionless property which is obtained by finding out the ratio between maximum relative altitude and absolute altitude in a unit area. The present research paper analyses the Morphometric analysis of Dissection index of Mandawariya hills. This area occupy Kishangarh and Nasirabad tehsil of Ajmer district in Rajasthan. The Mandawariya hills lying between 2616| |15| | North to 2645| |00| | North and 7438| |45| | East to 7500|00 | | East and cover an area about 1176 sq. km. Geological framework of the study area provides the stage on which the interplay of rock materials and sub areal forces has produced the present landscape through various geological periods. To the east and south east of study area the main outcrop is Banded Gneissic Complex , intruded by large and small bodies of pre-Aravalli granite saturated with pegmatite, soda-syenites along with pegmatites occur to the north-east of Kishangarh city and rocks of Delhi system is found all over the study area. The physiography of the study region has been greatly influenced and determined by geological formation and structure and has three major divisions. North-Western Piedmont Plain, Ridge-Valley Region, BGC Upland. Geological history and various climate changes have influenced the present drainage system of study area. Consequently, buried channels, dry beds, palaeo channels, braided streams and perennial streams, inland drainage and structurally controlled streams etc. have evolved as the product of these two factors. The data related to Dissection index extracted from the topographical sheet (scale1:50,000) published by survey of India, Dehradun. To calculate the frequencies and special coverage of dissection index, the grid method has been used. The study area has been covered by One Km×One Km grid. In proposed work the Dov'Nir method to calculate the dissection index has been used. For the preparation of Dissection index categories maps the dissection index values has been classified into four categories. 0.0-0.1 Very low dissection index, 0.1-0.2 Low dissection index, 0.2-0.3 Moderate dissection index, 0.3< High dissection index. For the conclusion Morphometric techniques, statistical techniques and mapping techniques has been used. The frequency, spatial and statistical analysis illustrated by isopleths maps and frequency distribution confirm the fact that degree of dissection is likely to be controlled to large extent by the absolute relief. Dissection index continues to increase with rising altitude. It followed from this that steeper the slope, higher is the amount of dissection.

GEOMORPHOLOGICAL RESPONSE OF THE RIVERS OF DUARS UNDER FLASH FLOODS: AN ASSESSMENT UPON FIELD INVESTIGATION DURING THE RAINY SEASON OF 2019

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A study of the pattern of Geomorphological response of the rivers of Duars to flash floods has been reported in the paper. The study has been conducted during the rainy season of 2019 by collecting meteorological data and observing the conditions as well as the effects of flash floods on the river bed and on the surrounding areas. Several field investigations have been conducted at an interval of every fortnight. The mighty rivers as well as the small rivulets of the Duars area of this part, particularly at the foothills of the Himalaya, are found to have given rise to flash floods following periodical heavy rains. It has been found that due to rampant deforestation in this area, land degradation with soil erosion has been aggravated to a great extent and on these regolith-free scars numerous gullies have formed. They have extended down-slope forming ephemeral stream channels. Recently these stream channels, in particular, have been found to continue to pose threat of severe flash floods in the advent of rainy season. As the consequence of flash floods the typical and ostensible geomorphological features that have developed on the river and stream beds are mid-channel bars, meander bars and bank erosion features. In many of the river beds like that of Lish and Ghish, the channel beds have been found to have become elevated markedly up to the bank level (even higher) chocking the water flow through the channel and as a result causing catastrophic floods in the surrounding areas, which have affected the tea gardens as well.

Keywords: Geomorphological, meteorological, flash floods, deforestation, meander bars.

MORPHOMETRIC ANALYSIS OF KALINJAR RIVER BASIN, ODISHA USING GEOSPATIAL TECHNIQUES

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Morphometric analysis of basin is the best method to identify the relationship of various aspects in the area. The study is based on geospatial techniques where quantitative measurement is made on topographical and hydrological characteristics of the basin. Drainage basins are the best geomorphic unit for planning development purposes. It is also well observed that satellite data is emerging as the most effective, time saving and accurate technique for morphometric analysis of a basin. This technique is found relevant for the extraction of river basin and its stream networks through ASTER (DEM) in conjunction with satellite data (LISS-III and georeferenced SOI Topo-sheet, 2009). In this study, Kalinjar basin a tributaries of river Baitarani has been selected for detailed morphometric analysis. Eight sub-watersheds are also delineated within this basin to calculate the different morphometric attributes viz; stream order, numbers, lengths, bifurcation ratio, drainage density, stream frequency, circulatory ratio, etc., are calculated. The area of the basin is 504 km² and shows sub-dendritic to dendritic type drainage network. The stream order of the basin is mainly controlled by physiographic and lithological conditions of the area. The stream order of basin ranges from first to sixth order with the drainage density varies from 0.01 - 4.86 km/km² which indicates that the drainage texture is very coarse to moderate. The

increase in stream length ratio shows that the basin area has reached a mature geomorphic stage. This study would help the people to utilize the resources for sustainable development of the study area.

CAUSES AND EFFECTS OF FLASH FLOOD IN ALIPURDUAR DISTRICT, WEST BENGAL

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A flash flood that rises and falls quite rapidly with little or no advance warning, usually as a result of intense rainfall over a relatively small area. Bhutan Himalaya adjacent Alipurduar district is a flash flood prone area. Almost every year flash floods of varying magnitude affect some parts of Alipurduar district. Such catastrophic flash flood events occurred in this district in 1993, 1996, 1998, 2000, 2004, 2007, 2010, 2012, 2014 and 2017. An attempt has been made in this paper to visualize the impact of flash flood hazard on the environment, economy and society. Applied methods are field survey, case studies and secondary data analysis. The study finds that extreme rainfall, drainage system, construction barrier and lack of embankment effects on flash flood. The paper identifies river bank erosion, aggradationand water logging problems in the study area.According to human life lost and cattle lost, flash flood of 1993 was terrible event. The study finds flash flood effects on tea gardens, forest resources, quality of soil and water. This study will help on flash flood management in Alipurduar district.

FLOOD HAZARDS AND MANAGEMENT: A CASE STUDY OF DEOCHARAI GRAM PANCHAYET, TUFANGANJ, KOCH BIHAR DISTRICT

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Flood is the overflow of channel pattern. Deocharai Gram Panchayet of Koch Bihar District is much vulnerable for flooding. The two large rivers, Gadadhar and Kaljani are passing over Deocharai. These two rivers are much prone to flood, as rainfall is high in this region. Average rainfall is about 4000 mm. per year. Excessive water passes over this areas when heavy rainfall occurs in the upper courses areas of Himalayan and Terai region. Kaljani-Torsa, Gadadhar Riversare shallower near Deocharai, due to siltation problems.These are the main reason for flooding in Deocharai. Flood appear nearly every year here. Large flood occurred in 1993, 2001. Havoc destruction occurred here. Amon paddy sapling swept away due to flood. Bank erosion during and after flood appear as another problems for the farmers. Torsa-Kaljani and Gadadhar River swallow vast fertile agriculture lands, roads, houses each year. Shifting of river beds also destroy agricultural lands. Sand covers by flood water also change fertile agricultural fields into infertile sandy lands which are not suitable for agriculture. Large flood often harmful for life and properties. Sometimes human beings die by sink in flood water and flooded by flood water. Flood not only harmful for Deocharai. It brings blessing also. Ground water and water bodies recharge through flood water. Agricultural fields became fertile due to alluvial deposition each year. People of this Gram Panchayet not to leave this area due to fertile agricultural lands and leaving with flood. Flood management practices in this area are mainly on construction of embankments and levees only. Re-digging the ponds, ox-bow-lakes, khal bill and dredging of river can be helpful for holding flood water in rivers and abating flood effects.

Keywords: Flood, vulnerable, siltation, alluvial.

CHANNEL PROFILE ASPECTS (CPA) FOR ASSESSING CHANNEL CHARACTERISTICS: A STUDY ON RAYENG BASIN, DARJEELING HIMALAYA, WEST BENGAL

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For sustainable restoration of geo-environmental quality and natural characteristics of river basins, understanding of fluviogeomorphic characteristics in a systematic manner is necessary for fluvial geomorphologist(s) and environmentalist(s). The fluviogeomorphic processes of a river are influenced by hydrologic, geomorphic, geologic and climatic conditions. Anthropogenic activities may alter the fluvial processes artificially. Analysis of channel profiles of the rivers is one of the important relief aspects for the understanding of channel chacteristics. This analysis conveys the nature of fluvial processes and consequents of these processes on fluvial system. Climatic, hydro-geomorphic, geologic characteristics and tectonic activities of river basin are also understandable from the analysis of profiles as influencing factors of fluvial system. Fluvial cycle of erosion is understandable in better way by profile analysis. Abnormality in natural behaviour in channel characteristics induced by anthropogenic activities is also indicated by long and cross profiles of a river. The study area, Rayeng basin is covering an area of about 145.50 sq. km. The basin is extended over the areas of three C.D Blocks of Darjeeling District, West Bengal, India. The main objectives of the study are to understand channel characteristics through longitudinal and cross profiles of the targeted river and alteration of natural behavior owing to human interference. Field observation techniques and GIS technology have been applied for collecting data related channel morphometry. Topographical sheet (SOI) is also incorporated for analyzing basin characteristics. For statistical analysis SPSS (20.0) software is used. Scenario of cross profile indicates that, cross section area, hydraulic radii, wetted perimeter and discharges fluctuate seasonally due climatic condition of the study area. The steep gradient of the long profile shows that apart from the confluence with Tista, throughout the longitudinal course of Rayeng River vertical erosion is vigorous. Concave longitudinal profile of Rayeng river point towards that channel gradient decreases downstream depending on discharge.

Keywords: Channel morphometry, fluvial cycle, wetted perimeter (WP), confluence, Channel Profile Aspects (CPA), sustainable restoration.

KOLKATA'S URBAN DRAINAGE SYSTEM: HISTORY, HERITAGE & PRESENT SCENARIO WITH SPECIAL REFERENCE TO THE ADI GANGA

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Adi Ganga, the heritage river in the lower Gangetic plains of West Bengal, was the main flow of the Hooghly River from 15th to 17th century and is mentioned in several literary records of the pre Chaitanya era. However over time it ceased to be a free flowing channel and subsequently dried up. In 1550, Jao De Barros, a Portuguese sailor designed a map which showed that the water of Hooghly river flowed through Adi Ganga. The flow was further seen in the map of Van Den Broucke of 1660. In 1772 when Major James Rennell surveyed Bengal, the

drying of Adi Ganga has already begun. To revive the dying Adi Ganga, Major William Tolly in 1775 re-excavated the bed of the river from its off take point and dug a canal from Garia to Samukpota to connect Adi-Ganga with Bidyadhari River near Tarda Port. This stretch afterwards came to be known as Tolly's Nullah. *Tolly's Nullah* became one of the important navigational routes for some more year in the pages of history. Kolkata Municipal Corporation (KMC) since 1876 conducted several dredging activities to get back the flow in the river. However growing population, development of railways, population pressure unplanned urbanization, encroachment in after partition, continuous dumping of industrial/ residential wastes, changing landuse and construction activity (studied from SoI Topographical Sheet No 79B/6 &79 B/7 of 1911, 1959-60 LANDSAT images of 2011, 2016, 2019) caused further silting and decay of the Adi Ganga. At present it flows NNW-SSE through 22 wards of KMC and is one of the best example of an urban drainage channel undergoing hydro-geomorphological changes over centuries and is facing threat of extinction. Primary Survey (2017- 2019) of fluvial parameters (channel depth, channel width, cross sectional area, hydraulic radius, and thalweg values) at 14 stations and study of bathymetric plans of Kolkata Port Trust reveals that the river has lost its capacity to flow. Outside KMC, Adi-Ganga's original path south of Garia flows towards Sonarpur, Baruipur and Surjyapur but becomes invisible for several kilometers in Narendrapur-Rajpur Township before reappearing at Joynagar.

Keywords: Adi Ganga, Chaitanya era, Tolly's Nullah, Heritage River, Bidyadhari River, Urban drainage channel.

CAUSES AND CONSEQUENCES OF RIVER SHIFTING ALONG THE NAGAVALI RIVER IN RAYAGADA DISTRICT, ORISSA

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The Nagavali River along the Rayagada Town is presently flowing in north-south direction through the weaker sedimentary deposit in between two ridges located at the eastern and western side respectively. Earlier the river used to flow through the piedmont slope of the eastern ridge formed of hard Khandelite-granite where a small waterfall has been formed, locally known as Hatipahar. In the year 2006, a narrow canal from the main channel had been dug along the sedimentary deposit avoiding the granite rock for construction of a hydyl power project. On 3rdJuly, 2006, torrential rainfall occurred at the upper catchment of the river, both in Kalahandi and Rayagada Districts that supplied huge discharge through that artificial channel, created flash flood and resulted enormous amount of bank erosion. Because of this flash flood the Nagavali River started to flow through this canal leaving the earlier granitic course abandoned. After that single event the river has shifted about 550m westward and tolled about 0.54 km^2 loss of land. The newly formed course has incised itself 32m deeper than the previous course and still continuing head-ward erosion. This change is actively noticed upto 9.84 km upstream of the river. Another river oscillation is also observed at 17km upstream of the Hatipahar region, but that change occurred before the growth of human civilization over there.Google Earth and SRTM DEM have been used for demarcating location and spatio-temporal changes along the river. Intensive field survey has been carried out in order to prepare a micro level elevation model and to understand stratigraphic -lithological scenario of the area.The aim of the present study is to detect the causes of such changes and to estimate the consequences of such fluvial hazards over the civilisation located at the western bank of the Nagavali River.

Keywords: River shifting, flash flood; human impact; fluvial hazards.

NATURE OF BANK SOIL AND THEIR CHARACTERISTIC IMPLICATION ON LAND LOSS: A CASE STUDY OF MALDA DISTRICT, WEST BENGAL

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River bank erosion in relation to the loss of land and property usually creates serious concerns from geomorphological point of view. The present work is aimed to study the shift of bank line of river Ganga in Malda district in view of identifying the major soil profile characteristics by taking selected soil samples and performing their mechanical analysis to correlate the onus of bank material and resultant erosion. Primary data base through field investigation and world soil Grid data has been aimed to use to attempt the work. The work may be worth to establish the cause effect factors behind such fluviogenetic processes.

Keywords: Bank erosion, Soil profile, Soil sample, World Soil grid data.

MORPHOLOGICAL CHARACTERISTICS OF BHAGIRATHI HUGLI BASED ON BATHYMETRIC SURVEY IN THE MATURE DELTAIC TRACT OF NORTH 24 PARGANAS AND HUGLI, WEST BENGAL

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The Bhagirathi Hooghly, one of the major distributaries of River Ganga flows through the deltaic tract of West Bengal for a stretch of 260 km. The present study explores the morphological characteristics of the river for a stretch of 6km passing through the mature deltaic plains of North 24 Parganas and Hugli. The objective of the research is to examine the various data on cross profile parameters; interpreted the channel morphology and analyze the rate as well as nature of sedimentation of the river over a period of 14 years. The investigation is based on field survey conducted in April 2019 and analysis of unpublished hydrographic chart of the river Bhagirathi Hugli prepared by Kolkata Port Trust from 2005 to 2018. Echo sounder Garmin GPSMAP 585 PLUS has been used for bathymetric survey to take depth across 29 sections including 12 popular Ferry ghats of the locality. Instruments like auto-level was used for measuring the benchmark and tidal fluctuation. Geomatica v.12 has been used for registration and digitization of the hydrographic plans and corresponding Survey of India Topographical sheets 79B/5, 79B/6. Landsat MSS and IKONOS image of the 2012, 2018 were also consulted. The study shows that channel configuration of the river in this stretch are as follows viz. maximum depth (19.5m); minimum depth (0.1m); mean depth (4.22m); maximum cross sectional area (3352.84 sq. m); minimum cross sectional area (2044.70 sq. m); maximum width (911.51m) and minimum width (346.56). Shallow depth (0.2 -0.6 m) for a continuous stretch of 1.2 km can also be observed along the eastern bank of the river along Barrackpore subdivision in N.24 Parganas due to the formation of a point bar. The gradual elevation of thalweg (7.9m -0.3m) in the eastern margin proves that accretion has resulted in the formation of shoals and bars.

Keywords: Bhagirathi Hooghly, bathymetric survey, Echo-sounder, Channel configuration, cross sectional parameters, channel morphology.

SPATIO-TEMPORAL VARIABILITY OF BANK EROSION AND ACCRETION ALONG THE PUTHARJHORA-KRANTI REACHES OF THE CHEL RIVER FROM 1955 TO 2017

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We have studied bank erosion and accretion along a reach (Putharjhora-Kranti) of the Chel River, piedmont Sikkim-Kalimpong Himalaya over a period of 62 years (1955-2017) using Topographical maps, multi- temporal Landsat images, and supplemented by fieldwork to verify the findings derived from GIS analysis. The study reach is part of a region popularly known as 'Dooars' ,the zone of transition between the dissected upper Himalayan hill surface and the lower gently rolling Teesta- Brahmaputra plains, and is famed for notorious incidents of channel avulsion and river capture activities. Straddle like situation with two distinct physiographic units makes Chel basin experience rapid overland flow, erosion and landslides in the northern hilly terrain above the elevation 350m (approx.) whereas its piedmont in the intermediate and alluvial plain in the south is observing large scale sediment deposition, rise in valley floor and consequent shifting of channels. Channel dynamism of river Chel is causing large scale erosion along its course, damaging Tea Gardens, forests and agricultural lands. We have deployed overlay method for determination of areas of bank erosion and accretion by superimposing and comparing sequential changes in the position of banks in these years. The total area of bank erosion from 1955-2017 equalled 34.77 km^2, of which 12.4 km^2 occurred along the left bank and 22.4 km^2 along the right bank. Whereas during the same period the total area of bank accretion equalled 35.16 km^2, of which 18.99 km^2 was recorded along the left bank and 16.17 km^2 along right bank. The annual rates of erosion and accretion was much variable during different time periods. Spatially, the Oodlabari Bazaar-Nipuchapur Tea Garden section has suffered the most extensive bank erosion whereas Rajadanga-Kranti section of the study reach sustained minimal bank erosion. Further, right bank has recorded larger erosion compared to the left.

MEASUREMENT AND MONITORING OF STREAM HYDRAULIC GEOMETRY OF THE RIVER TORSA IN DUARS AND TAL REGION, EASTERN INDIA

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Hydraulic geometry of a stream channel is the analysis of interrelationships between *stream velocity, discharge, channel shape, channel width, channel depth, channel slope* and *sediment load*. The present study deals with lower reach of the Torsa River (56 km), which is situated in the Duars and Tal region, Eastern India. The corresponding data was collected from the field to find out the spatial and seasonal changes of *Hydraulic Geometry* of the Torsa River. Thirty-one cross sections were selected to derive data in regard to *hydraulic geometry* through field measurement. Surface and bottom water velocity and *water velocity* at different depths was measured using *digital current meter*. *Water Discharge* was measured for 12 months of last three consecutive years. *Flow pattern* and *nature of flow* were identified using *Reynolds number* and *Froude Number*. In the downstream of the Torsa River, Spatial and temporal variation of stream depth and velocity indicates the non-uniform flow pattern during all season. The values of *Froude number* range in between 0.11 to 1.15. *Reynolds Number* range between 184.38 and 5519.01. During monsoon turbulent pattern of flow is dominant. Maximum water velocity was measured as 0.493–2.213 m/Sec in pre-monsoon, 1.295–3.678 m/Sec in monsoon and 0.423–1.502 m/Sec in post-monsoon season. During the dry season scarcity of rainfall causes less discharge of water (131.24–304.43 m^3/Sec), reduction of *stream power* (9.06 J), *specific stream power* (0.025 W m^{-2}) and sediment transporting capacity. But in monsoon, water discharge (2381–3668.65 m^3/Sec), *stream power*

(2485.09 J), *specific stream power* (2.57 W m^{-2}) and sediment transporting capacity are noticeable. During monsoon, the rate of sedimentation is 10 to 50 times larger than other seasons. It may be concluded that the stream channel and its hydraulics parameters are inconsistent and unpredictable in the present study area.

Keywords: Water velocity, Flow pattern, Stream Power, Bank Erosion, Remote Sensing & GIS

BRAIDING DYNAMICS IN THE LOWER COURSE OF THE BALASAN RIVER, WEST BENGAL, INDIA

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Balasan, a right bank tributary of Mahananda River, is noteworthy for its dynamic fluvial characteristics. It is responsible for the formation of braiding patterns at the lower course of the river and abrupt changes in channel gradient where the channel adjusts. This braiding is highly fluctuating in the present study area. The present study is an attempt to find out the causes of such dynamic character of braiding. The Soil Water Analysis Tool (SWAT) model has been used to estimate the basic geomorphological and hydrological responses, like runoff, soil erosion and so on. Survey of India (SOI) Topographical maps of 1961-71, satellite images of IRS LISS III and Landsat series have been used to demarcate the nature of braiding and its temporal variation in different segments of the lower course of the river. Braiding patterns have been digitized from high resolution world view II images (provided by Google map) and corrected using IRS LISS III dataset. Braiding morphology has been determined on the basis of Braiding and Planform Index of Brice (1964). High intensity rains accelerate landslides and surface runoff in the upper catchment of the Balasan River and supply huge amounts of sediment to the lower course.Considering the fluvio-geomorphological process, the River Balasan is incapable of transporting these bed-loads efficiently under the existing hydrological conditions, especially in its lower reaches. Moreover, uneven sediment mining from the river bed from the debouching point till the confluence of the river with the Mahanadi River disrupts the natural flow of river and thereby and is considered to be themost important cause of such dynamicity of the braiding.

Keywords: Dynamics of braiding, human activities, SWAT

MORPHOMETRIC ANALYSIS OF UPPER NARMADA BASIN BY INTEGRATION OF REMOTE SENSING AND GIS

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Monitoring and mapping of landform are very expensive with lots of difficulties, field work then laboratory work. Remote sensing and GIS using satellite imagery, DEM become an important geographical tool in morphometric analysis and ground water studies. Morphometric analysis helps in planning and development of the region, so present study signify the various morphometric parameters with the help of various ordering watershed of basin area. The parameters worked out include stream order, stream number, and stream length, bifurcation ration (Rb) and sinuosity index (SI),Circularity Ratio, Elongation Ratio, Form factor, Drainage Density ,Stream Frequency, Absolute relief, Relative Relief, Dissection index. Topo-sheet, satellite

imageries, DEM are used as data sources for the analysis. Horton, Strahler, Schumm laws are used to achieve the targeted result. Are GIS 10.6, Global Mapper 10.2 GIS software's and GPS have been used here for various findings. Upper Narmada basin has 23089 sq. km catchment area and its parameter is 1652.20 km. The Upper Narmada basin is eight order drainage basins with drainage density ranges from 0 to 6 km per sq. km. Entire study concluded that there is geological and lithological control over the Upper Narmada basin drainage development.

Keywords: Morphometry, upper Narmada Basin, Remote Sensing and GIS, ground water studies.

AEOLIAN PROCESSES

ASSESSING DESERTIFICATION IN INDIA'S ARID ZONE USING VULNERABILITY INDEX: A CASE STUDY OF BIKANER DISTRICT, RAJASTHAN

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Desertification is a major problem in India as about 96 m ha or 30 % of country's total geographical area is affected by various process of land degradation. The problem is severe in the hot arid NW part of country of which Rajasthan shares 62 % area. A land degradation vulnerability assessment was carried out in Bikaner district of western Rajasthan, where terrain is sandy in more than 80 % area. The dune covered sandy landscape (in > 80 % area)in the district is fast changing into irrigated croplands due to availability of canal and exploitation of ground water. Such factors have either improved or degraded the status of natural resources. Wind erosion in the form of dust storms, sand movement and blown sand deposits has affected croplands and infrastructures. Salt ranns in 3 km^2 areas at Lunkaransar, gypsum mining at Jamsar and Kolayet in 48 km^2 area and gullied lands in 108 km^2 areas are other forms of land degradation. Despite such terrain limitations, over few last decades, net-sown area in the district has increased by 30 %, while culturable wastelands area has decreased by 25 %. Three major pressure indicators of land degradation; climate, land utilization and socio-economic parameters were analysed. Results showed Very high LDVI (Land Degradation Vulnerability Index) values in 31.2 % area, high in 28.5% area, moderate in 26.2 % area and low in 13.9 % area. Among the tehsils, Kolayet showed maximum vulnerability (in 26 % area) and Khajuwala has the lowest (6.61 % area). Efficient irrigation water management, expanding area under irrigated croplands, sand control measures are some the reasons for improving situations of land degradation in the district.

COASTAL PROCESSES

GIS BASED ASSESSMENT OF GEOMORPHIC CHANGES ON NEARSHORE REGION OF PURBA MEDINIPUR COAST, WEST BENGAL

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Beach erosion is a problem in many maritime countries and tackling of such problems is a real tricky job. The main problem has arised in Purba Medinipur coast is due to the shoreline recession, reorientation of beach gradient and resultant geomorphic changes. Such changes are not only eliminate forest resources but also interfered in surface, subsurface and groundwater hydrological systems. The dynamic behaviour of geomorphic processes in the nearshore region followed by wave refraction is become concomitant to inland exuviation over time. Moreover, natural and anthropogenic reciprocation ensures squandering of sediments along the coast and influence beach lowering. In order to justify considerable lowering of beaches in nearshore region five prominent cross sections were formulated from Bengal-Orissa border to Digha Mohona. Digital cartographic method was adopted to delimit the nearshore region based on CARTOSAT (PAN; 2.5 m) and LANDSAT multispectral imageries (Band 2, 3; 30 m). Four Transverse Alongshore Cross Sectional Profiles has drawn in this region to find out nearshore sediment fluxing effects on the coastal exuviation process. Research reveals that Convexo-concave slope of transverse nearshore region is superintend for shoreline shifting, changes in beach gradient and differences in sediment distribution. Therefore, an attempt has been made using advaced GIS based tools and techniques to assess geomorphic changes in nearshore regions of Purba Medinipur coast,W.B.

SHORE PLATFORM GEOMORPHOLOGY OF RAMESHWARAM ISLAND, SOUTHERN TAMIL NADU COAST, INDIA

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Rameshwaram Island is fringed with diversified shore platforms and backed by shore cliffs in Gulf of Manner, Palk Bay and Bay of Bengal. The shore fringes are characterized by underlying Calcareous Sandstones and overlying Carbonate rocks of coralline deposits and reef building Limestones. Topographically, the island is elevated up to 27 meter in heights in its north-northwestern part and surrounded by interior platforms of two different heights (5 meter and 10 meter). All three surfaces of the interior platforms are overlain by sand dunes, beaches and bars. In few places, the lower most surface reveals as raised beach fossil coral bank of ancient marine environment. There are sloping platforms and sub-horizontal platforms across the inter-tidal zone of the island and terminated in the low tide cliff or ramp. The carbonate rocks are karstified along the shore line configurations and affected by wave attack, rock saturation level and sheltered locations with response of uneven rate of cliff recession. In the present study, twelve shore transects are drawn around the island fringe platforms and tidal ranges of each section are estimated to highlight the relationship between shore platform gradient and tidal range. The study reveals that exposure of the shore line to wave attack, shore fringe rock types, weathering rate and water levels of the sea have produced the diversified shore platforms in the island.

Keywords: Calcareous Sandstones, Carbonate rocks, Limestones, Shore platforms & Karstified rocks.

CONTROLS ON THE PATTERN AND RATE OF MAT-GRAZING BY COASTAL CRAB POPULATIONS IN SAGAR ISLAND, HUGLI ESTUARY

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Crabs are the dominant benthic group onshore that successfully utilizes the coastal environment subzones for their feeding, dwelling, locomotion and other activities. The present work aims at finding the differentiation of different feeding crab populations based on their feeding pattern and products. Onshore grazing pattern of different crab populations (on algal mat) in the coastal fringes of Sagar Island, Hugli Estuary, is documented, based on quantitative estimation of the rate of bioturbation and percent area bioturbated. Digitized field photographs were used to estimate the percent change in feeding pellet sizes. Varied pellet size distributions were compared for their number frequencies in major bioturbated zones (I–IV) along a land to shore trajectory and in a creek proximal zone (V). At every observation site (I–V), photos were taken at 10 min intervals for an hour to record the function of space and time on the amount and pace of pelletization. Pellet sizes have been taken as proxies for the size of the pellet-making crabs, since pellet size is primarily determined by the accommodation space available in the buccal cavity of individual crabs. It appears from data that larger crabs appear in greater proportion, in the land proximal zones that gradually reduces shoreward. However, participation of larger crabs are persistently higher around the creek, perhaps reflecting a control of more abundant nutrient availability and subtle geomorphological convenience owing to higher relief and lesser inundation around creek bar. Smaller crab activity is comparatively lower that persistently offer higher input of smaller pellets in all zones, for all intervals of observation, except in creek proximal zone, where they are perhaps debarred from sharing the meal with the larger crabs, monopolizing the niche. It is observed that overall variation in cluster orientation is low (80º-120º) for all stations sub-paralleling the coastline. Even lesser dispersion (100º-120º) in the initial instants perhaps indicates preference of individual decision to remain in the shore parallel nutrient zones. This empirical study on crab feeding identifies some interesting trend in bioturbation that primarily relates to the intrinsic differences in the ethological responses of crab populations to the varied geomorphological, ecological and sedimentological conditions that determines the primary factor, i.e., nutrient supply. The present hypothesis is empirical in nature and thus need to be tested against similar data collected under varied coastal environment conditions.

BIOTURBATION-INDUCED CHANGES IN SEDIMENT DISPERSAL PATHWAYS: GANGASAGAR, HUGLI ESTUARY

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Active grain manipulations by the crab populations were estimated based on the percent surface area bioturbated and quantitative changes in different size fractions of bioturbated and non-bioturbated sediments, in the southern coast of Sagar Island, Hugli estuary. Observations were made on 10 shore normal zones constrained by distinct combination of geomorphology, primary sedimentary structures, textural attributes of the substrate sediment and bioturbation fabric recognizable in the field. Surface area bioturbated varies between 0.08% and 29.92% in these zones. Substantial bioturbation were recorded in the back swamp (6.87% of surface area), upper foreshore (12.33–29.92%) and distal lower foreshore (up to 6.89%). Excavation of burrows (for dwelling) in upper foreshore homogenized the temporal sediment populations inflicting a coarser mode and lower sorting value compared to that of hydrodynamically emplaced substrate sediment. Pelletization (for sediment ingestion) in distinct shore parallel nutrient zones, on the other hand, inflicts better sorting, coarsening in the bioturbated sediments compared to non-bioturbated surface sediments through selective removal of silt and clay fractions

during sediment ingestion. Retrogradation of delta in the studied part of basin in the last decade may be supported from the observed gradual straightening of the adjacent creek, probably in response to landward propagation of tidal impact. A fining landward grain-size distribution is common in a retrogradational estuarine delta. Lack of any such trend in the studied part of Sagar coast may be attributed to grain manipulation through bioturbation that obliterated the texture of background substrate sediments, yielding bioturbated sediment populations with no hydrodynamic equivalence. This quantitative estimate of change in sediment attributes through biological interference might help to constrain modelling on sediment dispersal in similar marginal marine set up.

SHORELINE CHANGE FROM HOLOCENE TO PRESENT AND TREND ANALYSIS

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The western coastal zone of India, including Kerala coast is more stable than east coast of India, even though being a high energy coast. Prominent geomorphic features that are active in Kerala coast include marine, estuarine, fluvial and denudation processes. Kozhikode is one of the fast growing cities of the Nation in Kerala state. Three river systems viz. Kallai, Korapuzha and Chaliyar are debouching into the Lakshadweep Sea along the 50 km long coast under consideration in Northern Kerala (*Kozhikode*). The two main harbours (*Quilandi* and *Puthiyappa*) play a key role in the fishing activity of the region. Along with the major estuaries, they also influence the micro-geomorphology of the shoreline. The paleo-shoreline of Kozhikode coast is identified 2.5 to 5 km landward from the modern shoreline in the Southern region (Beypur – Kozhikode), 1 to 2 km in the central region (Kozhikode–Elathur) and 1 to 2.5 km in the Northern region (Kappad–Quilandi). This well identified accreting coast is recently showing a negative trend of erosion for the 40 % of the total coastline. The accretion trend is decreased to an 11.28 % of the shoreline due to the increased use of coastal zone in an un-sustainable manner after 1980s. Out of 47.12 km total length of the coastline of the study area 45.03 km is protected by different means of coastal protection measures. 5 ports, 9 break waters, 19 groins and more than 30 km long seawalls were constructed since 1970 on this coastline. This study describes the anthropogenic influence on coastal stability through shoreline analysis of paleo-shoreline of Holocene age from present coastline with interpretation the recent shoreline trend by analyzing the shoreline change for last 50 years by using Digital Shoreline Analysis System (USGS).

STUDY ON SHORELINE MORPHODYNAMICS USING SATELLITE IMAGES ALONGSOUTH KERALA COAST

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Shoreline is a dynamic system where sediment gets eroded and deposited, and establishes an equilibrium via coastal processes (viz.: man-made or natural). The location of shoreline and the changing boundary with time has become keen importance to coastal engineers, scientists and managers. In this study, the shoreline morphology has been analysed using the digital shoreline analysis system tools in ArcGIS. The shoreline of the Kerala coast is a dynamic and recent threat to cyclones and an increase in wave height leading to considerable erosion. This study includes the analysis of the shoreline morphology since 1988 to 2019 using satellite images such as Landsat and LISS 4 datasets. Long term, annual and seasonal analysis has been carried out using the available image datasets. From the linear regression shoreline change rate analysis, at Valliyathura, Punthura

and Edapadu have been identified as zones of erosion, whereas Kottakal, Poovar and Karumkulam regions identified as zones of accretion along the south Kerala coast. The beach profile and field-collected shoreline data have been used for the comparison and validation of the shoreline derived from the satellite image data. The average error from LANDSAT derived shoreline and LISS 4 data is -11.8m and -1.5m respectively.

SPATIO-TEMPORAL VARIATION IN BEACH MORPHOLOGY: A CASE STUDY OF MANDARMANI

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Seasonal change in beach morphology is traditionally ascribed to variations in the incident wave energy with calm conditions in post-monsoon resulting in sediment accumulation and high energy conditions in monsoon resulting in erosion. The 13.5 km coastline of Mandarmani, West Bengal, is characterized by seasonal variations in beach morphology which can be explained by seasonal reversal of wind, wave, current and tide. The main objective of this study is to understand the spatio-temporal characteristics of beach morphology and to recognize the impact of the construction structures on the sedimentary balance along this coastal stretch. Mandarmani is a relatively new tourist destination of coastal land sharks in West Bengal and from the beginning of 21st century hotels started to come up in the area. The construction of hotel and other artificial structures have contributed in changing the beach morphology. Geomorphic mapping and seasonal profiling along 26 beach-transects reveal that the eastern sector adjoining Pichaboni inlet is the undisturbed part of the beach where anthropogenic impact is less and natural dune belts are present. The beach is relatively stable and more than 300 m wide. The western sector on the other hand exhibits the alterations of natural sand dunes by hotel construction, which hinders sand supply from dune to beach, eventually disturbing the beach equilibrium, resulting in relatively narrow beach affected by beach lowering.

COMPARISON OF SPATIO-TEMPORAL CHANGES IN ISLAND AREAS OF HUGLI AND MEGHNA ESTUARIES, GANGA–BRAHMAPUTRA DELTA: 1973–2019

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14 estuaries constitute the Ganga–Brahmaputra Delta (GBD), India and Bangladesh. Of these, the Hugli and the Meghna form its western and eastern limits respectively. To determine the changes in the island areas of these two estuaries between 1973 and 2019, land-water discrimination is made using NIR bands of Landsat data of 1973 (MSS), 1988 (TM), 2000 (TM) and 2019 (OLI). Island erosion, accretion, and trends of area change are statistically analysed. Digital Shoreline Analysis System is employed for estimation of shoreline change in selected islands. The results show that the Nayachar Island in the Hugli estuary, and the Nijhum, Montaj, and Char Ekkaria islands in the Meghna estuary are progressively increasing in area. Conversely, the Ghoramara, Jambu and Mousuni islands in the Hugli, and the Hatia and Bhola in the Meghna are continuously decreasing in area. Other islands of the two estuaries do not show linear and/or progressive change in area. Total island area of both the estuaries are increasing although the accretion rates are different. Net accretion rates of the islands of the Hugli and Meghna estuaries are 0.275 km^2 yr^{-1} and 7.387 km^2 yr^{-1} respectively. Projected estimates of selected island areas up to 2030 reveal that the Nayachar (Ghoramara) in the Hugli, and the Nijhum (Bhola) in the Meghna estuary will increase (reduce) its area by 9.11 km^2 (0.1 km^2) and 8.49 km^2 (17.121 km^2) respectively. Overall, the study indicates that the eastern part of the GBD is more active than the western part in terms of delta

building. This can be mainly ascribed to the Swatch of No Ground submarine canyon of the offshore GBD that acts as a passage for southward bypassing of the western shelf region by the river sediments contributed by the Meghna. This restricts sediment accumulation in the western side of the delta.

TECTONIC GEOMORPHOLOGY

MORPHOTECTONIC EVOLUTION THROUGH GEOMORPHIC PROXIES IN KALLAR WATERSHED OFACTIVE TECTONIC AND HUMID TO SEMIARID REGIONS OF CAUVERY BASIN, INDIA

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Internal tectonic processes deform the lithosphere while external climate forcing shapes the surface topography. Any perturbation caused by these processes will shift a landscape from its state of dynamic equilibrium to a state of disequilibrium. In this scenario geomorphic proxies are useful insights into understanding long-term endogenic and exogenic response to erosion and landform uplift rates in Kallar watershed. By evaluating two major proxies i.e. areal proxies (asymmetry factor (Af), mountain front sinuosity (Smf), shape factor (Shp) hypsometric curve and hypsometric integral (Hi)); linear proxies (river sinuosity (R), stream length gradient (Sl) and Chi gradient (Mχ)) and longitudinal profile were calculated for each micro watersheds. The study aims to evaluate the relationship between basin maturity and geomorphic proxis; along with internal correlation within the geomorphic proxies and understanding of morphotectonic evolution in Kallar Watershed of active tectonic and humid to semiarid regions of Cauvery Basin, India. The North and northwest micro watershed display convex shape hypsometric curves indicating a youth stage and significant tectonic influence. Mid portion has high river sinuosity which indicates the mature meandering stage of Bhavani River. The low and moderate Smf values within the micro watersheds are indicative of mountain fronts witnessing a high level of tectonic activity. The recent resurgence of tectonism is not only reflected in the shifting of Trunk Rivers, but is also evidenced by seismicity and landslides/faulting. The areal and linear proxies are positively correlated each other in terms of erosion rate and faulting. Present study reveals the active tectonic and the upliftment of landforms in upper part and central portion experiencing higher erosion. Through this understanding of local to regional level of tectono-geomorphic activity, further leads to neotectonic level of study for better understanding in more tectonically active regions.

ACTIVE TECTONICS IN THE AREA AROUND PIEDMONT ZONE OF THE SUBANSIRI RIVER, ASSAM-ARUNACHAL PRADESH

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The present study encompasses piedmont zone of the Subansiri River, which is one of the major tributary of the Brahmaputra River flowing down from the Himalayan hills to the plains in the Papumpare and North Lakhimpur district of the Arunachal Pradesh and Assam. In the study, attempt is made to understand the ongoing active tectonic activity in the area. Techniques adopted are determination of morphotectonic indices and field evidences of active tectonic activities. Survey of India topographic maps and SRTM data are used for the calculation of indices. The tectonic activeness is evaluated by morphotectonic indices such as Mountain Front Sinuosity Index (Smf), Valley Floor Width to Valley Height Ratio (Vf), Asymmetry Factor (Af), Transverse Topographic Symmetry Factor (T), Basin Shape Index (Bs), Mountain Front Steepness Index (S), Stream Length Gradient Index (SL) and Relative Tectonic Activity Index (Iat). The field evidences of active tectonic activity in the area are thrusting of Older Alluvium over Newer Alluvium, folding of Quaternary alluvium, presence of straight terraces and unpaired river terraces. It is observed in the area that splays originating from HFT is propagating southward and deforming Quaternary sediments. Some of the morphotectonic indices indicate area as tectonically active but other shows area as tectonically less active. There is an ample field evidences which points towards active tectonic activities. Some of the tectonic indices cannot be used to determine the active tectonic in the area with soft lithology and heavy precipitation.

ROLE OF ROCK-STRUCTURE IN GEOMORPHIC FEATURES DEVELOPMENT IN THE RANGIT RIVER BASIN, SIKKIM-DARJILING HIMALAYA

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Geology and tectonic of an area plays a very important role in the development of landforms. Rangit River Basin is a part of Sikkim-Darjeeling Himalaya that contains distinguished geological and tectonic characteristics. The basin has mainly three rock groups- 1. Darjeeling group, 2. Daling group, and 3. Gondwana group. The main attraction of this basin is Rangit Windows where underlying Gondwana rock group is exposed from overlaying Daling group. Rangit basin is featured by folded and fault structure. Geology map of Geological Survey of India, Topographical maps of Survey of India and other maps and data are used for details study of litho-tectonic setup and to identify geomorphic features of this basin. This study shows the relation among litho-tectonic setup and landform structure. Thus, the basin is the product of climatogenetic as well as endogenetic geomorphic processes. Evidences and identified from the faulting, folding, thrusting, fractures and cracks appeared in the basin. The basin also experiences the influence of neo-tectonism. Some micro features are also identified.

APPRAISAL OF NEOTECTONIC DEFORMATION WITHIN THE QUATERNARIES NEAR THE EASTERN HIMALAYAN SYNTAXIS FROM GEOMORPHOLOGICAL, GEOLOGICAL AND GEOCHRONOLOGICAL STUDIES

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A detail geomorphic and geological study from satellite images, DEMs and extensive field studies in the area along the foredeep of Naga-Schuppen belt and Mishmi hill in southern bank of the Brahmaputra has been done to establish the tectonic scenario during Quaternary time. This area is characterized by a spectacular NNW-SSE trending anticlinal hill named Manabhum hill. We interpret that the Manabhum hill represents an asymmetric antiformal fold which is a ramp anticline over an ENE'ly dipping thrust splay towards foreland, parallel to the Mishmi thrust. One transverse strike slip fault parallel to Naga thrust has been displaced the anticlinal axis to divide the Manabhum hill in two parts. The higher southern part is a conical hill with steeper western limb and gentler eastern limb. A small piedmont zone with a distinct terrace system has been formed in the foreland of the western limb. For the first time we have dated the sediments of different stratigraphic horizons by OSL method and have found that the formation of Manabhum anticline started during late Pleistocene around 220+ 36ka and is still growing. The transverse strike slip fault represents the deformational adjustment to the complex compressive environment in the area and the last movement along this fault is in Holocene time around 9.2+ 0.5ka shifting the lowermost terrace. The present day geomorphology is mainly controlled by the ENE'ly dipping thrust with considerable effect of the strike slip fault. We interpret that though this area lies south west of Eastern Himalayan Syntaxis (EHS) within the Quaternaries, it is mostly affected by the movement of Mishmi thrust followed by Naga thrust. As it is one of the most tectonically active region during Quaternary time in South East Asia, it may act as a key to understand the movement of Indian Plate along Eastern Syntaxial zone.

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 Alaknanda River is a significant parental river of Ganga and forms an 11.5 km long and 2.5 km wide valley, 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 10.1 software. The approach of the study is that the Alaknanda River in Srinagar valley is divided into 8 meander segments of three reaches from Supana to Kiratinagar. 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 phages 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 wave length 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.

DISPLACEMENT-LENGTH RATIOS AND CONTRACTIONAL STRAINS OF WRINKLE RIDGES IN THAUMASIA MINOR, MARS

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Statistical analysis of the geometric properties of the populations of the planetary tectonic structures (e.g. faults, joints, veins, dikes and deformation bands) are commonly used to understand the basic mechanical controls on the growth of a wide range of these geologic structures. Studies conducted by earlier workers showed a relationship between the maximum displacement (D_{max}) and length (L) of fault populations on terrestrial and planetary surfaces. The D_{max}-L ratios have been used to describe an average long-term equilibrium stress field. Wrinkle ridges, formed due to blind thrust faults, are compressional structures found abundantly on Mars. Fifteen Wrinkle Ridges in Thaumasia Minor were studied using MOLA/HRSC Blended DEMs. Several topographic profiles were extracted for each wrinkle ridge near their midpoints to measure their height and maximum displacement (D_{max}). Displacement and length values of the wrinkle ridges were plotted on a graph. The D_{max}-L ratios (γ) is then calculated by a linear fit method according to the D-L data. The γ value of ridges in Thaumasia

Minor was found to be (1.2×10^{-3}). The contractional strains (ε) in Thaumasia Minor is estimated to be ~0.13% (fault plane dip θ is assumed to be 25°).

QUATERNARY BASIN EVOLUTION AND PALEOSEISMICITY ADJACENT TO NAGA SCHUPPEN BELT IN JORHAT AND GOLAGHAT DISTRICTS OF ASSAM

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In the study area number of river basins are present within Quaternary alluvium which implies that these basins are developed during Quaternary Period. These basins lies within the block bounded by Jorhat Fault, Naga Thrust and Dhansiri Lineament. The area is undergoing active tectonic deformation and upliftment. In the present study, the morphotectonic parameters have been computed from topographic map, satellite imageries, DEM and field evidences of active tectonics are collected from extensive field investigation. Morphotectonic indices such as Basin Shape Index (Bs), Asymmetry factor (Af) and Transverse Topographic Factor (T) have been calculated, which indicate active tectonic deformation. The upliftment of piedmont zone in the frontal region of Naga Thrust is evident from dissected topography due to northward propagation of Naga Schuppen Belt which is named as Jorhat Fault. Excavations made on the bank of the Desoi River at various sites revealed soft sediment deformation. The structures include gentle disharmonic folding, lateral spreading, minor fold, faults, sand dykes and sills. As this deformation and liquefaction structure are observed in the recent deposit of Desoi River which are of Holocene age it indicates active tectonic deformation and paleoseismicity of the area. The Inqua Environmental Seismic Intensity Scale (ESI-2007) is used to classify liquefaction structure according to intensity required for development of these structures. It has been accessed that the area experienced the earthquake of intensity between VIII to X.

Keywords: Jorhat fault, Naga Thrust, Dhansiri Lineament, Seismites, Desoi, Younger Alluvium, paleoseismicity.

PROVENANCE STUDIES THROUGH HEAVY MINERALS ANALYSIS OF TYRSAD-WEILOI CONGLOMERATE OF EAST KHASI HILLS, MEGHALAYA

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Heavy minerals are sensitive indicators of provenance with density denser than 2.85 g/cm^3 and can be identified based on their physical properties. Determination of sediment provenance is mostly done through heavy mineral studies as it provides important information on the mineralogical composition of source areas. For the present study heavy mineral analysis was carried out on fifteen conglomerate samples by gravity separation method using Bromoform to interpret the provenance of the sediments. Mineral compositions of conglomerate clasts vary as much within individual formations as they do from one formation to another. Conglomerate in this area consists dominantly of particles greater than 2mm in size. Heavy mineral analysis was carried out at the Petrology and Chemical Division, Geological Survey of India,North-Eastern Region,Shillong,Meghalaya. The result suggests that the heavy mineral assemblage of Apatite, Monazite, Sphene, Zircon, Epidote, Garnet, Magnetite and Biotite found in Tyrsad-Weiloi conglomerate of the study area is suggestive of multiple provenance dominated by the source igneous rocks mainly by acid igneous rocks and granite pegmatites few from basic igneous rocks and metamorphic rocks.

Keywords: Provenance, Heavy minerals, Zircon, Monazite, Garnet.

'PRESENT IS THE KEY TO THE PAST': A ROCK WITH MULTIPLE EVENTS

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'Present is the Key to the Past' a geological doctrine proposed by Sir Charles Lyell (1797-1875), is to be explained by the present-day evidences. The evidences of the present lead the researcher to explain the multiple events that occurred in the past. The present study deals with the rock sample which was predominant in the foothills of the Eastern Himalaya of eastern duars. The vast and large amount of rocks that were carried by the turbulent rills of the region reveals the history of the formation of the region. For this rock samples were collected from the Rocky Island which is situated on the banks of the river Murti. It is a small village settlement located 3kms away from Samsing, Jalpaiguri. The authors try to explore the tectonic activity, geological history as well as the processes involved. For this purpose, the authors visited the places several times and performed intensive field study. They have collected several rock samples and a sample (Mylonite) has been taken into consideration for the present study. They have analyzed the rock sample minutely and by this, they try to know the provenance which is dealt with the question where the rocks came from and how they got to the place they are today. The study area is a part of the extra peninsula, made up of rocks of ages ranging from pre-Cambrian to Quaternary. The geological formations of the region consist of Siwalik, Darjeeling Gneiss and Daling Group of Proterozoic era. The Quaternary deposits such as boulders, gravels, pebbles, sands, and silts which were formed by glacio-fluvial as well as fluvial action are also dominant in the region. The outcome of the result has been discussed and possible inferences have been made in this regard.

Keywords: Geological history, Field study, Provenance, Mylonite, Geological formations.

BURI RIVER, INDIA AND BANGLADESH: CHANNEL PLANFORM CHANGE AND ITS SIGNIFICANCE

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The Indian state of Tripura and some parts of eastern Bangladesh is characterised by six N–S aligned westerly convex anticlines and their intervening synclines belong to the Chittagong–Tripura Fold Belt (CTFB). The west-flowing Buri (110 km in 2017) originates from Baramura and falls into the Meghna River in Bangladesh plain. Topographical sheets, satellite images, and oral history suggest that the river is changing its planform since 1932-33. The aim of this work is to study the planform change for the last 85 years. The planform of the Buri is extracted for 1932-33 (Survey of India 'inch' maps), 1962 (Corona photos), 1975–88 (Landsat-1 MSS & Landsat-5 TM data), and 2017 (Resoucesat-2 L4fmx data). Based on curvature of the meander belts and change in the river course, the Buri is divided into 36 reaches – 33 of them alluvial. The sinuosity index of each reach is calculated for the four survey/imaging years to determine the extent of change. Shuttle Radar Topography Mission elevation data (3 arc second tiles) of the region is utilised to bring out structural signature on drainage using profile analysis, SLK Index and Basin Asymmetry Factor (AF). Finally, chi-map of the Buri and its surrounding basins is taken into consideration to observe the topographic stability of this region. Results show that changes in channel length and sinuosity are mostly confined to the alluvial reaches of the Buri. Notably, near Jampai (Reach–9), the channel length decreased from 4.56 km to 4.18 km and the sinuosity decreased from 1.6 to 1.4. In the stretch (Reach–17) between Nabachandrabari and Gholaghati, the channel length decreased from 9.45 km to 5.64 km and the sinuosity decreased from 2.1 to 1.2. From Sipahijala to Kasba (Reach–20), length decreased from 4.46 km to 3.09 km with decrease in sinuosity from 2.0 to 1.3. The long profile of the

Buri shows certain convexities along the profile, which coincide with the planform changing reaches. The convexities support the surface instability which are corroborated by morphotectonic indices. The variation in the SLK Index along the river profile suggests that the planform is reversely changing in the comparatively steeper reaches along the river profile. A basin AF of 31.9 indicates that it is a right-asymmetric basin. The χ map of this area shows that the water divide is migrating towards Buri basin at its headwater region. The probable reasons behind the irregularities might be the neotectonic activity in the CTFB. Other possible causes include long term increase in rainfall, and increase in sediment load due to land use change and/or landslides.

MATHEMATICAL MODELLING OF LONG PROFILES IN A TECTONICALLY ACTIVE AREA: OBSERVATIONS FROM THE RANGIT RIVER, INDIA

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The longitudinal profile of a river is one of the most popular indicators for assessing the degree of tectonic and structural control in a fluvial system. Sensitive to long-term tectonic, structural and climatic regimes, long profiles have been employed all over the globe and the anomalies in the long profiles are often been interpreted as evidence of active tectonic deformation. With the advent of high-resolution DEM datasets such as, SRTM, ASTER, etc. many large rivers of the world have been studied and analysed with respect to structure and tectonics. The present study is one such attempt for the Himalayan Rangit River in Eastern India. Physiographically located in the Eastern Himalayan Division of the Himalayas, this river is a small, steep-gradient tributary of the Tista River, debouching its waters into the Tista near Melli (27°04'47"N, 88°25'56"). SRTM DEM at 30m resolution was procured for the area and the drainage network and the watersheds of the major tributaries as well as the trunk stream were extracted using the D8 routine in an ArcGIS environment. The long profiles were smoothened by the 11-point Moving Average method so as to remove all the major artefacts and spikes that may have arisen due to the inherent limitations in the SRTM dataset. This was followed by mathematical modelling of long profiles and estimation of the SL Index. Steep segments in the rivers were identified by normalizing the SL Indices and comparing with the average SL index. Finally, the shape of the long profiles was quantified from the power law regression equation between basin area and channel slope. Analysis of the long profiles of the Rangit River and its major tributaries reveals elevated magnitudes of most of the long profile parameters suggesting intense erosional regimes in the rivers. It is a well-known fact that the Himalayas are under active tectonic movement due to continuous collision of the Indian plate with the Eurasian landmass. Therefore, it may be concluded that the anomalous characteristics of the long profiles in the Rangit River and its tributaries may be ascribed to active tectonic deformation.

EARTH'S INTERIOR AND RECENT ADVANCES IN GEOPHYSICAL MINERALS AND THERMODYNAMIC STUDIES

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In this paper, we have been studied about the Earth's interior and crucial understanding of the mineral composites and its thermodynamic behavior under enormous pressure and temperature. In fact, the most of Earth's interior is unpredicted samples from its. So how we know what is down to the Earth? Knowledge of the elastic behavior of rocks is required for the solution of many problems in geophysics. The elasticity of materials is important for our understanding of processes ranging from brittle failure, to flexure, to the propagation of elastic waves.

Seismologically revealed structure of the Earth's Interior, including the radial (one-dimensional) profile, lateral heterogeneity, and anisotropy are determined largely by the elasticity of the materials that make up this region. Despite its importance to geophysics our knowledge of the elasticity of potentially relevant mineral phases at conditions typical of the Earth's mantle is still limited: Measuring the elastic constants at elevated pressure temperature conditions in the laboratory and theoretically remains a major challenge.In the present study, the proposed equation of state and phenomenological theory is applied to investigate the study thermal expansivity and bulk modulus of various classes of geophysical minerals and provides the non-linear models for variation of both thermal expansivity and bulk modulus with temperatures and pressure. The results obtained for various Earth's minerals are discussed and compared with experimental results. The computed values of thermoelastic properties have shown a good agreement with available experimental results. It is concluded that a new expression is capable to predict the elastic properties of Earth's minerals under high temperature and pressure conditions.

Keywords: Earth's interior; geophysical minerals; AEOes; mantle; core; seismic waves; elastic properties; high pressure; high temperature.

TECTONIC CONTROL ON ALLUVIAL CHANNEL MORPHOLOGY: A CASE STUDY IN THE PINGLA FAULT ZONE OF KHARI RIVER BASIN, EASTERN INDIA

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North to south extended Chotanagpur Foothill Fault, Basin Margin Fault and Damodar Fault of Western Bengal Basin in the West Bengal part separates the *Rarh* physiography into three major morphotectonic blocks. Pingla Fault and Garhmayna Khandoghosh Fault are another two surface faults of the same fault system. The stretch of Khari River crossing the region of Pingla fault has been selected as the study reach. The reach length has been classified into upstream segment and downstream segment of fault based on the standardised composite Z score value of morphotectonic indices. Major objective of this paper is to study the downstream alteration of channel morphology at faulted zone. Stream profile, channel parameters and sedimentary facies have been applied for tectonic interpretation. The data have been collected through field survey and from topographical map which were analysed in ArcGIS and SPSS software. The results indicate the fault activity and that is reflected through downstream anomalies in the channel morphology, offset river channel and compressed meander to sinuous channel pattern. Downstream hydraulic gradient enhances 50% with comparison to fault upstream segment and that indicates increasing channel gradient which results to ~81% increment of stream length gradient. Lower gradient and compression of channel by faulting causes of compress meander with SI value of 2.85 which steadily decreases to 1.64 in downstream. The normal flow tendency of stream is NW to SE but at faulted zone stream is flowing from North to South.

Keywords: Channel morphology; channel pattern; tectonics.

GEOMORPHOLOGICAL HAZARDS AND RISK MANAGEMENT

FLOOD AS AN ANTHROPOGENIC HAZARD: CASE STUDY OF THE 2016 FLOOD OF BIHAR

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Bihar is one of the most flood prone states in India. During the August 2016 flood of the Ganga, 15 (out of 38) districts, 3,459 villages and, 8.82 million people of the state were affected. The present study was carried out to investigate the causes of this flood and the role of Farakka Barrage in it, as this structure was widely made responsible for the event. To explore the factors behind the event, we prepared drainage networks of the region by using SRTM elevation data and Landsat-8 OLI images. Inundated area was traced by applying MNDWI on MODIS data of 25 August 2016. Different hydrometeorological parameters employed in the study include percentage departure of monthly rainfall; discharge data of selected dams and barrages: Bansagar Dam (on River Son), Valmikinagar Barrage (Gandak), Birpur Barrage (Kosi), Indrapuri Barrage (Son), & Mohammadganj Barrage (North Koel); and gauge data from six stations along a 526 km stretch of the Ganga: Buxar, Gandhi Ghat (Patna), Hathidah, Munger, Kahalgaon, & Manikchak Ghat. It was found that the flood was mainly caused by rapid release of water from the Bansagar Dam on the Son from 18 to 20 August 2016, as a tropical storm traversed through its upper catchment. Contributions from the Ganga's upstream and the Himalayan tributaries were negligible. The flood peak (50.52 m), recorded at Gandhi Ghat on 21 August 2016, passed downstream, and reached Manikchak Ghat (25.78 m) on 27–28 August 2016. The upstream limit of flooding due to the highest recorded flood level at Farakka Barrage (26.66 m) can only reach up to 9 km below Kahalgaon. Therefore, the extensive flooding of the area between the Son outfall (27 km above Patna) and Kahalgaon cannot be explained by impoundment at the Farakka Barrage.

WATER CRISIS IN WESTERN REWA UPLAND, MADHYA PRADESH

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Present study region is drained by Bihar, Bichiya, Mahana, Odda, and their tributaries Bihar and Mahana are the tributaries of Tons river. All these rivers originate from Kaimur and Rewa scarps and central undulating plateau and make radial, barbed, dendritic, trellis and parallel drainage system. All these rivers are not Perennial River. These rivers get water in rainy season. Present study region has hot and humid monsoonal climatic conditions which are characterised by moderate winter, hot and dry summer, post rain season and hot-moist rainy season. In this way region receives maximum rainfall in rainy months of June, July, August and September. During rainfall season the rivers of study area flow with increased volume and velocity of water. Numerous small clay dams are constructed to chuck surface runoff so that people of study region can utilize the water of artificial reservoir during dry season. This water is used for irrigation and drinking purposes. But the rivers of study region have less amount of water from February to mid-June.Stored water is the life line for the people living in this region. This water is not long lasting because rainy season has the duration of four months and the water is consumed for the rest months. From March to mid-June people face severe problem of water. Bore holes fail to provide water in dry season whereas in wet months people grow paddy harvest due to excess amount of water. Some efforts were made to provide water to the region. The water of Bansagar project is a boon for the people living in the region. But this efforts is not sufficient to meet the needs of people. People fail to crop green vegetables in dry season due to scarcity of water and are dependent on the districts of Uttar Pradesh. This region needs some multi-purpose projects to meet the problem of water scarcity. Due to change in monsoon axis region is getting extra amount of rain water in wet months but this water flows through rivers and leaves region soon.

ANALYSIS OF FLOOD SUSCEPTIBILITY AND VULNERABILITY IN GHATAL BLOCK, PASCHIM MEDINIPUR DISTRICT, WEST BENGAL USING MACHINE LEARNING AND GIS METHODS

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Ghatal Block in Paschim Medinipur district, West Bengal experiences recurrent annual flooding and sustained water logging. For mitigating the resultant economic and environmental damages, proper flood risk assessment is paramount. This paper analyses this area's flood susceptibility and the socioeconomic vulnerability of its villages to inundation events through a combination of Analytical Hierarchy Process (AHP) and GIS methods. For analysing the flood susceptibility, spatial layers of eight causative parameters were prepared, which were standardised and weighted using the AHP-Fuzzy based method to obtain the final flood susceptibility output by comparison with historical inundation maps. Location Quotients were used to demarcate the Gram Panchayats which ranked higher in the aforesaid susceptibility risk assessment and were thus most inundated by the flood events. For ascertaining the local residents' vulnerability to these flood events in these Gram Panchayats, village level demographic and household amenities data were used, which were combined into a flood vulnerability index that elicited the villages most at risk. The results obtained during the susceptibility analysis revealed that the flat nature of the area's terrain characterised by its low elevation and slope and the confluence of a number of drainage lines within it, were the most influencing factors in causing such flood events. The division of the flood susceptible zones into high, medium and low categories and the computation of the location quotients of their coverage within each Gram Panchayats elicited the most affected areas. The vulnerability analysis of these Panchayats noted that villages located near the main river that were far away from the local town and had few road linkages were most at risk from these flood events.

FLOOD PLAIN MAPPING AND IDENTIFICATION OF FLOOD PRONE ZONES ALONG BANK OF GANGA RIVER WITHIN ALLAHABAD CITY UTTAR PRADESH

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Distribution of meander movements in space and time is an important geomorphological phenomenon for a river during its course in gentle plain. And it affects the peoples residing in vicinity of the river bank while flooding. Present study aims to identify the flood zones arising due to such meandering of Ganga River in Allahabad. Allahabad, officially known as Prayagraj is located between 'doab' of mighty Rivers Ganga and Yamuna. Northern part of the Allahabad city is affected by recurrent flood during monsoon as Ganga River encircles the northern extremes of the city. Within city, the areas occur along the western bank of Ganga in stretch of around 20 Km viz Kachar areas of Newa, Draupadi Ghat, Nawada, Ganga Nagar, Rajapur, Beli Mahendauri, Salori Baghadam Buxi bund and Daraganj as well as jhunsi at opposite bank are prone to flood. Haphazard construction and development of settlement within these active flood plains areas are creating alarming situation and prone to disastrous condition for the habitats in near future. Satellite images of the past years are utilized to prepare active flood zone map of these area. Also encroachments by people in the form of all structures (residential, commercial, religious, farm houses etc) lying in active flood plain of the River are demarcated and zones are identified susceptible to flood hazard. Identification of such zones is helpful to prepare the proper town of Allahabad City as regard to these areas.

GIS-BASED LANDSLIDE SUSCEPTIBILITY MAPPING OF RESHI RIVER BASIN

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Landslides are among the most important natural hazards that lead to modification of the environment. Landslides cause adverse effects on human lives and economy worldwide. Therefore, studying of this phenomenon is so important in many areas.The high hillsides of the Reshi river basin are prone to landslides due to the climatic conditions and the geological, geomorphological characteristics of the region. At first, landslides occurred in Reshi river basin was identified using Google earth image. Therefore, it is vitally important that landslide susceptibility maps of the region be prepared. This paper presents modelling of landslide susceptibility mapping using remote sensing data and GIS tools.A total number of 14 landslide causative factors, such as elevation, Slope, Curvature, Lineament density, Rainfall, Drainage density, Soil, Lithology, Relative relief, Road density, Settlement density, Land use/ Land coverand the topographic wetness index (TWI) were used in the analysis. All these factors are extracted from the spatial database constructed using remotely sensed data and topographic maps. Next, weighted raster thematic maps with assigned values for their classes were multiplied by the corresponding weights and combined to yield a simple map where each cell has a certain landslide susceptibility index (LSI) value. After reclassification, this represents the final susceptibility map of the study area. The susceptibility maps produced using LCM, FR and AHP models had four different susceptibility classes such as low, moderate, high, and very high. From the prepared map 90% of these landslide zones fall into the high and very high susceptibility zones of the analytic hierarchy process (AHP) method, or 80% in the case of the linear compositing model (LCM) method and 95.2% with the frequency ratio (FR) method. The results showed the AHP and FR methods to give a more realistic picture of the actual distribution of landslide susceptibility than the LCM method.

ROLE OF CULTURAL INSTITUTIONS IN DISASTER MANAGEMENT: A STUDY IN CULTURAL GEOMORPHOLOGY OF MAJULI ISLAND, ASSAM

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Riverbank erosion by River Brahmaputra has led to the loss of land in 110 out of 243 villages in Majuli Island of Assam. The most significant impact of riverbank erosion has been on the livelihood pattern of the island, as erosion has affected both agriculture and fishing activities. The villagers, who have lost their agricultural land, or have seen fishing grounds move from their village, receive very little help from the government because of a clause in India's disaster management law that does not recognise riverbank erosion as a natural hazard. As a result of this limited government intervention, cultural and religious institutions like *Satras* help in providing relief, supporting adaptation, and increasing the resilience of the hazard hit communities of Majuli. This research uses geospatial technologies to assess the damage caused by riverbank erosion and explores how in the absence of government support, the cultural institutions are helping the citizens of Majuli to cope with riverbank erosion and its impact on agriculture in the island.

Keywords: Cultural Geomorphology, Majuli, Riverbank Erosion, Cultural Institutions, Disaster Management, Geospatial Technologies.

AN ASSESSMENT OF SPATIAL VARIABILITY OF SOIL SALINITY AND ITS IMPACTS ON MANGROVES: A STUDY IN THE PARTS OF HENRY'S ISLAND, SOUTH-WESTERN SUNDARBAN

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The coast of Henry's island, extending from Saptamukhi River in the east to Bakkhali River in the West. In the hot and humid climate of the Sundarban, a negligible input of fresh water through tidal creeks,high evaporation rate at the surface area are the probable reasons behind the evolution of saline patches of Henry's Island. The growth of saline blanks over the mature tidal flat surface of the Sundarban create a negative impact on regeneration process on mangroves. The present paper attempts to highlight the characteristics of saline blanks ,covering the issues i) Identification and evolution of hypersaline areas ii) Characteristics of mangroves seasonally iii)Analysis of soil properties iv)Impact on degradation of mangroves etc. Monitoring of soil and water quality, total station survey,repeated field checking and application of Remote Sensing and GIS techniques are employed for temporal mapping analysis of soil as well as to analyse the growth and evolution of saline patches. Major study reveals that the degradation of the mangroves in Sundarban are mainly due to the rapid rate of extension of hyper saline blanks , climate change and increasing rate of pore water salinity due to sea level rise. Intervention of human activities is another factor of mangrove degeneration in Henry's Island. Development of such saline blanks are mainly observed within mangrove swamp where these blanks retard the growth of mangrove along with collapsing the ecosystem. Forest department has come forward with new techniques of afforestation and ditching to combat the problem, but without proper understanding the geomorphology and background of the area it is not possible to control the situation and save the Island for better place for floras and faunas.

Keywords: Regeneration, Saline blank, Swamp, tidal flat,tidal creek.

SPATIAL PATTERN OF LANDSLIDES IN UTTARAKHAND: A GEOGRAPHICAL ANALYSIS

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Landslides are simply defined as downslope movement of rock, debris or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. India has a diverse physiography, active plate boundary, complex fluvial geomorphology and extreme climatic condition which make it more vulnerable to the natural disasters. In India, about 0.42 million sq. km i.e. 12.6 percent of land area, excluding snow covered area is prone to landslide hazard. In North West Himalayan region Uttarakhand state has higher number of landslide zones than Himachal Pradesh and Jammu Kashmir. Various Physical as well as anthropogenic factors are responsible for the occurrence of landslides. Geological structure, fault and thrust zones, slopes, elevation, drainage and earthquakes are the major factors that are responsible for triggering the landslides. The state of Uttarakhand is vastly covered by high Himalayan Mountains comprising of Himadri and Siwalik ranges, where several major and minor rivers originate. The existence of such mountainous terrain in the state makes it prone to many natural disasters such as earthquakes, landslides and floods. The entire state is tectonically very active and lies in seismic zone IV; therefore it is subjected to landslides, even due to low frequency earthquakes. Besides physical factors, anthropogenic factors such as construction of roads, massive scale deforestation for developing the area are also responsible for occurrence of landslides. Landslides not only affect human life and property but also have a devastating impact on the flora

and fauna. In the present study an attempt has been made to analyze the spatial pattern of landslide occurrence in Uttarakhand state.

Keywords: Landslide, Physiography, Thrust & Fault, Vulnerable, Anthropogenic, Gravity, Seismic zones.

IMPACT OF FLOOD AND SILTATION ON SOCIO-ECONOMY: A CASE STUDY OF PAGLAM CIRCLE, LOWER DIBANG VALLEY DISTRICT, ARUNACHAL PRADESH, INDIA

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Lower Dibang valley district of Arunachal Pradesh is very prone to flood and siltation because of various hydrometeorological and topographical characteristics of the river basin. Dibang the main river of Lower Dibang valley district has long been considered as a problematic river in the history of the area due to recurrent and extensive flooding. Flood and siltation in the lower course of Dibang river basin is characterized by their extensive devastation. Paglam circle of Lower Dibang valley district is being falls under the downstream area of the Dibang River. The area has been studied with special reference to recurrent of floods and impacts of flood on socioeconomic. Similarly 7 sample villages were selected from the active floodplain area viz, Anpum-I, Anpum-II, Anpum-III, Loklung, Paglam-I, Paglam-II and Paglam-III. Household survey was carried out with detailed questionnaire. Statistical methods were applied to understand the intensity of impact of the river on socioeconomic activities of the people. The study revealed that in the study area flood caused by heavy rainfall, rapid melting of the snow and anthropogenic factors which accelerate intensity of floods and enhance resultant damages in the region. It is found that in 2014 &2015 floods more than 350 houses were washout by Dibang and Sinkin Rivers apart from that tremendous loss to cropland, Govt. properties, livestock etc. Losing of residential and agricultural land are key issue and problematic issue. The proper management, flood mitigation measures are of vital importance for bringing prosperity in the pre dominantly agro-based economy of this circle and district as a whole.

DISPLACEMENT OF THE SHORE FRINGE SETTLEMENTS: THE POSSIBLE SIGNATURE OF SEA LEVEL RISE IN THE SUNDARBAN

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The global warming induced sea level rise has produced two major effects along the shorelines of the Sundarban coastal zones. Among them the rapid rate of shoreline recession and submergence of the low land coasts during coastal floods in the northern Bay of Bengal. The present study reveals that the long stretch of earthen embankments and associated settlements behind them are demolished in many places along the shore fringes of Boatkhali-Shibpur, Bishalakshipur, Beguakhali, Ghoramara, Lakshmipur and Gobardhanpur villages of the Sundarban. The repeated landfall of cyclones, high surges of tidal waves and the high water level during the monsoon months are now regulating the coastal dynamics along the sea face of the Sundarban. The repeated field survey, SOI Topo-sheets, Sentinel 2 A and Google Earth Images of the area provided information for the above study to identify the abandoned settlements and damaged embankments of the island fringes. The rapid rate of shore line recession is recorded with analysis of temporal satellite images and DSAS Software uses for the study region. The above study shows that many settlements of the sea face are getting submerged and

engulfed by the sea since the previous decades of the last century by advancement of the sea into the interior parts of the land in the Sundarban islands. The relationships between high tidal ranges, increasing tidal prisms, cyclone catastrophes of the past and relative sea level rise due to land subsidence are established in the present study to highlight the impacts of sea level rise in the region.

Keywords: Global Warming, Sea level rise, Sentinel 2A Images, DSAS, Abandoned settlement.

FLOOD HAZARD: HOUSEHOLD VULNERABILITY AND RESILIENCE IN SOUTHERN DISTRICTS OF WEST BENGAL WITH SPECIAL REFERENCE TO 2017 FLOOD

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Flood is a serious, common, and costly hazard in southern districts of West Bengal and the state has a long-recorded history of flood. The main objective of this study is to assess the flood hazard scenario alonh with vulnerability and their resilience capacity in southern districts of West Bengal. Flood inundated area was delineatedby using remote sensing data (Radersat 2). Flood danger level and warning level was identified by using maximum instantaneous discharge data and gauge height of various Gauge stations.Socio-economic elements i.e. population density, female population ratio, 0-6 age group population, literacy rate, income were considered for assessing the vulnerability at district level. Village level flood vulnerability was carried out by considering the parameter like height of the water level, damage, house type, preparedness, income, emergency service etc. Rainfall, river and dam discharge data were analyzed for assessing the flood scenario. Damage related data were collected to assessing the spatial variation of hazard intensity. The result shows that 42.4% of the total geographical area of the southern districts of West Bengal was affected by flood. Rainfall data analysis revealed that South Bengal district received excess rainfall from 31% to 72% during July 2017. Apart from excess rainfall, release of water from different reservoirs created flood havoc in the vulnerable blocks of Hooghly and Howrah districts during last week of July. From 25th July to 8th August, the cumulative discharge from Durgapur barrage was 26,57,750 acre-feet of water with the peak discharge of 2,49,450 cusecs on 27th July. Vulnerability assessment at district level of Hooghly district shows that the Polba, Dadpur and Arambagh block have very high socio-economic vulnerability. Village level vulnerability assessment at Kalipur Village of Arambag block of Hooghly district shows that 11% of surveyed houses are made up with bamboo and earth materials and 28% of households are equipped with good emergency services whereas, only 15% of households have safe drinking water availability during flood.

Keywords: Flood, hazard, vulnerability, rainfall.

RESILIENCE IN THE FACE OF NATURAL HAZARDS: A CASE STUDY OF GHORAMARA ISLAND, SUNDARBAN, INDIA

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The ecosystem of Sundarban is the largest coastal wetland of the world. Shared by two countries India (38%) and Bangladesh (62%), Sundarban has been vulnerable to natural hazards mostly ravaged by tropical cyclones, embankment breaching, saltwater incursion and resultant shift in occupation. The Indian Sundarban comprises of 19 community development blocks, 13 of which belong to South 24 Parganas and 6 of which belong to North 24 Parganas. Physiographically, Sundarban is a deltaic plain criss-crossed by a network of creeks. The inhabitants of Indian Sundarban (4.2 million according to 2011 census) earn a living from agriculture which is largely monocropping. Other occupations as aquaculture, extraction of non-timber forest products also exist. Ghoramara, an island on the Hooghly estuary has been eroding due to fluvial erosion. Temporal change analysis from previous studies indicates a rate of erosion of 6.72 hectares per annum at Ghoramara. Premature reclamation of islands for settlement in the form of constructing embankments has resulted in loss of sediment input by the rivers as a result of which Ghoramara remains starved of sedimentation. Ghoramara is presently peopled by about 1000 families. A total of 5500 voters still exist in the island. The major source of income is betel vine cultivation. According to local inhabitants, the eastern, north western and northern sides have been eroded much. The recent measure of fortifying the western side with boulders and mesh has arrested erosion there. Though erosion still continues, the local inhabitants are resilient enough. They opine that they have nowhere to go. Some families have been relocated in Jibantala Colony of Sagar, Kakdwip and Namkhana. The people still staying at Ghoramara choose to remain there. The premonition of a quickly vanishing island is far flung.

FLOOD SUSCEPTIBILITY PREDICTION ASSESSING THE GEOMORPHOLOGICAL CONDITION OF THE RIVER BY USING WEIGHTED BASED RATING METHODS IN GIS PLATFORM: A CASE STUDY IN LOWER AJAY BASIN, INDIA

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Flood is most common and natural disaster of the world. Fluvial flood occurred by the combination of hydro-geomorphological effect. But during the flood risk assessment geomorphological condition analysis is always ignored. Present research is aimed to focus on flood assessment in the lower part of the Ajay river on the basis of present geomorphological conditions. Flood character analysis on the basis of present geomorphological status of the river also helps in the management strategy formulation. Remote sensing data, traditional topographical sheet and field work reach the present geomorphological status of the river. Most significantly the channel property like cannel carrying capacity, sinuosity, active channel ratio, channel width depth ratio, bar formation, shifting of the channel etc. are considered for measuring the spatial flood probability. Different layers of geomorphic character are prepared in the GIS field as per objective. By using the weighted score from the decision based matrix flood predicted area is extracted in the field of GIS and the risk area is also classified according to intensity of the flood. The extracted flood predicted area also validated with the past flood history and evaluated the importance of the existence flood protected measuring. The variation of the channel width and depth of the river is also responsible for flood condition. Due to the bed sand quarrying and embankment construction in this river rate of the sediment deposition is rising and decreasing the channel carrying capacity of the river. High sinuosity of the channel is increasing the flood risk probability in the lower part region and embankment failure is very common due to sinuous channel.

Keywords: Disaster, Hydro-geomorphology,GIS, Sinuosity, Carrying capacity.

DELINEATION OF FLOOD PRONE AREA USING REMOTE SENSING AND GIS TECHNIQUE: A CASE STUDY OF ALIPURDUAR DISTRICT, WEST BENGAL, INDIA

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Flood hazard is one of the most harmful disasters in the world. The occurrence of flood event has become common phenomena in several parts of the sub Himalayan region during monsoon period. There are numbers of river like Kaljani, Sankosh, Raidak, Jayanti, Dima. Torsa originated in Himalaya and passes through Alipurduar district. Being a riverine district, every year people are experiences flood. Almost all the administrative blocks of the district are more or less flood prone. The main objective of this study is to identify the flood prone area within the district. The purpose of this study is delineating the flood affected vulnerable zone and suggests some remedial measures to get out of it. In order to carry out the study Land sat images is used to identify the land use and land cover by using remote sensing and GIS technique. All information extracted from satellite imageries are imported into Arc GIS, and spatial analysis is carried out to identify the vulnerable zone of the study area. Digital Elevation Model data is used for two dimensional modelling. This data interprets of topographic data that implemented flood inundation area. Demographic and socio-economic factors are playing a role in increasing society's exposure to weather and climate related damage, through factors such as housing developments in areas vulnerable to flooding and other risks. The result shows that flood area has observed within the study area. Hence the flood vulnerable area is able to be identified anddelineated.

Keywords: Flood, settlement, remote sensing, GIS, vulnerability.

FLOODS IN UPPER KRISHNA BASIN AND THEIR REPERCUSSIONS

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River flooding and erosion are common natural disasters that severely affect the landscape, lives and economy of the country. Krishna River is one of the important river systems in Maharashtra State. The Krishna River and its major tributaries like Koyna, Panchganga, and Dudhganga Rivers originate in Western Ghat between 600 and 1400m ASL from South to North. The source region of these rivers receives high average annual rainfall which is more than 2500 mm. These conditions lead very high discharges through these rivers during monsoon season. The altitude and high rainfall in the source region is suitable for dam construction and therefore, several dams are constructed in this area. Heavy downpour in the source region causes frequent floods in downstream areas of these rivers. The discharges of the dam water and natural runoff caused recent flood in this region. The floodplain region of Krishna and its tributaries is one of the most fertile and intensively cultivated regions of Maharashtra State. The tributaries like Panchganga and Dudhganga drain as a part of upper Krishna River and exhibit meandering planform morphology. Flood discharge conditions of these channels cause change in channel morphology like formation of chute channels or cut-off channels. The chute channels along the Panchganga, Dudhganga and Krishna River are observed near Kurundwad, Akivat, Shirguppi and Sadalgi. The floods in Panchganga and Krishna cause flooding of these chute channels. The flooding and the process of cutting off the channels is causing erosion, loss of agriculture land, damages to the crops and halts the agrarian practices. The recent floods in the areas Sangali and Kolhapur District are the evidences of economic losses, damages caused to agriculture land, the crops, cattle and human losses.

APPLICATION OF REMOTE SENSING AND GIS IN FLOOD MANAGEMENT: A CASE STUDY OF THE JIADHAL RIVER BASIN OF DHEMAJI DISTRICT, ASSAM, INDIA

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Flood is among the most common natural hazard or the destructive act of nature which destroys many lives and properties including agriculture, houses, roads and bridges, etc. Flood occurs when there is heavy rainfall in the upstream areas and it also occurs due to the dam failure, breach of embankments and many other topographical and hydrological factors. Jiadhal River frequently changes its channel and creates flood havoc in the district. Most often flood in Jiadhal Catchment is due to failure of embankments and shifting of channel course in the river. Application of space technology has been regarded as the most powerful tool in many aspects of flood management. Jiadhal River draining in Dhemaji District of Assam has been taken as the study area. Elevation data from ASTER DEM has been processed for Elevation class, Slope class, drainage density class, Flow accumulation, Geomorphologic unit, Proximity to drainage, proximity to confluence. Data on Land Use Land Cover, Ground water table, Soil type from different sources have been integrated with geomorphometric data using weighted overlay method using standard weights for each parameter. A flood hazard zone map has thus been created on the basis of overlay method. Village level flooding and vulnerability map has been generated. The result is encouraging and it can be used for flood management, flood warning system and rehabilitation purpose in the Jiadhal basin.

Keyword: Remote Sensing, Flood Management, Jiadhal River, Dhemaji.

LANDSLIDES IN DARJEELING HIMALAYA: CAUSES AND ITS MANAGEMENT

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Landslides are the significant form of natural disaster that causes the loss of properties and lives, especially in the mountainous regions. Landslides are usually related to instabilities of slopes. In the foothills of Himalaya, where the rainfall is prominent the occurrences of landslides is significant. The Darjeeling Himalaya is among the most vulnerable areas of landslide. Rapid modernization, large scale deforestation, lack of proper and controlled drainage system, lack of proper construction, excessive vehicle movement, development of town and tourism industry are also responsible for the increase of vulnerability of landslides in this region.

RIVER BANK STABILITY MEASUREMENT THROUGH SOIL TEXTURE ANALYSIS: A STUDY ON UPSTREAM OF GANGA NEAR MANIKCHAK, MALDA, WEST BENGAL

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One of the important geo-hazards associated with a river is bank erosion. In recent years the district of Malda has been facing ravages of this hazard by the continuous left bank erosion by the river Ganga although the entire district has witnessed rapid bank erosion, the riverine villages of Diara blocks in Malda district has become famous in terms of this hazard as it has been at the receiving end for a major proportion. A large chunk of land has been lost due to continuous bank erosion by the River Ganga. Therefore, numerous papers concentrating on the bank erosion and the consequent socio-economic transition in Diara blocks are available. This paper focuses on river bank stability measurement through soil textural analysis of bank materials in respect to different layers of its whole vertical stratigraphie on selective sites along left bank. Basic objectives of this study are to model the spatial variations in the bank stability and bank erosivity and to determine the shear strength and erosivity of soil and their implications on the river bank stability of the Ganga River between Rajmahal and Farakka. Here river bank strengthens measures through arrangement of bank materials and their uniformity level in respect to its whole vertical extension, similar bank materials extension and Locational analysis within extension and its capability of resistance of water heat of river.

RIVER DYNAMICS AND FLOOD HAZARD MANAGEMENT: APPLICATION OF RS AND GIS

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River dynamics and discharge of water are interlinked by a number of factors. The flow pattern, energy transformation and the basin components are the major factors behind the modulation in river dynamics and flood situation. The explanation of the theory of river dynamics is the basis to account for the flood hazard occurrence as well as the practical applications of river dynamics phenomena in the flood hazard management is the practical component of a particular basis area. The rate of water discharge and energy input can create a massive change to water level at any stream and at in the area of interest. Hence it is the theory and the practical application of river dynamics to management and modifications of flood hazard management of the area. The present study seeks to unfold such implication through maps, diagrams and interpretations. To extend the dynamic features of river dynamics in flood management few selected river basins have been selected as the study area. The data have been collected from IMD, Irrigation department, NATMO and Survey of India. All the data are secondary in nature. Apart from the above mentioned sources some other books and journals are taken as a good source of information about these area of study. Apart from these satellite images are also taken to derive information for the same purpose. The analysis have been done in GIS and RS software , Microsoft and finally they have been presented in diagrams and maps .The various applications like DEM , NDVI have used to strengthen the analysis part . The maps has components of the river basin and the susceptibility for flood occurrence as well as scope for management in the study which has been elaborated by the application of RS and GIS.

Keywords: Basin component, River dynamics, Flood management, DEM, NDVI

HYDRO-GEOMORPHOLOGICAL CHARACTERIZATION AND PRIORITIZATION OF SIKKIM-DARJEELING -BHUTAN HIMALAYAS WATERSHEDS USING REMOTE SENSING AND GIS

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The study aimed to characterize the hydrogeomorphological nature of the Sikkim-Darjeeling-Bhutan Himalayas' (SDBH) watersheds and prioritize them using quantitative morphometric approach coupled with remote sensing and GIS techniques. Jaxa 30m DSM, Sentinel 2B satellite image, digitized drainage network, geological and geomorphological maps were analyzed in GIS environment to infer the hydrogeomorphological character and behaviour of the different watersheds of SDBH. Results from the morphometric analysis show that the most of the watersheds originating from Sikkim, Darjeeling and Bhutan Himalayas possess medium to high drainage density, stream frequency and infiltration number, low to medium Rho coefficient, very high average watershed slope, ruggedness number and relief ratio and high to very high relief. Findings of this research suggest that the watersheds are underlain by various resistant rocks, more prone to flooding and high sediment yielding which are responsible for hazardous behaviour in their downstream reaches spread over the piedmont region. There is a need to manage these types of watersheds with a very high energy environment to minimize the severity of hazards and reduces their casualties. To phase-wise management implementation, watershed prioritizations have made using Weighted Sum Average (WSA) method. It is found that 16 watersheds covering 4200 sq.km fall under very high priority. Thus, the study demonstrates the usefulness of morphometry aided by statistical analysis and Remote Sensing and GIS in hydrogeomorphological characterization and prioritization of watersheds.

Keywords: Watershed, Morphometric, Remote Sensing, GIS, DSM, Drainage network.

LANDSLIDE AND GULLY FORMATION IN TWO GRAM PANCHAYETS OF RIMBICK AND SIRI KHOLA, DARJILING DISTRICT: THEIR CAUSES AND IMPACTS ON LOCAL PEOPLE

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Landslide and gully formation are two geomorphic processes solely guided by gravitational force. Though the magnitude of these downslope movements is mostly dependent on physical factors like the structure, climate and slope of the ground; but may sometimes depend also on human activities. The region under study, i.e. two Gram Panchayets–Rimbick and Siri khola, located in the north-western part of Darjeeling district, shows a typical mountainous physiography along with high altitudinal environment. Apart from fragile ecology large parts of the villages are covered with human settlements and associated roadways. The Rimbick dam is located just below the Rimbick Gram Panchayet. All these physical and anthropogenic factors have made the region susceptible to various types of mass movements of which landslide and gully formation are most spectacular. The developmental activities during the last three decades have increased the areas affected by mass movements considerably. These denudation processes also retard the planning system in many parts – causing frequently civic and economic losses too. The present paper is hereby trying to find out main causes of landslide and gully formation in the said region along with their impact on activities of local people in brief but vividly.

A CATASTROPHIC FLOODING EVENT IN NORTH BENGAL, 2017 AND ITS IMPACT ASSESSMENT: A CASE STUDY OF RAIGANJ C.D BLOCK UTTAR DINAJPUR, WEST BENGAL

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Flood is the condition when a river spread their waters in nearby adjacent areas after cutting their banks. In 2017 Raiganj (Uttar Dinajpur) was experienced a dismal flood due to massive rainfall at the Mahananda river basin area. Because of this pungent rainfall, there was an excessive water flow in the Kulik River (Main River of Raiganj city). The water carrying capacity of the Kulik River was not enough to carry the excessive water and as a result, the river was overflowed by the water. Water spreads over the floodplain areas as well as Raiganj city area and was created flooding like conditions in urban areas. Actually, Urban Flood is caused by the blockage of water in an urban city and there is no alternative way to pass the blockage water from the city. Due to this destructive flood a vast area of Raiganj block was poorly affected, such as part of Bhatun, part of Jagadishpur, Part of Mahipur, Part of Bindole, part of Sherur and part of Subhashganj and another hand ward no 3, 11, 13, 18, 16, and 22 badly affected due to this flood of Raiganj Municipality region. Poor maintenance of drainage system, unplanned development, Excessive rainfall, Unhealthy growth in human settlements, etc are the reasons for that type of Flooding. The destruction that was caused by the flood was very much pungent and tormenting. There are some remedial to avoid or reduced such types of destruction caused by floods, such as Reforestation, Making Concrete Dams, Time to time management of dams, etc.

GEOMORPHOSITES

EVALUATION OF SPRINGS AND WATERFALLS AS GEOTOURISM SITES THROUGH SWOT AND TOWS MODEL AT AJODHYA HILL, PURULIYA DISTRICT, EASTERN INDIA

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Ajodhya hill is an extended part of 'Chota Nagpur Gneissic Complex' (CGC) located at the western part of West Bengal in the district of Puruliya. This uplifted plateau land is primarily composed of Archean granite and gneissic rock with the sharp break at the plateau fringe. Ground water comes out through the fractures of the granitic rock base situated under the permeable red soil as spring. Waterfalls are prominent along the steep slope of the plateau fringe. Thirteen springs and four waterfalls have been identified as important Geomorphosites to analyse their Geotourism potential at Ajodhya hill in response to its geologic and geomorphic background. SWOT analysis has been applied in order to gauge the Geotourism potentiality of Ajodhya hill. To analyse the potentiality, weight and score has been given under each factors and weighted score has been calculated. The total weighted score of IFEM (internal factor estimate matrix) which includes strengths and weaknesses is 3.3 and total weighted score of EFEM (external factor estimate matrix) which includes opportunities and threats is 3.12. Both the final weighted score is more than 2.5 which means the strengths overweight the weaknesses in case of IFEM and vice-versa. Few strategies have been suggested for enriching the Geotourism potentiality at Ajodhya hill with the help of TOWS matrix. Prioritization of the strategies has been ascertained by QSPM (quantitative strategies planning matrix) model through which the ranking of total attractiveness score (RTAS) has been estimated. These quantitative analysis and models can be well suited for determining the tourism potentiality of a place.

PROBLEMS AND PROSPECTS OF GEOMORPHOSITE-TOURISM IN THE INTERFLUVES OF INDIAN SUNDARBANS

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Sundarbans is the playfield to the tidal channels shaping and reshaping numerous geomorphic features since thousands of years. Not only it is the single largest growing mangrove delta in the world but is the only homeland left to lots of endangered mammals, fish, reptiles and many varieties of species of the tropical South Asia. The typical fluvio-geomorphological environment of the habited and uninhabited interfluvial parts of this delta, the dynamic erosional and depositional landforms forming/formed by the intangible tidal channels, and the historically adventurous mangrove-safari in search of tigers inside the creeks along the Bay of Bengal, have made the Matla-Bidyadhari, Jamira-Matla, Gosaba-Harinbhanga Interfluves etc. most attracting tidal geomorphosites in India and abroad since decades. But geographically, these interfluvial parts of Indian Sundarbans are yet, not so developed as expected like other delta-oriented geomorphosites-tourism in different countries. This paper is mainly oriented to the need for searching the major natural and/or artificial obstacles coming in the way of the development of geomorphosites-tourism in Indian Sundarbans with some new prospects.

SUSTAINABLE DEVELOPMENT GOALS AND GEODIVERSITY-GEOTOURISM: TOWARDS EXPLORING THE POSSIBILITIES OF GLOBAL PARTNERSHIP FOR MUTUAL BENEFITS

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The Sustainable Development Goals (SDGs) were conceptualized at the United Nations Conference on Sustainable Development in Rio de Janeiro, in 2012. The primary objective was to produce a set of universal goals that meet the urgent environmental, political and economic challenges facing our world. The SDGs replaced the Millennium Development Goals (MDGs), which started as a global effort in 2000 to tackle the ignominy of poverty. The MDGs established measurable, universally-agreed objectives for tackling extreme poverty and hunger, preventing deadly diseases, and expanding primary education to all children, among other development priorities. The SDGs came into effect in January 2016, and these will continue to guide UNDP policy and funding until 2030. UNDP, as the lead UN development agency, is distinctively placed to help implement the Goals through its works spread in almost 170 countries and regional units. A 3-tier grouping of the 17 SDGs clearly proposes to achieve the highest level of possible welfare of mankind in harmony with the diversity of nature and culture. SDGs 1- 10 are mainly people-centric, followed by ecological (SDGs 11-15), and spiritual (SDGs 16-17) which may be placed in a pyramidal arrangement. The last two goals seek to promote peaceful co-existence of people and nature, and are possible only through mutual respect and cooperation at both global and local scales. Geodiversity-Geotourism (GDGT) may be recognized as an effective means to develop this partnership through universal brotherhood for a win-win solution of many pressing problems of our days. This paper is an attempt to explore the possibilities of implementing the SDGs through GDGT in the context of the *Jangalmahal* area of West Bengal.

Keywords: Sustainable Development Goals (SDGs), Geodiversity-Geotourism (GDGT), Jangalmahal, human welfare, and universal brotherhood.

ASSESSMENT OF MORPHOMETRIC CHANGE OF LOWER MEGHNA RIVER OF BANGLADESH USING REMOTELY SENSED DATA

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River channel dynamics are natural autogenic occurrences for fluvial rivers with influences from human modifications and climatic factors. Remote sensing and geographic information system tools and techniques, aerial photographs, and satellite imagery have been used to determine epochal channel erosion, accretion, and unchanged locations along Meghna River, Bangladesh's widest river. In this study the dynamics in Meghan's morphometry has been assessed from satellite remote sensing data. In order to assess the fluvial channel dynamics, land water ratio, sinuosity ratio, braided index, shifting of mid channel and erosion and deposition of the selected study area have been studied and measured in GIS tools. Through the implementation Modified Normalized Difference Water Index (MNDWI) the water surface of 1978, 1999 and 2018 have been extracted which were the base of all the computations. The island area percentage of 2018 (around 35%) was much higher than the other two years indicating deposition in islands. Though the Meghna River is not a sinus river or completely meander river, the results from sinuosity (1.07 in 1978 to 1.13 in 2018) and braided index (2.85 in

1978 to 4.38 in 2018) depicted the increase in sinuosity and meanderings. The mid channel shifting analysis showed that the Meghna is highly dynamic with its migration in both West and East direction. The migration rate is higher in 1999-2018 than 1978-1999 in almost all the segments. The Meghna River have been found to be highly unstable since the erosion and deposition rate is very high. This rate of erosion and deposition is much higher in the present time than before. Formation of island through extensive deposition and erosion of bank line are the main factors of Meghna's instability and migration. Morphometric analysis has high level of implementation for water resource management of the Meghna river basin. Subsequently, the morphometric parameters could be integrated with hydrological and hydrogeological data, and geophysical information, that will help to take decision regarding suitable sites for water conservation structures for groundwater development and management program. This information is crucial for understanding river evolution characteristics and aid in planning and management at the lower reaches which has remained poorly understood. Use of remote sensing data in concert with GIS provides efficient and economical quantitative spatial and temporal analysis of river channel changes.

Keywords: Fluvial channel dynamics, temporal analysis and morphometric analysis.

GEOMORPHOSITES OF THE ANDAMAN ISLANDS

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The Andaman group of islands is renowned for its rich biodiversity and natural resources. The unique geological and geomorphological features found in different parts of the archipelago are natural assets, which should be conserved. The term 'geomorphosite' or 'geomorphological heritage' includes sites or places of natural landforms that gained lot of attention due to human intervention and have the potential to attract tourists. These landscapes also provide scope for various research activities. There are several geomorphic sites or areas of scientific, aesthetic and economic value in South and Middle Andaman that should be included in the national geoheritage list. The Andaman Islands have a dark history stemming from the British colonial rule that attracts many visitors, who wish to learn about the island's ancient records. The terminology 'Geotourism' refers to tourism that sustains or enhances the distinctive geographical characteristics of a place which is gaining attention all over the world.These islands well qualify to become a Geotourism hub if proper promotion is undertaken by the authorities. In order to bring this to reality, a comprehensive documentation of these sites is required that should be subsequently published over web portals to attract attention across the globe. In this case study, an attempt has been made to prepare an inventory of the geomorphosites of the Middle and South Andaman Islands. Three of the major sites that can be considered as geomorphosites here include Baratang Island (mud volcano), Neil Island (rocky coast features including natural arch), and Barren Island (stratovolcano). This exercise is expected to promote Andaman's tourism industry into the limelight, which is currently in a nascent stage.

URBAN GEOMORPHOLOGY

DELINEATION OF THE SPHERE OF URBAN INFLUENCE: A SPATIAL APPROACH OF SIX MUNICIPALITIES OF Cooch Behar DISTRICT, WEST BENGAL, INDIA

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Growth of an urban centre and the regional development of that place are correlated to each other. Availability of different facilities affect the people of that place by changing their socio economic condition and also its benefit spread over the people on those who resides in the hinterland of that urban centre. Optimum level of urban growth mainly depends on the capacity to provide the required facilities to peoples. Hierarchical growth of urban centres in associated with available basic amenities help in regional development in a hierarchical way. But in case of developing countries, like India, some urban centres have more facilities with the higher regional influence whereas some are deprive for the facilities though having a large number of population.This paper is an attempt to calculate the functionality and delineating the extension of influence with radius over the rural part of six municipalities of Cooch Behar district which was a princely state in pre independence period. The result shows that, the highest radius (km) of circle indicating the sphere of influence is for Cooch Behar municipality and the least is for Mekhliganj municipality. Along with this, this paper also examines the adequacy and inadequacy of facilities for the urban centres which will be helpful for the future planning of these urban centres and a balanced regional development would be achieved.

Keywords: Urbanization, Functional weightage, Sphere of influence.

SPATIO-TEMPORAL ASSESSMENT OF URBAN FLOODING AND ITS GEO-ENVIRONMENTAL CONSEQUENCES: A CASE STUDY OF LUCKNOW CITY

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Urban flooding is an exclusive term used to denote the extensiveness of flood and large scale water logging in the cities as a cumulative urban manifestation of the interaction of heavy rainfall and upstream-downstream dynamics during the monsoons, disappearance of natural drainage system, unplanned urbanization and poor infiltration due to widespread concrete surfaces in urban areas. Indian citiesare being increasingly the specific targets of regular urban floods and their vulnerability against the same has increased many folds. Many cities in India, therefore, have recently experienced loss of lives and properties, disruptions of power, transport and communications and incidences of epidemics. Most notable amongst them are Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009 and Delhi and Ahmedabad in 2010. Again in 2011, 2012 and 2013; Delhi, Mumbai and Chandigarh have suffered the plight of urban flooding. Recently in 2018 and 2019, Kerala, Mumbai, Chennai and many more have gone through one of the worst urban flooding during the last 50 years. Lucknow has also been a regular victim of urban flooding disrupting the life of city dwellers. Present paper attempts to identify the factors which are responsible for the urban flooding and localised water logging in the Lucknow city.GIS technique has been used to identify the vulnerable areas with the help of LISS-III and Cartosat imageries. The present study is an attempt to highlight the role of natural drainage system in creating and mitigating the problem of urban flooding in Lucknow city.

Keywords: Urban flooding, Monsoon season, Natural drainage, Vulnerability, Mitigation.

ESTIMATION OF TOTAL IMPERVIOUS SURFACE AREA IN MICRO WATERSHEDS OF NASIK URBAN AGGLOMERATION

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The increasing impervious surfaces within urbanizing watersheds pose threats to naturally built environment. It includes increased runoff, decreased water quality, degraded terrestrial habitats and diminished aesthetic look of streams and landscape. Impervious surfaces are mainly constructed surfaces such as roads, parking lots, sidewalks, rooftops covered by impermeable materials such as asphalt, concrete and stone paving. Impervious surfaces occur within urbanized areas containing commercial, industrial, transportation and medium to high density residential areas. Identification of total impervious surfaces within urbanized watersheds is important for urban environment planning and management. Present work attempts to estimates spatio-temporal growth of impervious surfaces within micro watersheds of three sub-basins in Nasik urban agglomeration from the year 1989 to 2017. Analysis reveals that from 1989 to 2017 i. e. during 26 years, micro watersheds of the Godavari sub-basin and Nasardi sub-basin shows 20 to 40 percent growth of impervious surface as compare to Waldevi-Darna sub-basin with 15 to 20 % growth. This uncontrolled conversion of land from permeable to impervious is a serious threat to both natural and built environment within urbanized watershed of Nasik city. The destruction and alteration of natural land cover and transformation of cropland to residential area, malls and parking lots are degrading the aesthetic quality of many micro watershed of Godavari, Waldevi and Darna sub-basins of Nasik urban agglomeration.

AN ASSESSMENT OF CAUSES AND CONSEQUENCES OF URBAN FLOODING IN PRAYAGRAJ CITY: A CASE STUDY IN URBAN GEOMORPHOLOGY

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The recent flood situation in Prayagraj city has made the life of city residents miserable especially in low lying areas of the city. The flood situation in the city is basically an imported flood as it is caused by the influx of rainwater coming through the tributaries of River Yamuna from Madhya Pradesh and not from the local rainfall. The situation has been aggravated by the excess water released from the dams of Madhya Pradesh. However, heavy rainfall in Prayagraj city during the last few days of the month of September had made the situation out of control as it re-energizes the receding level of water in the River Ganga and the River Yamuna below danger mark. The other prominent reasons behind it are increasing urban population, habitation in low lying areas, encroachment on drainage channels, increasing impervious surface due to concrete structures, improper waste disposal, poor sewerage system and lack of understanding of urban morphology. Thousands of people residing in the low lying areas of the city such as Allahpur, Chhota Baghara, Daraganj, Salori, Rasoolabad, and Shivkuti have been forced to abandon their homes and seek shelter in safer places. To identify the vulnerable regions three buffer rings based on DEM have been generated at an interval of 500m around the rivers. The density of settlements along the rivers within these buffer zones has also been carried out to assess the damage to the residential structures and population in low lying areas of the city. Finally, it can be concluded that human encroachment into the flood plains of the rivers and lack of preparedness seems to be the underlying cause behind this catastrophe.

Keywords: Urban flooding, Prayagraj, buffer zone, flood plain, urban geomorphology.

URBANIZATION AND ITS IMPACT ON ENVIRONMENT: A CASE OF KALIMPONG

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Mountains are home to about 12 percent of the global population. It is the largest storehouse of resources and provider of services which are both tangible and intangible in nature. It is the source of water. It is an important source for biodiversity, culture and most importantly it provides livelihood to thousands of people. They are the 'barometers of climate change' as they are the most sensitive indicators of its impact. Urbanisation is not a new phenomenon in India, urbanisation can be characterised as an increase in human population and settlement coupled with an increased per capita energy consumption and extensive modification of landscape, a process which brings about changes in the spatial distribution of people, resource as well as how people use and consume land which fosters social and economic development (UNHABITAT, 2014). Urban growth is one such consequences of urbanisation process which can be defined as, the rate at which the population of an urban area increases.The towns of Darjeeling and Kalimpong districts are not as large as the other Indian cities but they are endowed by numerous small and medium sized towns which play a very important role in socio-economy of these regions. Environmental conditions play a major role in conditioning the livelihood of the people. The topography, climatic variations and soil conditions all have influenced human occupancy (Bhutia, 2014). However, the less accessible areas of the Himalayan regions are experiencing rapid growth of urban areas due to the extension of the road network, growth in tourism and economic globalisation which result in intense utilisation of land (Tiwari & Joshi, 2016). This unprecedented development has resulted in the deterioration of living conditions and environment and also the visual quality of hilly areas (Kumar, 2015).Therefore, the major challenge is the unchecked construction which is actually a step towards improving the infrastructure and other facilities. The hill area urbanisation is challenging and it faces many problems. This paper would highlight the challenges and the difficulties faced by the urban areas of the Himalayan regions focusing mainly in the hill town of Kalimpong. The haphazard growth of urban centres and their unplanned urbanisation has deteriorated the environment and increased pollution problems. The lush green slopes are converted to barren concrete buildings results in forest reduction, slope failure and landslides, coupled with problems like overcrowding, pollution, traffic jams which ultimately have a huge impact on environmental degradation.

Keywords: Urbanisation, towns, urban growth, environmental degradation.

CAUSES AND CONSEQUENCES OF WATER LOGGING IN DHAKA CITY, BANGLADESH

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Dhaka city, the capital of Bangladesh is one of the densely populated Mega Cities in South Asian Region. The city consists of Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) and is facing water logging problem every year during monsoon. Some parts of city go under water for 2-4 hours. Water logging in Dhaka City creates many social, economic and environmental problems. This paper focuses on existing water logging in the city. It also tries to identify the most affected areas due to water logging in the city. As many as 25 areas in the city have been identified through field survey which submerges under water for 2-4 hours or more. Causes and consequences of water logging are also explored in this study. Social, economic and environmental impacts of water loggings are determined through questionnaire survey among the respondents who are the sufferers. They include local people, CNG/bus driver, small businessmen, hawkers and rickshaw pullers. Three hundred respondents have been interviewed from seven zones of the city to understand the causes and impacts of water logging. Among others, mismanagement of drainage system of Dhaka City is considered

to be a major cause of water logging. Coordinated efforts from public and private organization are required to mitigate the water logging problems in Dhaka city.

GEOMORPHIC SYSTEM OF MEGA CITIES: A CASE STUDY OF KOLKATA

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City region as an open system forces the energy flow in two ways first, Intrinsic in which changes takes place within the system, such as a movement of a Glacier; second, Extrinsic where change is brought from external factor, such as loss of vegetation cover due to gullies erosion from excess rainfall, makes the geophysical nature unstable for living organism. The city region also draws its topographical bifurcation from next physical region through the Green Belt, a region which is covered through vegetation and serves as a buffer zone or zone of change in topographical Region. In wake of this vulnerable communities such as ghetto and other weaker sections have to struggle to find their places in the geomorphic system due to optimum land use patterns and limited availability of natural resources. When Population Density coupled with Geomorphic Threshold capacity on the local landscape, it starts changing people's mind-set because of change in their Living conditions challenges, which finally alters the city morphology at large. In that context, Kolkata in the recent decades has gone under different layers of landscape alteration which has triggered the city morphology to upscale at the cost of natural factors such as green belt and depletion of natural source of water at the smaller scale. More will be discussed at the time of conference.

Keywords: Open System, Energy Flow, Intrinsic, Extrinsic, Green Belt, Ghetto, Geomorphic System, Geomorphic Threshold.

URBANIZATION, SLOPE INSTABILITY, LANDSLIDE AND SUSTAINABLE MANAGEMENT IN DARJEELING HILL

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Rapid movements of sliding rock and soil particles separated from the underlying stationary part of the slope by a definite plane of separation are designed as landslides in the strict sense. The landslide leaves a basin shaped scar on the slope and a mass of debris at the foot, often projecting forward as a tounge. Landslide and related slope movement have attracted the attention of man in the same way as other uncontrollable natural phenomena which threaten his life and property. In some hilly regions, landslides occur rarely while in others, they are so frequent that they represent an important factor in the remodelling of the micro-landscape. Landslide is a natural phenomenon fairly common in the hilly tracts and is the most pervasive geo-environmental hazard that undermines the economic and cultural prosperity of Darjeeling Himalayas. Records, since 1899 show a sharp acceleration in the rate of devastating slide occurrences along with lesser slips leading to great loss of life and heavy damage to land and property. Diversity in slope component, micro-geology, extensive deforestation, tea plantation, unplanned road and sewer systems, rapid urbanization, haphazard and illegal housing construction, inadequate drainage outlets along with incessant rainfall have led to trigger the recurring landslides almost in every years. The present paper highlights that each slide has its own peculiarities and its initiation is not due to

any single factor rather it is the combined result of several natural and human induced factors and requires a sustainable management planning to mitigate.

Keywords: Slope, landslide, pervasive, geo-environmental hazard, rapid urbanization, incessant rainfall, sustainable management.

AN ASSESSMENT OF SPATIO TEMPORAL CHANGES IN THE COURSE OF RIVER GANGA AND ITS IMPACT ON THE URBAN MORPHOLOGY: A CASE STUDY OF PRAYAGRAJ CITY

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River Ganga is one of the two big rivers flowing by the Prayagraj City, the other being Yamuna and the two meeting at Sangam where the city is situated. The landscape of the city lies almost entirely in the Doab of these two rivers, therefore they seem to play a vital role in the foundation and development of the city. In the wake of changed land use pattern and increased demographic pressure across the entire Ganga plain, the river has been subjected to several sequential phenomena such as bed forms, turbidity, bank erosion, aggradations and scouring, shifting of its course, formation of meandering channels and so on. There have been many studies that have proved the shifting of Ganga river course. Although it is a natural process for a river of such vigour, however, shifting of river course & bank erosion pose a potential threat for such settlements which are located close to the river bank. Since Prayagraj is located at the bank of not only river Ganga but also Yamuna, thus bounded by rivers from three sides, therefore in case of a shifting of the river Ganga in the city will have severe implications on other fluvial processes around the city as well as on the urban morphology and population living in these areas. In the present paper, an attempt has been made to assess the spatio- temporal changes in the course of river Ganga at Prayagraj using Remote Sensing and GIS Techniques as well as its impact on the urban morphology. Multi-temporal imagery has been used for the study. It has been observed that there has been a significant change in the course of river Ganga at Prayagraj which has affected the city in several ways.

Keywords: Ganga, bed forms, bank erosion, aggradations, shifting, river course, meandering channels, fluvial processes, urban morphology, population, spatio-temporal.

MOUNTAIN GEOMORPHOLOGY, HAZARD VULNERABILITY VIS-À-VIS SMART CITY FRAMEWORK: A CASE STUDY OF URBAN HOUSING IN ITANAGAR

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Itanagar, Arunachal Pradesh is a township established in 1978 to function as administrative centre and capital of the State. Since then, it has been a hub for administration and residential place for employees. It has also attracted businessmen and families to settle in the capital for various reasons. Now, there is a stream of migration from rural areas to the town to avail opportunities in the form of livelihood, healthcare, education, connectivity, better amenities. This has resulted in choking the urban space and facilities. At this juncture of visible stress, the town has been included in the list of Smart Cities of India with a hope to reduce the pressure on land and resources and ease of living. The town is located on the Siwaliks of Himalaya Mountain, where terrain conditions are very fragile and susceptible to degradation and hazard. As there is no rule or guideline for site selection, housing types; people are using whatever place is available to them for housing and commercial activities; thereby making themselves vulnerable to hazards associated with mountains. A GIS based study has been carried out by

evaluating and integrating geomorphological parameters for the town area. Subsequently, categories of houses and buildings have been cross tabulated in estimating proportions of each category versus vulnerability. The analysis shows there are about fifteen percent of houses have been constructed in vulnerable areas to landslide, landslip, channel shift, channel bank erosion. Government residential units and office buildings constructed during 1980 – 90s have better terrain condition scores and these are not vulnerable to hazard. Privately owned houses of higher income and wealth group have their houses built on safe areas. The recent migrants and lower income groups have crowded vulnerable areas. Due to scarcity as well as high cost of land, in many cases setbacks are not maintained leading to collapse of house on the upper elevation. Building by-laws of 2010 and approval of commercial building by authority are not rigidly followed leading to violation of master plan and safety norms. The present requirement for Itanagar is to create a framework and guidelines that factor into hazard and vulnerability issues on priority basis before development activities like housing, infrastructure, drainage, etc. take place for the Smart City.

A VULNERABILITY ASSESSMENT OF ITANAGAR TOWNSHIP, ARUNACHAL PRADESH

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Many urban disasters are anthropogenic in nature. With advances in technology and availability of advance machineries, hilly areas like North East of India are now more prone to potential disasters in the event of natural calamities. A discipline growth of towns is the need of the hour. The present paper is an attempt to study how human activities induce environment hazard in surrounding landscape. The method includes study of available secondary data on urbanization along with the primary data in the form of images taken from the sites. Remotely sensed satellite images are also used to compare the status over a period of time. This paper also give emphasis to encroachment on river and rivulets and how improper landscaping leads to stress creating factors for urbanization in the study area - Itanagar.

Keywords: Urban, disaster, anthropogenic, remotely sensed, landscape, vulnerability.

HUMAN IMPACT ON ENVIRONMENT

SOIL PROPERTIES AND LAND USE MANAGEMENT OF SILIGURI SUB-DIVISION, WEST BENGAL

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An important factor influencing the productivity of our planet's various ecosystem is the nature of their soils. Soils are vital for the existence of many forms of life that have evolved on our planet. Properties of soil plays a very important role in the development of land use and land cover of an area. It is very important to know the soil properties to cultivate any crop. In the recent time huge transformation has been seen in the study area, the size of the town and the area of the cities has increased, engulfing the neighbouring areas, hence management of land is very essential. Human habitation also depends upon the soil. Farmers prefer those soil which will give maximum yield by using less or no fertilizers. This paper will help the farmers of the study area to know about the soil properties and use appropriate fertilizers. The soil of the study area is sandy in nature and is of acidic type soil and also receives very heavy rainfall of about 300 cm per year. So, it restricts major agriculture plants therefore the soil supports only those plants that grows well in acidic sandy soil for example tea, pineapple, etc. Land use planning is one of the most important aspect now a days, commercial, residential and agricultural landscape requires proper management and planning. The primary target of this paper is to bring a layout of the physical and chemical properties of soil and study the related problems. Also to measure the land capability and suitability of soil and help us to understand the soil fertility and to suggest a better land use management.

Keywords: Soil properties, productivity, land use, nutrients, management.

SPATIO-TEMPORAL VARIATIONS IN LAND SURFACE TEMPERATURE: A CASE STUDY OF LATUR CITY, MAHARASHTRA

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An increasing trend in Land Surface Temperature (LST), over the urbanized areas, is prominently experienced in the recent decades. Urbanization coupled with industrialization, has boosted the growth of urban built surfaces, which in turn have a definitive impact on the surface temperatures. The present paper aims at bringing out the spatio-temporal variations in LST over Latur city from the Marathwada region of Maharashtra. In order to extract LST, Landsat ETM+ (May 2009) and OLI/TIRS (April 2019) data sets are used. The methodology adopted was divided in to two parts, firstly supervised classification technique, employing the maximum classifier, and was used to obtain the land use land cover (LULC) maps of the study area. Next step involved the extraction of LST for both the time frames. LST were extracted by using the single channel algorithm by adopting the standard procedure outlined in Landsat (7 and 8) user handbook. The results obtained for LULC clearly brought out the spatial growth in the built up areas. Almost 14% of increase in built up areas were observed within a span of last 10 years. The mean LST extracted for Latur for the same period also indicated a rising trend. Mean LST for 2009 was noted to be 36.7^0C, while the same was recorded as 44.3^0C in 2019. Vegetated areas and waterbodies recorded relatively lower LST for both the time periods. An interesting spatial pattern of LST was observed over Latur city. The city centre with higher percent of built up area actually recorded moderate values of LST (32 to 34^0C in 2009 and 41 to 44^0C in 2019) and the barren peripheral areas had much higher values of LST (ranging up to 46-47^0C in 2019).The fact that vegetated areas maintained low LST values highlights the significance of developing and maintaining urban green spaces.

Keywords: Land use/ land cover, Land Surface Temperature, Vegetation, Single channel algorithm.

IMPACT OF URBAN BUILT SPACES ON IMPERVIOUS SURFACE GROWTH OF THANE CITY, MS, INDIA

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Urbanization is one of the key factors leading to the growth in impervious surfaces in a metropolitan region. Thane city has seen considerable rise in its population in the last two decades that has definitely triggered the changes in land use pattern. Continuous sprawl in built-up area culminates into the generation and growth of impervious surfaces. Present work is an attempt at bringing out the sprawl in built-up areas within the city limit and mapping the impervious surface areas. Landsat TM5 for the summer months of 1999 and 2010 and OLI/TIRS data for 2017 were utilized for this work. Land use land cover changes were assessed by employing the supervised classification scheme involving multiple classifier method and the imperious surface areas were extracted by developing a multiple regression model in GIS environment. The results obtained indicated that with a net population rise of 1million from 2001 to 2017, the built up area has gone up by 15%. Correspondingly, mean impervious surface areas have recorded an increase of 18% from 1999 (44%) to 2017 (62%). The imperviousness values extracted for 1999 ranged between 25 to 80 %, whereas in 2010 the range was 30 to 88%. Further increase in ISA was observed by 2017 where the percent ISA ranges up to 100%. Significant increase in imperviousness is observed along the major transportation arteries and the newly built up areas which were earlier covered with mudflats and vegetation. Such changing land use and imperviousness are crucial parameters to define government strategies as well as would prove to be beneficial for urban zone management.

Keywords: Urbanization, Land use land cover, impervious surfaces.

HUMAN ELEPHANT CONFLICT IN NORTH BENGAL: A SPATIO-TEMPORAL ANALYSIS

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Human elephant conflict refers to conflict between human and elephant due to rapid population growth, development activities, habitat fragmentation, reduction of food supply in forest area etc. In West Bengal most of the encounters between human and elephant is recorded from northern districts (hill, terai, dooars region). The conflicts lead to loss of life, injury of both human and elephants. This situation makes environmentalists little much worry because it increase day by day. This paper is an attempt to find out current status of forest area, population status of elephant, different types of human elephant conflict, find out its causes and consequence and suggest some remedies to save elephant and human being in North Bengal.

ROLE OF ARTESIAN WELL ON LIVELIHOOD PATTERN OF NICHINTA AND PARATIA VILLAGE

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Artesian Well is a simply a well that doesn't require a pump to bring water to the surface; this occur when there is enough pressure of the aquifer. The pressure forces the water to the surface without any sort of assistance. They are in common use in Nichinta and Paratia village where 40 years ago the wells have been find out. This paper presents the impact of Artesian Well on Livelihood pattern of the Nichinta and Paratia village. We study the sources of water in these artesian well; uses, misuses, restoration of hot water and Eco-tourism potentiality of those area. The objective is to see how the livelihood pattern of the people in those villages is being changed due to the dependence of hot water and also the eco-tourism potentiality of those area in future. A structured questionnaire survey conducted in this two villages. In Nichinta village 34 household out of 125 household and also 25 household out of 98 household selected randomly which is 25% of the total household. Data regarding various physical-chemical characteristics of hot water have been collected from the village panchayet office. From the study it has been found that in Nichinta village the P^H of water is 7.6 but In Paratia village it is 7.8. The findings revealed that the major sources of drinking water is Hot Water but it is also used in domestic purpose. 93% people using the water in drinking purpose of Nichinta village and 94% people using the water in drinking purpose of Paratia village. Abuse is more common than using hot water in agricultural field. Therefore, the dependence of hot water and other attractive place of those villages are potentiality of the Eco-tourism in future.

Keywords: Artesian Well, Livelihood Pattern, Eco-tourism.

GEOMORPHOLOGICAL ASSESSMENT OF MINING AND ITS GEO-ENVIRONMENTAL IMPACT ON THE LANDSCAPE: A CASE STUDY OF SONBHADRA DISTRICT, UTTAR PRADESH

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Mining is the process of extracting geological materials from the earth. It is of great importance from geomorphological point of view. Assessment of mining landscapes helps geomorphologists to gain knowledge about the geological evolution of the area. It also creates various type of particular landscapes through excavation of the land and accumulation of the waste materials. Removal of vegetation, sediments and activities such as blasting, dumping of wastes, and increased slopes make the landscape vulnerable to flood, erosion and other geomorphic hazards. Sonbhadra district has rich mineral base mainly in the southern part of the district. Coal, limestone, dolomite etc. are some important minerals that are extracted through mining. Opencast mining in the study area resulted in formation of excavated landscapes. Extracted waste materials are dumped that give birth to accumulated landscape. Coal mining is practiced on large scale as this region comes under Singrauli coal field region. Apart from economic benefit, mining has contributed negatively in degrading the geo-environmental setup of the region. Human health has also been affected severely due to pollution generated by these mining activities. This research paper attempts to assess and analyze the mining activities and their impacts on whole geo-environmental setup of the area. Secondary data has been taken from concerned authorities such as Pollution Control Board, Mining Department OF Uttar Pradesh, and National Green Tribunal etc. Geo-spatial techniques have been used for mapping of existing mining sites and identifying zones of derelict lands which have endangered the entire study area.

Keywords: Landscape, Geo-environmental, Mining, Opencast, Geomorphological.

CHANGING GEO-ENVIRONMENTAL CONDITIONS, ITS IMPACT ON ENDEMIC SPECIES AND MANAGEMENT CHALLENGES: A CASE STUDY OF INDIA

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Endemic species are unique to a defined geographic location or habitat type.Physical, climatic and biological factors are key contributors to endemism of plants and animals. Species with thin distribution range or fewer individuals are considered to be the most prone to extinction due to changing geo-environmental conditions and competition by alien species. India has 4 Hotspot regions out of 35 at global level, which represents 11% of world's flora in about 2.4% of global land mass. Approximately 28% of the total Indian flora and 33% of angiosperms occurring in India are endemic. Higher population density and their interruption put undue pressure on the sensitive eco-regions. The overall future distribution is predicted to shift in the northern and north eastern direction, compared to the present distribution while in south it will be in western and south western part of Western Ghats towards coastal region. The projected changes suggest that the endemic flora and fauna will be adversely impacted, even under a moderate climate scenario. In the future distribution of endemic plants (Royle's pika, Geum and Fragaria) and animals (Asiatic lions, Tigers, Kashmir stag, Turtles), a significant shift and reduction observed in distribution range compared to the present distribution. Despite of several laws that protect the habitat of these species, regulatory agencies still permit ecological alterations and economic activities leading to disturbance in the habitat along with natural disasters. The main reasons behind declining endemic species are loss of habitat due to climate change, natural disasters and anthropogenic activities along with increasing population pressure, urbanisation and industrialization. In the present paper GIS technique has been used in order to identify and represent the vulnerable areas of endemic species. Assessing present and future distribution of endemic species would be crucial contribution toward their conservation, planning and management.

Keywords: Endemic Species, Biodiversity, Geo-environmental changes, Conservation, GIS

INSTITUTIONAL ANALYSIS AND DEVELOPMENT FRAMEWORK AND ITS APPLICATION IN INCREASING RESILIENCE OF DISASTER AFFECTED MAJULI ISLAND OF INDIA

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The study of ecological systems that affect and are affected by human actions is now increasingly being linked with the social system that it cohabitates with. Such an approach to study the complexity of human interactions with ecological system is called social-ecological-system (SES) and is defined as complex, integrated systems in which, humans are part of, not apart from nature. Elinor Ostrom, through her Institutional Analysis and Development framework also called Ostrom framework has used SES concept to find the relationship between resource, resource users and governance systems. Ostrom's concept provides an approach to assess the social and ecological dimensions that contribute to sustainable resource management. At the same time, recent studies on role of governing institutions in times of disaster stress on the ever changing relations between rights and responsibilities of the government, the private sector, the voluntary organizations (NGOs and civil society), and

the individuals and thus, argue for a renegotiation of social contracts in disaster zones. The current study would try to synthesise these two different approaches to understand the roles and responsibilities of different stakeholders in disaster zone of Majuli Island of India and thereby, give a model of economic governance for disaster hit communities of Majuli.

Keywords: Social-Ecological Systems, Ostrom Framework, Social Contract, Disaster Zones, Majuli Island.

IDENTIFICATION OF HUMAN INDUCED ADVANCES IN THE MORPHOLOGY OF DESERT LANDSCAPES: A CASE STUDY IN INDIAN ARID LANDS

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Desertification is the outcome of various natural and anthropogenic causative factors. It has been observed that the study area is affected by a combination of natural and human induced desertification processes. In this paper an attempt has been made to identify the human induced desertification processes and its impact on the desert landscape. The main objective of this paper is to evaluate the risk of desertification hazards through the study of rainfall pattern, nature and characteristics of dunes, soil characteristics, grazing pressure and water table heterogeneity in the study area. The study has been incorporated through satellite derived data using LANDSAT TM+ and AWIFS data. Extensive field surveys have been conducted in order to understand the nature of the problem. In the present study various indices of satellite data have been processed. It has been observed that the study area reported varying morphological vulnerability in the desert ecosystem due to adverse human practices.

Keywords: Desertification, heterogeneity, morphological, vulnerability.

ANTHROPOGENIC IMPACT ON KARALA RIVER IN JALPAIGURI MUNICIPALITY: AN OVERVIEW

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River Karala sourced from the Baikunthapur forest area near Gazoldoba and after draining a few kilometers it enters in Jalpaiguri Municipality, and finally discharged water into the river Teesta. In the rainy session, a huge amount of water is discharged through this torrential channel but in winter it remains comparatively drier. The river bears historical fames and affections to the local people since the time immemorial. The water of this river is essential to grow crops in upper course and biodiversity of this river is also very rich. Local people are very fond of its local variety of fishes for unique tastes. But with increasing urbanization and population pressure this river becomes a big drain to carry the urban wastes and garbage. As a result the river health has been getting worse day by day. Empirical study indicates the fragile condition of this river. Attempt has been made in this paper to find out the nature, consequences and probable suggestive measures to cure the river health for the greater interest of the society.

FOREST MAPPING BY USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM: A CASE STUDY OF ALIPURDUAR DISTRICT

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Forest cover is an important natural resource which should be conserved on priority basis for sustainable environmental management. However, escalating levels of anthropogenic disturbances have exhorted tremendous pressure on the forests. Due to the increase in human and cattle population and widespread rural poverty, forests all over the globe are subject to enormous pressure resulting in deforestation and degradation. As a result, there is significant loss of forest cover at an alarming rate. Depletion of forest affects many ecological, social and economic consequences including extinction of biotic communities leading to loss of biodiversity, soil erosion, global warming and loss in income to forest dwellers. Alipurduar district is the newly formed district separate from Jalpaiguri district of West Bengal. The district is located in the foothills of Bhutan and is a gate way to Bhutan. The district has a significant forest land i.e. 38.3% of the district. But the forest cover has been decreasing rapidly in the last few decades due to the human interference whereas built up area is increasing gradually.Condition of the forest cover and change detection of the forest cover. The land use/ land cover map has been prepared by supervised classification method. Following indices are used for mapping process such as Ratio Vegetation Index (RVI), Normalized Difference Vegetation Index (NDVI), Difference Vegetation Index (DVI), Soil Adjusted Vegetation Index (SAVI) etc. by using remote sensing data and GIS technique. The Satellite data has been collected from USGS Earth Explorer site with 30 meter resolution; for the three years i.e. 1996, 2006 and 2016.

Keywords: Forest mapping, Vegetation index.

LAND USE AND LAND COVER CHANGES PATTERN USING GEOSPATIAL TECHNIQUES AND ITS IMPACT ON ENVIRONMENT–SILIGURI SUBDIVISION OF DARJILING DISTRICT, WEST BENGAL

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Land use and land cover is a key factor in understanding the relations of human activities with the environment and thus necessary to be able to simulate change. The present study investigates the land use and land cover of Siliguri Subdivision of Darjeeling District, West Bengal using Landsat satellite images for the year 1990 and 2011. With the help of satellite imagery and GIS technique five category of general land use has been delineated. These are agricultural land, forest land, tea garden, built up area and river and water body. Supervised maximum likelihood algorithm has been used to classify the imageries into different land use categories. The significant change has been took place in case of agricultural land. In Siliguri subdivision 12.43% agricultural land decreased over the periods. This reduction in agricultural land is for the conversion of agricultural land to other purposes like forest land, tea garden and built up area. Similarly, change detection for remaining categories has been done. This paper also illustrates the impact of changes in land use and land cover on environment. The digitization of maps has been done using ArcGIS. The information about land use and land cover change study is extremely useful to local government and planners for the betterment for future plans of sustainable progress of the Subdivision.

Keywords: GIS, Remote Sensing, Change Detection.

FUTURE PREDICTIVE MODELLING ON LAND USE AND LAND COVER CHANGES AND ITS IMPACT ON NATURAL HABITAT: A CASE STUDY OF JORE POKHRI WILD LIFE SANCTUARY, DARJEELING, WEST BENGAL

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Land use changes generally affect the integrity of an ecosystem. The effect of this change can be very severe if the conversion disrupts a crucial habitat of major plants and animals. The Jorepokhri Wildlife Sanctuary is one such area of west Bengal which is facing a serious problem of rapid land use change. In this study, the future trend of land use change of the area was modelled using Artificial Neural Network. Several driver variables were also incorporated to determine their effect on land use change. This the critical analysis suggests that Cellular Automata is not a good fit to simulate the future land uses as it misdirects the analysis both spatially and numerically. The incorporation of driver variables gives strength to the Artificial Neural Network to predict the future. The neural network was found to be a good fit for future land use prediction. Distance from locality, Distance from highway and distance to the road and slope were the driver variables which were used to predicting the probability of forest land use change. The study will help the management authority of this critical habitat to take proper action before further degradation occurs.

Keywords: Ecosystem, Wildlife Sanctuary, Land use land cover, Artificial Neural Network.

THE INFLUENCE OF RIVER BED OCCUPANCY: A CASE STUDY IN THE LOWER BASIN OF RIVER TEESTA, WEST BENGAL, INDIA

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The present study deal with the human impact on morphology of the lower basin of river Teesta in India includes large number of dam and barrage constructions, bank stabilization, artificial levees, human settlement and economic activity on the bed of river Teesta. In this regard, extensive field work was conducted in present decade to observe environmental impact of human activities in the study area. In present era Intensive agriculture and sand mining causes various negative impacts on the morphology of the river Teesta. In addition, throughout the history of human activity, people inhabits on the bed of the river Teesta influence by flood in every year and it is recognised one of the most dramatic influences between man and his surrounding environment. Emphasizing both the less shear strength of natural events and man's inadequate efforts that necessary to control them himself reside along the river bed. Therefore the study suggests that Govt. as well as local people may be taken initiative to reduce the anthropogenic impact on morphology of River Teesta.

Keywords: Occupancy, Intensive agriculture, sand mining, bank stabilization, flood.

ENVIRONMENTAL IMPACT OF BRICK KILN AND LAND USE CHANGE IN THE VICINITY OF WETLANDS: A CASE STUDY ON MALDA DISTRICT, WEST BENGAL

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The brick industry in India is the second largest brick producer in the world, after China, and is essential for the economic growth and development of a region. Malda district experiences rapid expansion of brick kilns after 1990-95 at the time of rapid construction work and resultant high rise buildings. The authorized total number of brick kilns in the entire district is 284. In spite of having economic potential, the brick kilns pose severe environmental hazards on the wetland water resources. In the present study two wetlands have been selected in order to identify their ecological status, which is affected by the presence of brick kilns, adjacent to the wetland periphery. Out of the studied wetlands, one is located at rural periphery, while the other is considered a peri-urban wetland (adjacent to urban area), located in Malda district, West Bengal. Both these wetlands receive sewage inflow from the adjacent brick kilns as well as record maximum amount of total dissolved solids and total hardness and very low amount of dissolved oxygen within wetland water. Moreover, the presence of brick kilns as well as its sewage inflow into wetlands is found vulnerable to the health of the entire aquatic biota. Furthermore, the rapid expansion of brick fields are found at the cost of agricultural land conversion, wherein the most fertile soil is a major ingredient in order to produce good quality bricks for construction and other purposes. Therefore, the present study attempts to discuss the effects of brick kilns on the wetland ecology as well as the land use land cover change at the vicinity of wetlands.

Keywords: Brick kiln, environmental hazards, peri-urban wetland, ecological status, sewage inflow, aquatic biota, land conversion.

IMPACT OF HUMAN ACTIVITIES ON WATER QUALITY IN SAGAR LAKE SAGAR JANPAD, M.P., INDIA

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Sagar Lake located in Sagar city, Madhya Pradesh, India has been subjected to domestic and agricultural wastewater discharges from many decades. Sagar Lake is situated in the heart of Sagar city (23°50'N latitude and 78°45' E longitude and 517 MSL), Madhya Pradesh (State), India with an area of 1.37 sq. km. It is a shallow lake with a small catchment (11.06 sq. km). Due to the rapid industrial and agricultural development around the city and transport of sewage water into the lake, it was observed increased contaminants were observed in the lake. From past few years we have been conducting several research studies on Sagar Lake pollution. This study is based on secondary data collected from various research papers and govt. Institutions. The average of alkalinity has exceeded due to improper drainage system. It is recommended that lakes water analysis should be carried out from time to time to monitor the rate and kind of contamination. A regular environmental monitoring program must be conducted in Sagar Lake for pollution abatement needs to be initiated as per WHO guidelines, it would be useful for pollution abatement program to be implemented for an effective result. The consumption of unsafe water has been implicated as one of the major causes of this disease. As one of the famous Lake, as well as tourist point of view Sagar Lake water should be preserved for the protection of natural environment.

Keywords: human activities, Sagar Lake, water quality, rapid industrial, population growth.

IDENTIFYING THE CAUSES OF WATER SCARCITY IN BANKURA DISTRICT, WEST BENGAL, A GEOGRAPHICAL PERSPECTIVE

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Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region and it's the biggest threat to food production. In this regard it can be said that the Bankura district of West Bengal is facing acute water crisis in present situation, as water scarcity has become a regular menace for the people of Bankura district, it is very crucial to free the people of this district from the curse of water scarcity. In Bankura district water crisis is increasing day by day due to extreme heat, Physiographic and socio-economic factors. People of Bankura district are facing this scarcity mainly in summer season. So the present work is about to identify the causes of such deficiency of water which can be an important step to reduce the present day scenario of water scarcity of Bankura District.

IMPACT OF IRRIGATION ON SUSTAINABLE GROUNDWATER MANAGEMENT UNDER CHANGING CLIMATE BY AN INNOVATIVE METHOD

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Groundwater based irrigation is one of the key factors for rapid agricultural development in India. Therefore, understanding the sustainability of irrigation water management is utmost necessary for agricultural development. This study investigated the sustainability of groundwater based irrigation by identifying recent (1996-2017) trend of groundwater depth of 527 dug wells of Lower Ganga River Basin (LGRB) using an Innovative Trend Analysis (ITA) method and Mann-Kendall (MK) or Modified MK test and its magnitude by Sen's slope analysis method. This study also find out the relationships of groundwater depth with rainfall intensity and irrigated areas. Results of ITA showed that almost 85.77%, 61.86%, 66.79% and 57.31% wells for pre-monsoon, monsoon, post-monsoon, and winter seasons respectively showed increasing trends in groundwater depth. The reliability of ITA was verified by comparing with the results of Z statistic, which were almost similar. The result of Z statistic showed that about 81.78%, 66.22%, 74.38%, and 66.79% of wells faced increasing of groundwater depth in the same data. The rapidly increasing trend (slope: 8.95 to 104.46 cm/year) in monsoon season indicates shallow groundwater resource depletion and groundwater abstraction exceeds the groundwater recharge showing unsustainable development. Moreover, dry seasons increasing trends infer that shallow pumps will not be functioning in the future; as a result, irrigation cost will increase. Although irrigated areas remain almost same (1997-2014), decreasing rainfall along with abstraction of groundwater during dry season is primarily identified as main driving force for groundwater depletion. Further study is necessary to characterize the groundwater depletion. Planned water management is urgent for ensuring sustainable irrigation water management.

Keywords: Trend analysis, ITA, MK, MMK, Sen's Slope, Lower Ganga Basin.

RIPARIAN WETLAND SHRINKAGES IN RELATION TO ANTHROPOGENIC INTERFERENCE IN THE BARIND TRACT OF WEST BENGAL USING GEOSPATIAL TECHNIQUES

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Barind tract is primarily considered as elevated landmass composed of Pleistocene terraces and it has been widely identified as a unit of older alluvium deposit which differs from the surrounding floodplain. In West Bengal Barind tract covers mainly the district of Dakshin Dinajpur, part of Uttar Dinajpur and Malda. This tract comprises several numbers of riparian wetlands which mainly reserve water during rains through the inundation of rivers and the rainfall over the region is quite excessive. From the last few decade construction of dams and reservoirs on the river in the upstream region has resulted serious morphological changes in wetland characteristics over the tract. These changes have been detected through Normalised Differential Water Index (NDWI) approached by using Landsat imageries from 1990 to 2017 collected from USGS site. Quantitative approach is considered to identify the degree of changes of wetlands over the period by analysing pre-dam construction and post-dam construction situation. From study the expected outcome is that after the construction of dams wetland are reducing which resulting an unusual morphological changes over the Barind tract. Both the quantitative and qualitative assessments of wetland shrinkages will help to evaluate the ecological loss of wetland of the Barind tract from environmental perspectives.

Keywords: Wetlands, Barind tract, Morphological changes, NDWI

WATER RESOURCE OF THE SALDA RIVER BASIN AND ITS IMPACT ON AGRICULTURE

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Agricultural development of any region depends mainly upon the availability of water resources and irrigation facilities with the favorable quality of land and soil resources and other technological inputs. The Salda River basin being agriculture dominated area in the drier part of Purulia District with unreliable monsoon rainfall needs special attention towards efficient management of water for increasing agricultural productivity. In the study area, both water availability and agricultural parameters like crop yield, cropping pattern vary spatially and varies with categories of land. The main objectives of the present study are: (i) to give an account of water resource both surface and ground water in respect of occurrence, seasonality, availability including its spatial variations, (ii) to find out the present utilization of water resource in agriculture and its limitation, and (iii) to analyze the impact of water resource on agricultural activities including cropping pattern, production etc. The present study is based on both primary and secondary sources of data. Primary data were collected by intensive field survey for soil profile study, Dug well observation, and socio-economic survey, water use and farmer's perception survey in selected villages. Secondary data were collected from various Government departments like Census of India, Geological Survey of India, District statistical handbook and District statistical office of Purulia, Department of Agriculture, Govt. of West Bengal, Block Development Offices. Based on the analysis of secondary and primary data and information the authors in the present context have given appropriate suggestions towards the sustainable development of agriculture in Salda River Basin through efficient use and management of water resources.

Keywords: Water Resource, agriculture, utilization, management, impact.

ENVIRONMENTAL IMPACT OF INORGANIC FERTILIZERS AND PESTICIDES IN AGRICULTURE: A CASE STUDY ON JALPAIGURI DISTRICT

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Fertilizers and pesticides are the most important component in modern agricultural activity. Pesticides are included in a broad range of organic micro pollutants that have ecological impact. Different categories of

inorganic fertilizers and pesticides have different types of effects on the living organism with direct and indirect implication. Excessive use of pesticides and inorganic fertilizers may lead to the destruction of biodiversity. This study intends to discuss the farmer's perception on use of inorganic fertilizers and pesticides for improving their agricultural productivity and also its environmental impact. For this a questionnaire based primary survey (random sampling method) has conducted on 560 farmers from 28 villages of Jalpaiguri district spread over 7 CD Blocks. The study indicates that most of the farmers of this region are not too much aware about the fact that excessive use of inorganic fertilizers and pesticides may harm the environment and lead to the other hazardous impact. If the credits of pesticides include enhanced economic potential in terms of increased production of food crops, vegetables and fibers and amelioration of vector-borne diseases then their debits have resulted in serious health implication to man and his environment.

Keywords: Ecological adaptation, biodiversity, productivity, hazardous impact, vector-borne diseases.

MONITORING LAND USE AND LAND COVER CHANGES IN RESPONSE TO POPULATION GROWTH OF BALURGHAT BLOCK USING GEOSPATIAL TECHNOLOGY, WEST BENGAL

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It is a recognised fact that increasing population of any area creates direct impact on land use and land cover pattern as well as the total environment. The last few decades have experienced very rapid growth of population in the Balurghat Block of Dakshin Dinajpur district. This study aims at analysing the growth of population of this block since 1951 and its impact on the land use and land cover scenario over the last few decades. Necessary data on population growth has been procured from the Census of India and Landsat image as well has been used to evaluate the land use and land cover condition and their pattern of change from 1990 to 2018. In order to quantify the dynamics of these two parameters supervised classification has been made using GIS technique. From the result of analysis, it has been found that increasing population has created a strong negative impact on the environment as urban expansion is increasingly encroaching upon the agricultural lands. This exploration is expected to formulate planning process using well framed policies for overall development of this area.

Keywords: Population growth, Land use and Land cover change, supervised classification, Geospatial technology

A GEOMORPHOLOGICAL APPROACH TO ASSESS LAND USE SUITABILITY TO LOWER SASURKHADERI RIVER SUB-BASIN, YAMUNA BASIN, KAUSHAMBI, U.P. USING GIS

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The development of any region is related to levels of utilization of land resources. In the present study attempt has been made to study land use suitability of lower Sasurkhaderi river basin, a tributary of river Yamuna, U.P. Here land use suitability analysis is a multi-criteria evaluation. Main purpose of this study is to identify the most

appropriate spatial pattern for future land use with in Sasurkhaderi river sub basin. An empirical methodology has been used for analysis of land use suitability using the GIS technology.The study is mainly based on the Analytic Hierarchy Process in which the criteria like slope, drainage relief, physical & chemical properties of soil are considered and weights are assigned to each criterion. The weights are defined through the Analytic Hierarchy Process (AHP) module by maps prepared using Arc GIS software. The aim of land suitability analysis is to express the importance or preference of each factor relative to other factor. This study is important to assess the required changes in land use pattern of the area.

Keywords: GIS Technology, Land-use Suitability, Multi-Criteria evaluation, Analytic Hierarchy Process, Arc Map.

ROLE OF THE LOCAL PEOPLE FOR SUSTAINABLE FOREST MANAGEMENT: A CASE STUDY ON LATAGURI FOREST FRINGE AND ADJOINING AREA

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Forest is the most important economic viability for village respondents. As per the economic sustainability, the village people used to collect leaf, woods, honey, etc from the forest. According to temporal notion of time, forest areas have been decreasing due to innumerable activities like deforestation, poaching, forest fire, extend agriculture land as well as illegal construction. The Indian Government and State Government have taken various actions in terms of law & schemes. In the year of 1992, West Bengal Government has involved in different Joint Forest Management in different period of time. However, the Government and local people are jointly involved in forest management which is denoted as Joint Forest Management (JFM) according to Department of Forest, Government of West Bengal. In the West Bengal Arabari village first introduce of JFM in which FPC (Forest Protection Committee) is part of JFM. FPC members are the local people residing in the forest fringe area. The role of FPC is to achieve the main aims and objectives are to protect forest, forest resource as well as wildlife animals. The members are doing shifting duty within their own FPC area. Therefore in this study, the author has selected one FPC on Lataguri Forest Range area of Malbazar subdivision in Jalpaiguri district to know about the role of local people in sustainable forest management followed by their collaborative effort with existing FPC. Therefore in this study an attempt has been made to point out the role of local respondents in forest management followed by their identical problems and respective remedial measures in order to justify the dimension.

Keywords: Economic Sustainability, Joint Forest Management, FPC, Forest Management.

ANTHROPOGENIC IMPACT ON THE SPATIAL VARIATION OF CRAB BURROW CHARACTERISTICS: A COMPARATIVE STUDY OF DIGHA, TAJPUR AND MANDARMANI BEACH, WEST BENGAL

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The beach ecosystem reflects a delicate balance between the processes, material and biotic communities. This interface invites biodiversity of species and their bioturbation features on the beach. One of the most commonly observed fauna on beach is the crab. The Medinipur coastal tract of West Bengal has sandy beaches intervened by tidal inlets, modified by anthropogenic activities creating a unique habitat for variety of crab population. Three coastal stretches were selected to study the impact of anthropogenic activities on the diversity of crab habitat, and the threats posed to them.Digha Coast is erosion prone, characterised by dune migration.

Construction of a sea wall along the beach has threatened the habitat of the large crab species. Tajpur beach is situated east of Digha, bounded by Jaldah inlet at its east. This stretch is relatively free from any major structural interventions and large burrows are dominant near inlet mouth. Mandarmani beach, situated further east, is flanked by the Pichaboni inlet in the east and the Jaldah inlet at its west. The western part of the beach has been affected by anthropogenic activities due to formation of tourist destination recently.Crab burrow measurements were done by placing a frame of 1sq m. along the beach profile and burrow frequency, diameter and orientation were measured (clinometer). Beach elevation map done by Total Station survey and submergence map also prepared.Regarding spatial variation, the comparison that have come out is decreasing nature of burrow frequency from Digha Mohona to Old Digha due to sea wall and havoc tourist pressure. Tajpur shows least affected due to less anthropogenic influences. Burrow diameters decrease markedly in Mandarmani from 5 cm near Pichaboni to less than 0.5 cm towards Jaldah inlet mouth as hotels dominate in Jaldah section. Humans have affected distribution of larger crab species to the extent that at places the larger species have ceased to exist altogether, only smaller species are observed.

DELINEATION OF GROUNDWATER QUALITY ZONES FOR DOMESTIC AND AGRICULTURAL PURPOSES IN UPPER KARHA RIVER BASIN USING GIS TOOL

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Water is essential resource for the survival of human being. The rapid urbanization in the urban and semi urban region resulted in steep increase of groundwater demand for the domestic utilization and agricultural use as well. An immeasurable mainstream of groundwater contamination problems causing today are mostly because of improper management of groundwater resources and over use of available resources, or by combination of both. Because of inadequate knowledge about groundwater resources the population residing in the particular area faces the problem of water contamination for long period of time.The present study is of Upper Karha River Basin located in Pune District Maharashtra State. The study area is upper part of Karha river basin started from origin of the river up to the Malharsagar water body. Study area enjoys monsoon rainfall and there is rapid increase in Urbanisation results in more demand of Groundwater for domestic and agricultural needs. In the present paper the main objective is to study the quality of groundwater for the estimation of suitable and non-suitable groundwater zones in the Karha river basin. For the delineation of groundwater quality zones, various groundwater quality parameters have been taken in to consideration. Sample water wells are selected to collect water sample and those samples has been analyse in the laboratory. The results obtained by the analysis converted in to thematic layers and further weight has been assigned to each thematic layer by using Arc GIS environment with weighted over lay index method. There are three zones observed in the study area likewise Suitable, Non suitable and suitable in the critical condition. The villages Askar wadi, Chambhli, Pathar wadi, Bhivri, Pimple, Khalad Khanavdi, Kothale and Naralicha mala facing the groundwater contamination problem as values of some samples exceeded the permissible limit prescribe by BIS. The pH value for these villages is less than 7 which is not suitable for drinking. Electric conductivity is also showing the higher concentration in these samples and it is >2366 Siemens/ml. All groundwater samples are showing good properties for Agricultural utilization. Groundwater quality zonation has been displayed in map.

Keywords: Urbanisation, Groundwater Quality, GIS tool.

ENVIRONMENTAL PROBLEMS IN URBAN SLUMS: A CASE STUDY OF ALIPURDUAR MUNICIPALITY

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The urban landscape incorporates slum as an integral part of its structure. Slums cannot be kept aside while considering urbanization and modernization. Lack of basic amenities, absence of basic infrastructure and unplanned, haphazard development of settlements in urban area leads to proliferation of slums and this has a direct impact on environment. The rapidly growing demographic structure with materialistic demands leads to massive utilization of natural resources and other aspects of environment get severely influenced. Environmental problems include over exploitation of natural resources, emission of greenhouse and other hazardous gases in atmosphere, thus arising air, water pollution along with heaps of waste materials. The environmental issues create environmental crisis which leads to severe health problems among the people, especially the dwellers in slum. These areas are overcrowded with lack of civic amenities, dwelling units consists of unwanted materials further accentuating the level of pollution. In this paper environmental problems in slum area in Alipurduar Municipality will be analyzed by considering different indicators like house structure, drinking water facility, sanitation facility, drainage condition and electricity facility along with analyzing air, water and noise pollution.

Keywords: Environment, urbanization, Slums, pollution.

TREND OF URBANIZATION AND ITS ENVIRONMENTAL IMPLICATION IN JHUNSI, PRAYAGRAJ DISTRICT (U.P.)

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Urbanisation represents revolutionary changes in the whole pattern of social life. Itself a product of basic economy and technological development intends intern, once it comes into effect every aspect of existence. Urbanisation is concerned with the growth of urban Centre. These two factors are considered as a basic for the growth of urban population. In term of developing countries like ours where urban centres originate as growth Centre to provide job opportunities. Social amenities and better life to the president of particular urban Centre. The social and economic future of countries is increasingly being determined in their urban areas. Globally the process of decentralization is shifting power and resource two sides' cities and their citizens, raising the importance of how will cities are managed and how will City economics are performing. Two alternative scenarios are emerging: one of cities character characterized by increasing poverty, social exclusion and decline; the order of increasing cities characterized by equality table and sustainable growth. It is after the quality of urban governance that divided decline cities form prosperous cities. India is a country, where maximum population lives in villages. Here, the process of organisation has been started quite late and still about 27% population live in the urban area. Even in the low process the urbanization lead saver problems several problems related with daily life. It is due to mismanagement of the towns and cities .lacking in infrastructural facilities, most of the urban Centre are facing acute problem of population and health hazards. Meanwhile, the trend of urbanisation is increasing. The studies so that it the trend of urbanization will remain the same in the future, the situation would be critical in the urban Centres. The study was mainly based upon the data collected from the secondary sources- Census of India. Case study of *Jhuns*i in Prayagraj district was carried out to understand the trends.

Keywords: urbanization, environment, implications, urban population

ROLE OF EMBANKMENTS IN THE SUNDARBAN: A CASE STUDY IN PATHARPRATIMA C. D. BLOCK, SOUTH 24 PARGANAS DISTRICT OF WEST BENGAL

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There are various means by which population of different area adapt and adjust themselves, during crisis, particularly arising out of adversities from natural and other hazards. Riverine and coastal areas are usually the most vulnerable regions in the developing countries as regular floods and related phenomena pose moderate to severe threats to the natural and manmade structures. In Patharpratima C D block of the Sundarban, embankments can be referred to as one of the most significant arrangements which have been protecting the habitations along with other entities within the close vicinity of the rivers and seas. Aim of this paper is to find out the trend of relationships between the changes of embankments and rural livelihoods, economic and psychological issues, and also to assess the impacts of embankments on different resources like land, water body, settlements and institutional set ups for sustainable development of the area. The data used have been collected mainly through household questionnaire survey and field observation, and extraction of information from relevant satellite images. It is observed that most of the respondents use embankments as a road, flood shelter and protector of fishery. In the present context, the role of embankment is not a mere construction to protect the riverine and coastal areas, but its various functions and implications in the context of socioeconomic, psychological and environmental impacts within this area are quite appreciable.

Keywords: Embankments, the Sundarban, capacity building, changing lifestyle.

DEGRADATION OF WETLAND ENVIRONMENT: A CASE STUDY OF KACHUA BEEL OF KOOCH BEHAR DISTRICT

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Wetland is significant geomorphic agent and natural resource over the globe. From the last decade it has been observed that the wetland gradually shrinking and damage due to various causes like climactic –change, human activities. Wetland has great importance not for ecology but also for economy. But growing Pressure of human interference has been degrading the wetland biodiversity constantly and it has posed a serious threat to overall wetland ecology. An attempt has been made in this paper to know the present status of sweet wetland and analyze its environment degradation. The main objective of the present study finds out the major causes of wetland degradation and put forth some eco-friendly measures and conservation and management and sustainable development of the wetland biodiversity and the people around the wetland. The study based on primary and secondary data.

Keywords: Bio-diversity, Conservation, Management, Sustainable development.

IMPACT OF LAND USE CHANGE ON NOAI RIVER: A GEOMORPHIC AND ENVIRONMENTAL APPRAISAL

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The Noai River was originally a spill-over channel of Hugli discharging into the Haroa Gang through the Bidhyadhari River. The river originates from Barti Beel near Barrackpore, and flows thorough the North 24 Parganas district of West Bengal. In its 28.2 km long course the river flows through stretches of rural, urban and industrial areas. The objectives of the study are i) to evaluate the geomorphic character of the channel, ii) to assess the land use land cover change along the Noai river and iii) to analyse the water quality of the river at the surveyed locations.The changes in the geomorphic character of the river 18 cross-sections were surveyed during 2015 and 2019 with the help of theodolite and positions were marked by GPS. Tide monitoring was carried out to determine the limit of tidal influence. Eighteen water samples were collected to analyse the pH, DO, BOD, alkalinity. Concentration of phosphate, CO_2, Nitrogen and faecal coliform was also determined. Land use and land cover changes have been determine by supervised classification of Landsat OLI, 2019 image.Out of eighteen stations, 5 exhibit marked decrease in both channel depth and width since 2015. In two stations recent dredging has resulted in increase of channel depth and width. At some stations there is shifting of thalweg without much change in channel configuration, whereas at few stations the channel has narrowed down with marginal increase in depth. Tidal effect is not uniform along the entire river and even the spring tidal water does not reach beyond 18 km from the mouth. Compared to 2015 data, the DO of the river water has decreased, pH level is very high and more than four stations nitrate level has decreased. Faecal coliform is marked positive at all the locations, rendering the water unsuitable for both agriculture and domestic use. Industrial and domestic wastewater from the entire river basin is discharged into the river which is degrading the water quality.

HUMAN IMPACT ON THE ENVIRONMENT VIS-À-VISCHANGING RAINFALL CHARACTERISTICS IN THE TERAI PLAINS AND ADJACENT HILLS IN THE DARJEELING DISTRICT, WEST BENGAL

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In a natural environmental setup it has been observed that annual or daily rainfall occurs in a persisting manner i.e. both dry and wet years or days occur in groups and the trend of rainfall does not become haphazard or random. The occurrence of rainy days due to local reason other than monsoonal effect is also seen to remain almost unchanged in an unaltered natural environment. The Terai plains and the adjacent hills of the Darjeeling district, West Bengal is seen to have undergone severe deforestation, upsurge of population agglomeration and steady growth of hill tourism since independence. These lead to the alteration of the normal geo-environmental setup of the region. Therefore, an attempt has been made in this paper to see whether the annual rainfall pattern of the available 8 rain gauge stations (more or less evenly distributed over this region) have desirable persistence and trend in the occurrence of rainfall or not. Moreover, the daily rainfall of monsoon and non-monsoon seasons has also been studied to see whether rainy days follow the rainy days and dry days follow the dry days in the monsoon season and any reduction of rainy days has been associated with non-monsoonal rainfall.It is found from the data analysis that some rain gauge stations have shown adequate rainfall persistence and trend where natural setup remains more or less unaltered and noticeable lack of persistence and trend where alteration of natural ecosystem has taken place. Similarly in case of daily monsoonal and non-monsoonal rainfall it is observed that daily occurrence of rain in monsoon period does not become erratic and no reduction of rainy days in non-monsoon period where sufficient forest cover remains intact as against the part of the region where vegetation cover has been removed.

Keywords: Geo-environmental setup; Rainfall persistence and trend; Erratic; Reduction of rainy days

COMPARATIVE STUDY OF LANDUSE PATTERN THE HILLY TERRAIN: A CASE STUDY

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Land is the basic resources for the emergence and Development of all living things including, human beings. The land meets multi-facts demands of human beings that range from sustenance level to highest level of economic development. The ever increasing population on the one hand demands for more food grains and on the other many of the developmental activities like as housing, buildings, roads industries and dam etc. encroach on productive land and other sustainable Development. In appropriate land use is one of the main reasons for soil erosion and nutrient loss in the hilly area. Keeping this fact in view an attempt will be made to know the comparative study of land use pattern and sustainable development in hilly Terrain. In Una District typical terrain and climate conditions restrict the human activities to a great extant. The expansion of crop lands has been done by cleaning forests and at the same time crop land has also, got diverted to non- agricultural uses such as urbanization, industrialization and various other development activities. The trend of comparative changing land use results in several environment hazards like deforestation, soil erosion, landslides, congestion, drought and flood etc. The objective of present paper land use is to identify and delineate land systems and land use; to examine relationship between fluvial morphology and land use. As per the Methodology materials have been collected through primary & secondary field work source and through published sources like maps, literature, Census Data etc. The study area Collected data shows that there is an increase in forest (.27%), Permanent pasture and Grazing land (.62%), Cultivable waste land (38.44%), Area sown more than one (19.31), Total cropped area (3.72) and Decrease land put to non-Agriculture use (-.34), Net area Sown (-7.62) in the year 2011 as compared to the year 2001. Such type study will be fruitful of sustainable development of agriculture in study area.

Keywords: Soil Erosion, Nutrient, Landuse Pattern, Temporal Changes and Grazing Land.

ASSESSMENT OF WATER QUALITY USING WATER QUALITY INDEX (WQI) METHOD OF SELECTED PART OF DAMODAR RIVER, INDIA

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The physicochemical and microbiological properties of river water are degrading for long time due to human activities like indiscriminate disposal of sewerage, industrial pollutants and waste water to the river. Present research work has been conducted to assess the water quality of Damodar River with special reference to the probable impact of dam construction on the river. Data on water temperature, pH, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and suspended solids (SS) have been obtained from the authorized sources of central and concerned state governments. Mean value for each parameter are calculated and compared spatially with the permissible standard given by the Central Pollution Control Board of India. A modified Water Quality Index (WQI) has been calculated for both the upstream and downstream section of the dam. Results indicate a moderate to good condition of water with slight decrease of water temperature and COD below the dam. TSS and TDS value have also been decreased. Wastewater discharge from

various coal-based industries and urban centres, and abstraction of chemical compounds by dam are the major determinants for such status of water quality of the river.

Keywords: Dam, Damodar River, Physicochemical properties, Water quality, Water Quality Index.

SPATIO-TEMPORAL ANALYSIS OF LAND USE/LAND COVER CHANGE AND LAND SURFACE TEMPERATURE IN THE NCT OF DELHI USING GEO-SPATIAL TECHNIQUES

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Human beings and environment are linked to each other through reciprocal relationship. In this relationship of 'man and nature', overuse of resources has degraded environment and also resulted in land transformation. The landscape of the earth is altered or transformed either by natural changes or by anthropogenic changes. The alteration in landscape characterized by the dominance of grey infrastructure and subservient vegetation have resulted in increased land surface temperature (LST) during the period of 1990-2015. Land surface temperature (LST) is a key parameter in land surface temperature, not only acting as climate change but also due to its control of the upward terrestrial radiation, and consequently, the control of the surface sensible and latent heat flux exchange with the atmosphere (Aires, 2001). Land surface temperature rise by various anthropogenic activities like increased land surface coverage by artificial materials and energy consumption, which have high heat capacity and conductivity, and are also associated with the decrease in vegetation and water surfaces, which are major factors that reduce surface temperature through evapotranspiration. The changes in land use/land cover have direct on the radiant surface temperature which in turn play a major role in altering the surface energy budget. The present research study carries out spatio-temporal analysis of land use/land cover change (LU/LC) and land surface temperature (LST) in the NCT of Delhi. The satellite data used include Landsat- 4,5 (TM), Landsat -7 (ETM+) and Landsat – 8 (OLI) for three different time periods 1990, 2000 and 2015 respectively. The present research study identifies the increase in land surface temperature over the period of 1990-2015 and its impact on urban environment.

Keywords: Land Use (LU), Land Cover (LC), Land Surface Temperature (LST), urban environment.

SLUMS AND URBAN ENVIRONMENTAL CHALLENGES: A CASE STUDY OF KOCH BIHAR MUNICIPALITY

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Rapid urban growth is a sign of growing economy and progressing society but it creates many environmental problems which is a serious issue of concern in present day. Slum is an essential part of urbanization which throws many challenges to environment like pollution, degradation. In this paper, an attempt has been made to analyze the living conditions of slum areas and finding out the most critical and problematic zone of the slums and environmental problems and issues that causes such degradation in Koch Bihar municipality based on mainly secondary data from various sources. Cartographic technique has been used to highlight the scenario and maps have been prepared with the help of Arc GIS 10.1.Study concentrates on some of the environmental problems caused by over population, unplanned drainage system, and poverty in slum areas. Result shows that the poverty related environmental issues are also coexisting with economic development related environmental issues which causes pollution at a greater level.

Keywords: Slum, environmental degradation, urban growth, pollution.

ENVIRONMENTAL SUSTAINABILITY WITH CHALLENGES AND OPPORTUNITIES FOR URBANIZATION IN THE 21st CENTURY

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Urbanization is a global phenomenon and currently more than half of the world's population live in urban area. This is one of the biggest social transformations of modern time, driving and driven by multiple social, economic and environmental processes. The impacts of urbanization on the environment are profound, multifaceted and are manifested at the local, regional and global scale. This article reviews recent advances in conceptual and empirical knowledge linking urbanization and environment. There are several emerging trends and remaining questions in urban environmental research. It is commonly observed phenomenon that ever since the emergence of an urban settlement, the urban population has been growing much more rapidly than its rural counterpart. Moreover, the urban centres once established tend to be centres of power and influence the whole socio-economic growth of the area. This has given rise to continuing process of urbanization. Consequently, not only many problems associated with it are yet to be solved but also many new problems are emerging in the rapid changing pattern of spatial interaction. Apart of this the degree of urbanization in considered a fair index of the level of socio-economic development of a country.Urbanization presents one of the greatest challenges of sustainability. Urbanization refers to the process of becoming urban or in other words urbanization is a cyclical process through which the nation passes as they evolve from agrarian to industrial societies. It is a spatial phenomenon involving population concentration, structural transformation and socio-cultural change affecting people, place and infrastructure. Although there were also many positive effects of urbanization including improving housing condition, better urban amenities and services as well as higher living standards, these benefits were often ignored in respect of urban environmental issues.

Keywords: Phenomenon, Manifested, Conceptual, Emerging, Sustainability.

PROBLEMS AND PROSPECTS OF DRINKING WATER SUPPLY IN SILIGURI MUNICIPAL CORPORATION

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Located at the confluence of rivers, the city Siliguri satisfies its 6, 87,000 inhabitants spreading across 47 wards. Gradually over time, the human interventions disturbed the environmental symphony in and around this locality. Mainly, the river Teesta caters the water need of the city, failing which river Mahananda plays a substitute. The high river water turbidity, conductivity, hardness, bearing of considerable amount of nitrate, chloride, fluoride, iron, Total Dissolved Solids (TDS), and at times holding traces of Total Coliform (TC) and Fecal Coliform (FC) is a clear indication of increasing anthropogenic alteration to the nature and henceforth possessing a serious threat to the supply of drinking water in the municipal corporation. The paper deals with the causes of the everyday crisis the PHE Water Treatment Plant (Phulbari) and the department of Jhankar Water Tanks is facing. The machinery capacities and the physical, chemical and bacteriological testing of the river water in the plant laboratories have been evaluated in this paper. The results revealed river Teesta to be far a better source, while the presence of extreme hardness, sewage and TDS in the water of river Mahananda makes it too unfit for

consuming. But, in the coming days, the disproportionate ratio between the increasing population, the obsolete infrastructure and the over-constrained space may result into severe drinking water crisis in the Siliguri Municipal Corporation (SMC) areas.

EASTIMATION OF LANDSURFACE TEMPERATURE OF COOCH BEHAR MUNICIPALITY TO STUDY SURFACE URBAN HEAT ISLAND INTENSITY USING LANDSAT 8 IMAGE

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Global warming has obtained more and more attention because the global mean surface temperature has increased since the 19th century. As more than 50% of the human population lives in cities, Urbanization has become an important contributor for global warming. The changes in land use/cover include loss of agricultural lands, loss of forest lands, increase of barren area, increase of impermeable surface of the area because of the built up area, etc. Development of land use land cover is very much useful to the city planner and policy makers. For the sustainable urban ecosystems the amount of land required for growing the vegetation can be estimated from these studies. One of the major implications of urbanization is increase of surface temperature and development of Urban Heat Island. Surface temperature is increased by anthropogenic heat discharges due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decrease in vegetation and water pervious surfaces which reduce the surface temperature through evapotranspiration. Landsat8 images are widely used to observe the land surface temperature. In addition to the development of Land use/cover maps band 6 of the Landsat8 imagery is useful for deriving the surface temperature. Several researchers used the Landsat8 imagery to develop land use/cover images as well as temperature images.

FRAGMENTATION OF FOREST COVERAGE IN URBAN PERIPHERAL REGION USING GEOGRAPHICAL INFORMATION SCIENCE

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This study introspects on the forest coverage fragmentation in urban peripheral region in North Bengal as a result of human intervention on the physical environment. This study estimated the degree of fragmentation of forests the peripheral areas of Siliguri and Jalpaiguri Municipality of last two decades. Urban peripheral region have been delineated by the growth of artificial light as well as urban sky glow through Mutation Index (MI). Changing scenario of forest coverage has been discussed here by the Multi-temporal Satellite dataset using patch analysis in ArcGIS platform. Larger numbers of patches inferences the higher fragmentation of forest area as well as disturbances of ecological services. Study also analysis the comparative situation of such kind of fragmentation in the peripheral region of above mentioned statutory towns.

Keywords: Fragmentation, Peripheral region, Mutation Index, Patch analysis, statutory town.

AN APPRAISAL OF HUMAN INTERVENTION ON DRAINAGE SYSTEM - A CONTROL SYSTEM: A STUDY IN GOSABA ISLAND, SUNDARBAN, INDIA

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The internal pattern of surface drainage in Gosaba Island has been modified by unscientific human interventions since the period of land reclamation. Topographically this island is a flat alluvial land remains below the high tide line. The water circulation system in this deltaic region is maintained by interlinking rivers, creeks and canals. Drainage has its own self-regulatory system to maintain its equilibrium if other external factors are not imposed on it. When the self-regulatory process response system is interrupted by some extrinsic factors it is called controlled system. The rapid growths of population, construction of embankment, haphazard erection of closures, land transformation and unscientific human encroachment have modified the surface drainage system. The changing pattern of the surface drainage has direct or indirect impact on livelihood of coastal people. To understand the change of surface drainage pattern different multi-temporal satellite images (Landsat MSS 1972, Landsat TM 1997, Landsat 8 OLI) are used in the present study. In addition to this, instrumental survey has conducted to understand the changes in direction of surface slope in response to land use land cover along with intensive perception survey has also done to identify various types of human interventions on the immature drainage system. The study reveals that unscientific human interventions on drainage has been modified the local slope and creates obstruction in flow direction of surface drainage. It causes waterlogging problem in interfluves zone. The problem of waterlogging affects farming system and land use pattern of the deltaic island. The human induced obstruction on drainage may create a massive fluvial disaster in future for coastal inhabitants if immediate action is not taken for sustainable management of the drainage system.

Keywords: Drainage system, Human interventions, Surface slope, Waterlogging, Land use land cover.

MODEL-BASED SIMULATION OF URBAN THERMAL FIELDS FOR CHARACTERIZATION UHI EFFECTS IN THE TROPICAL CONTEXT

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The present study uses mono-window and improved mono-window algorithms to Landsat (TM and TIRS) images of summer and winter seasons for the years 1995, 2005 and 2015 in order to retrieve LST with an objective to investigate the dynamics of the thermal heterogeneity in the Kolkata Metropolitan Area (KMA). The fractal net evolution approach (FNEA) is adopted for segmenting the LST images into thermal objects by hierarchical merging of the pixels based on geometry and reflectance of the ground objects. The FRAGSTAT indices are considered to explore the spatial structure of the thermal landscape of KMA and General G* index to determine the spatial agglomerative degree of the thermal objects with their neighbours. The rule-based application of fuzzy logic allows a proper scaling of the thermal fields and such an effort has made it possible to classify the study area into thermal classes that corresponds to classification based on urban morphology. The fuzzy-based classification considers the present status and observed trends of the thermal fields. The study area is classified into possible number of land use/land cover classes by implementation of Support Vector Machine (SVM) that has performed at the acceptable degree of accuracy. To examine the contribution of land use change

types in intensifying the UHI effects thermal fields under each of the thermal classes are individually evaluated. The results show that the UHI effects in KMA is more conspicuous during winter as compared to the summer season and the higher order thermal fields have increased in spatial coverage and contiguity over the period under consideration. As regards the contribution of change in land use/land cover type it can be said that the conversion of lands into compact low rise-residential areas are mainly responsible for the intensification of UHI effects.

Keywords: Landsat, UHI, Fractal Net Evolution Approach, FRAGSTAT, Fuzzy classification, Local Climate Zone.

IMPACT OF OPENCAST COAL MINING ON RIVER HEALTH: A CASE STUDY OF AJAY-DAMODAR INTERFLUVE OF RANIGANJ COALFIELD

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Coal is generally extracted by using two type of method: the underground method, and the opencast method. Opencast method is more profitable due to an easier mode of extraction, less manpower requirement, andlarge scale mechanization. However, in opencast method, removal of waste materials (overburden) and its dumping, formed different anthropogenic landforms like mine pit, overburden dumps etc. These anthropogenic landforms affect the surrounding land and water environment. Rivers are affected by opencast mines as the alteration of topography disrupts the natural drainage systems and flow of the rivers. Several small river basins of Ajay-Damodar interfluve zone of the Raniganj Coalfield (23°83’30”N - 23°85’30”N and 86°83’70”E - 87°82’30”E) are affected by opencast coal mining. Main objective of the present research work is to identify the impact of opencast mining on River Health of the study area. To fulfil this, Remote Sensing and GIS method were used along with field study (measurement of channel morphology). The study reveals that river beds are used as a dumping site of waste materials from the opencast mines. Thus, natural flow of the rivers are blocked by the mine dumps. A number of bars are formed within river beds due to the deposition of sediments from the mine dumps. River courses are also diverted to facilitate the extraction of coal. Wastewater from the opencast nines are discharged into the rivers without any treatment. Thus, the rivers of Raniganj Coalfield are affected by the opencast coal mines, which requires urgent attention for further management.

STUDY ON THE EVOLUTION OF COASTAL REGULATION ZONES AND ASSESSMENT OF IMPLEMENTATION STATUS ALONG THE COASTAL ENVIRONMENT OF PURBA MEDINIPUR, WEST BENGAL

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Coastal Regulation Zone (CRZ) notification was implemented on 19th February, 1991 and amended over 25times, subsequently a new notification following the M.S. Swaminathan’s Committee report were introduced by Ministry of Environment and Forest (MoEF) on 6th January, 2011 and in 2018 a drafted notification were Published by the Ministry of Environment, Forest and Climate Change (MoEF&CC). The main objectives of these notifications are to protect the coastal zone from the negative impact of climate change, to provide livelihood security to the coastal communities and to promote sustainable economic development.Available literature on CRZ indicates several problems associated with these notifications, e.g. non effective implementation, fuzzy policies, improper demarcation of CRZ areas, frequent amendment and changes etc. Now after 28 years of the notification, it is important to understand the effectiveness of CRZ in regulating the activities along the coast and its efficiency in promoting livelihood security to the coastal communities.This present study focuses on understanding the evolution of CRZ area along the Coastal stretch of Purba Medinipur with subsequent changes in the notification during 1991 and 2018, this study also focuses on finding out the present

violating activities and their impact on coastal environment. To fulfil the objectives CRZ maps were prepared on the basis of 1991, 2011 and 2018 notifications and following the West Bengal Coastal Zone Management Plans to understand the evolution of CRZ areas due to changes in the notification, then NDVI and MNDWI indices were carried out for the year 1991, 2011 and 2019 along with LULC and Geomorphic change analysis and then those data were superimposed on CRZ base maps to identify the Violated areas. Problems of the coastal inhabitants and the violating activities along the coast were identified during the field survey in between 2017 and 2019.

IMPACT OF TERRAIN ON LIVELIHOOD OF WOMEN WORKERS IN TEA GARDENS OF DARJEELING DISTRICT, WEST BENGAL, INDIA

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In the Darjeeling district tea industry has flourished over hilly terrains and undulating plains since the colonial period. Rugged and undulating terrains of this district are convenient for tea cultivation which reached highest level of excellence with women workers as the integral part of tea plantation. Life and livelihood of women workers are directly shaped by the terrain. Women workers are bound to work on steep slope for the plantation work, daily house chore and fetching water from nearby streams. So musculoskeletal problem is common among the women workers of the district. Sufficient facilities can enhance the health conditions of women workers. Supply of running water, good transportation on rugged topography and other facilities can enhance the livelihood of women workers. On the other hand Terai plains depict complete different terrain type in the tea garden areas reducing the risk of health problems for the women workers.Tea gardens of Darjeeling district renders two different terrain in hill area and Terai region. So life is differently shaped for the women workers in plantation in these two regions. Detailed primary survey have been conducted in the study area. Data reveals the fact that hill terrains are not convenient for the women workers in the Darjeeling where terrain associated health hazards are prominent. So better facilities can be the main driving factors for the smooth livelihood and work environment.

Keywords: Terrain, rugged topography, musculoskeletal problem, facilities.

ESTIMATION, MONITORING AND CONTROL OF EPHEMERAL RILL AND GULLY EROSION USING FIELD MEASUREMENT, REMOTE SENSING, GIS AND DEMS: A CASE STUDY OF LATERITIC SOIL REGION OF SANTINIKETAN- SRINEKATAN AREA, BIRBHUM, WEST BENGAL

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Badlands are considered as one of the most exquisite geomorphological features of humid tropical regime. Due to the abundance of lateritic soil, there is lack of vegetation in these regions, thereby making the soil vulnerable to increased erosion. In recent times, the erosion occurring in this region has badly affected the equilibrium condition of the existing landforms which is a matter of great concern. Thus, focus should be made to protect these geomorphological features. The lateritic Santiniketan-Sriniketan area (23°41.8'N, 87°40.1'E) situated on the northern slope of Ajoy-Kopai interfluve of Birbhum district is one of the well acquainted Badlands (denominated as *Khoai* by Tagore) of West Bengal. The entire region is characterized by lateritic cap, non-lateritic cap and reflects different forms and intensities of surface lowering, rill and gully erosion. Lateritic cap region resists surface lowering rate to some extent due to positioning of lateritic duricrust over the surface. Sparse

eucalyptus forest is not able to protect soil erosion significantly. Rill and gully extension rate is remarkably high in the fragile non lateritic region. The soil erosion of the study area from rill and gully has been calculated by primary data and has been validated with the results of temporal data. After validation of primary and temporal data, an appropriate hard engineering measurement, Reservoir Cascade System (RCS) has been suggested by which the eroded sediment can be stored into the reservoir which can further control the velocity of the river and the rate of soil erosion from the main channel.

Keywords: Temporal Monitoring, Remote Sensing, GIS, DEM, Estimation of Soil Erosion, Critical Zone, Reservoir Cascade System**.**

ASSESSMENT OF THE HYDRO-MORPHOLOGICAL CONDITION OF HEAVILY MODIFIED MAHANANDA-BALASON RIVER SYSTEM IN DARJEELING DISTRICT, WEST BENGAL

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Anthropogenic intervention results into hydro-morphological alterations is creating severe river degradation and associated hazards worldwide; more noticeably the hydro-morphological condition of the rivers are altered over time, resulting into severe river degradation and associated hazards. Mahananda has become a narrow single threaded river from a multi-threaded one and Balason is relatively more connected with its floodplains but due to extensive bed load extraction, its planform has modified to a larger extent. This study attempts to assess the nature and degree of anthropogenic alterations and its effect on river hydro-morphology. This method was initially designed to comply with the EU Water Framework Directive in which the evaluation of stream morphological quality was introduced after a detailed morphological character wise reach segmentation of the river network.This evaluation procedure of Morphological Quality Index (MQI) was derived by measuring 18 indicators including longitudinal and lateral continuity, channel pattern, cross-section configuration, bed structure and substrate, and vegetation in the riparian corridor, etc. The assessment result indicates that lower part of both Balason and Mahananda River, mainly Siliguri Municipal Corporation (SMC) part is characterised by severely altered hydro-morphology, with the MQI values ranging from less than 3.4 to 1.8; which was designated as moderate to poor hydro-morphological conditions. On the contrary, the upper reaches where disturbance due to human intervention is least, the value ranges from greater than 4 to 5; designated as having good to very good hydro-morphological condition. The assessment result of these highly threatened rivers could be very useful for identification, planning and prioritization of actions for enhancing morphological as well as habitat quality for sustenance of river health in terms of geomorphological as well as ecological view point.

Keywords: Anthropogenic intervention; Hydro-morphology; Morphological Quality Index (MQI); River degradation.

TOURISM AND ENVIRONMENT: A CASE STUDY ON SILLERY GAON - AN ECOTOURISM SITE

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Tourism and environment have always remained intertwined since the time tourism became a global phenomenon. The success of the tourism industry has always been largely dependent on the natural environment

of any given tourist destinations. A place endowed with natural scenic beauty, clean and pristine environment, fresh air and clear water bodies, lush green forests is more likely to draw tourists who are in search of such places where they get to leave behind the hustle bustle of city life and enjoy their solitude by being in close contact with nature. However, the influx of tourists to these destinations often results in the damage of the surrounding natural environment, and tourism continues to grow but at the cost of the environment. Thus, it becomes the prerogative of the various stakeholders in the tourism business, the locals and the tourists to deliberatively take steps towards lessening the impact of tourism on the surrounding environment. Sillery Gaon is a small mountain village, known as an offbeat tourist destination which offers an eco-friendly environment to the tourists, where nature and tourism go hand in hand. In this paper the relationship between tourism and environment in the small village Sillery Gaon, of Kalimpong district will be studied.

Keywords: Eco-friendly, influx, tourism, environment.

CATCHMENT-SCALE ASSESSMENT OF LATERAL AND LONGITUDINAL (DIS)CONNECTIVITY BY TRANSPORT NETWORK IN LOWLAND RIVERS OF EASTERN INDIA

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The connectivity in river system is often disturbed by the extension of transport network, however, which is essential for regional development. Present paper deals with the problem of lateral and longitudinal connectivity in an alluvial river basin of eastern India. The basin is temporally damaged by the development of transport infrastructure in the last five decades (1970s – 2010s). Potential effect on the lateral connectivity has been analyzed by multiple buffer analysis, road curvature index, proximity mapping. The hydro-geomorphological problems in longitudinal connectivity have been examined at ten sample road-stream crossings using intensive geometric survey, flow modelling in HEC-RAS. Significant ($p < 0.001$) growth in total road length and number of road-stream crossing during the last five decades contributes to making longitudinal and lateral disconnection in the present fluvial system. Channel geometry from ten road-stream crossings shows significant differences in channel parameters between upstream and downstream of crossing structure and created problems like downstream scouring, increased drop height at outlet, formation of stable bars, severe bank erosion, and make barriers for river biota. Limited streamside development, delineation of stream corridor, regular monitoring and engineering efficiency for the construction of road and road-stream crossing might be effective in managing river geomorphology and riverine landscape.

URBAN EXPANSION AND LOCAL CLIMATE CHANGE IN SILIGURI MUNICIPAL CORPORATION AREA, WEST BENGAL

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Expansions of cities are the outcome of differential factors of growth. Siliguri had a village like appearance at the beginning of the 20th century but currently this city is experiencing rapid uneven growth of urbanization as well as over population. Evidences for influences of urban expansion on local climate in the Siliguri municipal Corporation (SMC) area, west Bengal, are presented in this paper. This model based analysis shows that urban expansion has significantly changes the local climate. Temperature is increasing from year 1967 to 2016 and

rainfall is decreasing in respective years, which can lead to increase the problem of urban heat island. Monthly rainfall and temperature data has been collected from IMD and NDVI, NDBI, BSI and MNDWI data has been calculated from LANDSAT satellite images. All the data are represented to show the significant changes in local climate. Analysis of Land-Surface Temperature (LST) in this area suggests the thermal inertia, which is also an important aspect of climatic change in urban thermal structure.

IMPACT OF POPULATION INCREASE ON THE ENVIRONMENT: A STUDY OF SILIGURI MUNICIPAL CORPORATION

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Increase of population as a result of urbanization has multifarious effects on the residents of the region which is going through the process of urbanization. Population increase leads to increased demand of the basic needs which ultimately causes resource exploitation and its misuse which in turn has negative impact on the environment. It has to be kept in mind that the lives of the common people are the most affected. Siliguri city has also not been spared from the changing environment caused by urbanization. When the elderly people are asked about the environment of Siliguri, most of them complain of poorer air quality and stinking roads as compared to earlier days. This work aims at analyzing the problems faced by the inhabitants mainly regarding unplanned dumping of wastes, degrading air quality, inadequate safe drinking water and problems of sanitation. To conduct the study, data has been collected through a set of questionnaire followed by random sampling method and the data has been analysed using statistical and cartographic techniques. The present study reveals that development, along with it brings various problems that create inhumane conditions for the residents to live. The primary requisite is therefore to address the issues so as to promote awareness regarding the damaging effects of urbanization. So, it has been tried to give some remedial measures that can help in improving the worsening situation of the city.

INVESTIGATING THE RISK FACTORS OF TUBERCULOSIS: A CASE STUDY IN MALDA DISTRICT, WEST BENGAL

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Tuberculosis is caused by mycobacterium tuberculosis and it is spread through air. It is an infectious disease. Several risk factors play a vital role for the development of tuberculosis but few studies were carried out to identify their perspectives role in Malda District. Convenience sampling techniques has been used for collecting data of tuberculosis patients from the study area. Secondary data has been collected from the district tuberculosis centre and Ministry of Health and Family Welfare, New Delhi form 2011 to 2016. Household survey shows that TB was associated with the family history of TB, smoking, overcrowding, alcohol, anemia, malnutrition, HIV infection and contact of MDR and XDR patients. Smear positive patients were found more in the Englishbazar Urban, Kaliachak, Baishnabnagar and Sujapur *Tuberculosis Unit*. Investigations were made for the environmental factors based on family history of the TB, smoking, HIV infection, spiting condition of TB patients, household drainage system, educational status, drinking water facility and distance of primary health centre form home, crowding of people and throwing garbage or wastage. TB is a multifactor disorder in which environmental conditions play a major role for spreading. This study provides a useful information for environmental factors inducing tuberculosis towards improvement of control measures in the present study area.

PERCEPTIONS AND ATTITUDES OF FOREST VILLAGERS ON FORESTS VALUES: A CASE STUDY OF ALIPURDUAR DISTRICT, WEST BENGAL

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Protection of forest resources is one of the precaution and preconditions of taking sustainable benefit from forest resources, particularly in countries where forests fulfilled livelihood needs of million forests villagers. So for the purpose of assuring a healthy forest resources management, there must be contribution of idea of local inhabitants (forest villagers) who have close interaction with forests along with their attitudes, perspectives, suggestions and ideas concerning sustainable forests protection on their locality. Based on a participatory approach, the prime aim of this study was to identify the forests values such as economic, social and ecological value of the villagers who are living within and fringe area in Alipurduar district as well as to know the attitude, perception and suggestion on environmental impact of forests. In this study, face-to-face survey was conducted amongst 878 head of forest village households of the 39 forest villages in the Alipurduar district of West Bengal. The study indicated that forest villagers preferred more economic value as well as ecological values of forests than social values. Respondents believed that the ecological values of the forests is being very relevant in present days due to phenomenal change of local environment, and predicted that the forests cover will have increased for their livelihoods, health and future generation. They are convinced that only central and state forests organizations are not successful enough in terms of forest protection and sustainable development. So in terms of managing and protecting local forests, it has been understood that forest villagers are more willing to protect forest resources through participatory and cooperative approach with central and state forests organization.

Keywords: Forest Villagers; Forest Values; Forest Protection; Sustainable Development.

RELATIONSHIP BETWEEN FRAGMENTATION OF FOREST AND HUMAN INTERVENTION: A CASE STUDY OF ALIPURDUAR DISTRICT

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With a wide spectrum of population growth and other allied activities forest change and fragmentation is a major issue of research now a days. The current study evaluated the status of phenomenon of forest cover with relation to human intervention and their impact in Alipurduar District from 2000-2018. Three time frame data were downloaded from 2000, 2010, 2018 USGS Earth explorer. Forest cover change meanwhile fragmentation measured by several models and forest intactness pattern. Primary data has also been collected to make out a scenario of changes and its causes. Several statistical procedure has been used for calculating this human co-relation and forest change in spatio-temporal framework. Alipurduar district has the distinction of having the highest forest cover change in west Bengal. This region has experiencing changes in its forest cover and consequent things in forest ecosystem .With the 3 decades forest cover having negative change whereas built-up, plantation, crop-land increasing rapidly. This type of research provide useful insight on understanding the present scenario and causes of forest cover change in particular manner and future trend. Considering the accelerating rate of forest change in recent time the focus should not only be regeneration and reforestation of forest, as well alternating of livelihood of local people.

Keywords: Spectrum, fragmentation, consequent, regeneration.

CHALLENGES OF KARLI CREEK MANAGEMENT IN COASTAL MAHARASHTRA (INDIA)

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Village Devbag, (15^{o} 57' to 16^{o} 01' N latitude and 73^{o} 29' to 73^{o} 31' E longitude) is part of the 6 km long beautiful Tarkarli- Devbag spit, a detached type of beach about 10 km South of Malvan along Maharashtra coast. The spit bar is connected to mainland near Tarkarli. Southern end of the bar abruptly ends at sea near Mobarwadi. The eastern edge of the spit is bordered by tidal stretch of river Karli while western margin faces the Arabian Sea. Village Devbag is showing a tendency of severe breaching from the river Karli side and erosion of shore front by Arabian Sea for the last decade. There is a growing need to monitor and manage the increasingly vulnerable coastline of Devbag. This paper attempts to analyze the erosion based on bathymetry data between year 2005 and 2012. Interaction with local people, interviews, and questionnaires are source to bring forward current issues coming up with rapid growth of tourism in study area. Authors would like to opine their perception, how Karli creek can meaningfully be used for tourism as well as for fisheries sustainably, with scientific approach.

Keywords: Spit, Breaching, Vulnerable, Local People and Sustainable.

GEOSPATIAL TECHNOLOGY FOR HUMAN WELFARE

MONITORING AND PREDICTION OF LAND USE LAND COVER USING MARKOV CHAIN MODEL IN GANGARAMPUR MUNICIPALITY, WEST BENGAL

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Geospatial technology has made the land use and land cover (LULC) change study in urban areas easier and more lucrative. Specially, the cellular automata model-based study of LULC change simulation has an impact on detecting the changes in different LULC classes; these models also helps to predict future land use which is highly effective on sustainable urban planning. Gangarampur Municipality is a growing town in Dakshin Dinajpur district of West Bengal. A buffer zone of 15 K.M. from the municipality boundary covering 958.5 sq. km. area has been included as the study area. The present study mainly focused on LULC change detection and future LULC change prediction over the extended study area. Landsat ETM+ and Landsat OLI/TIRS data of 2003, 2015 and 2019 has been used to prepare LULC map. As a stochastic model, markov chain model was chosen to assess the quantification of LULC changes. Nevertheless, the comparisons of the LULC changes has been done for the time period in between 2003 and 2015. The model based simulated LULC map was prepared for the year 2019 for validation of simulation. Later on, the predicted LULC map of 2027 and 2039 has been obtained with the help of that Markov chain model. The result exhibits the significant changes in LULC parameters; specially, for the built-up areas in the study area.

Keywords: LULC, Landsat, Change detection, urban growth, Markov Chain.

MODELLING OF SPATIAL DETERMINANTS OF URBAN GROWTH OF SILIGURI METROPOLITAN AREA USING LOGISTIC REGRESSION: A GEOSPATIAL APPROACH

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Siliguri is the Metropolitan city in West Bengal has been experiencing extensive and rapid urban outgrowth during the next two decades. This tremendous urban expansion led to the loss ofnatural landscape, agriculture lands, forest cover, and creating problems to run urban utility services effectively in expanded areas. Analyzing the spatial determinants of urban expansion is helpful for urban planning and management of sprawl areas. Therefore in the present investigation we have analyzed the responsible driving factors for urban expansion of Siliguri Metropolitan area duringthe period 1991–2017 with the help of binary logistic regression using random and stratified sampling. Fourteen independent variables wereapplied in this model; Elevation, slope land value distance from forest, distance to river proximity of nearest urban centre, proximity of education centres,proximity of major road, railway line, Built-up density, etc. This research showed that over the past two decades, Built-up area expanded rapidly in the towns. Among the driving factor elevation, Proximity of Major Road, land value, proximity of Education centre and medical centre, have highest regression coefficients and are the most significant driving factors of urban expansion duringthe last 27 years (1991–2017). Based on the results of the LRM, a probability map of urbanexpansion of the SMC has been created, which shows that most urban expansion would be around theexisting urban areas and along the major roads in the southwest direction. The relative operating characteristic (ROC) value of 0.88 indicatesthat the probability map of urban expansion model is valid.

Keywords: Urban growth; driving factor; urban dynamics; logistic regression.

URBAN GROWTH DYNAMICS USING REMOTE SENSING TO PROPOSE FUTURE URBAN GROWTH IN SILIGURI AND ADJACENT BUFFERING DOMAIN: A CASE STUDY

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Urbanization is an inescapable phenomenon and most of the cities of India have already been experienced Urbanization or in a process of gathering experience through it. In developing countries, Urban sprawl is one of the most important feature of urban growth which creates problem in defining urban administrative boundaries. Especially in India, there are many small to medium towns have developed beside big urban centres. This results haphazard urban growth. Here Siliguri and adjacent area is no exception. In this research paper major land change detected from 2000, 2010 and 2019. On the basis of predictive modelling through the rate of Land use and land cover change between previous years and after its validation future urban growth has been predicted. Here urban expansion through different time periods were analysed considering the variables that drives the future urban growth.

MORPHOMETRIC ANALYSIS OF TRANS YAMUNA UPLAND REGION THROUGH CARTOSAT-1 DEM DATA

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Morphometric analysis of Trans Yamuna Upland Region is carried out to understand the hydrological behavior for assessing ground water potential, water resource management, hazard reduction, flood control etc. CARTOSAT-1 DEM data is a major data source for extracting drainage network and for delineating Yamuna basin, Tons basin & all the 8 watershed belongs to both basin. Arc-hydro tool of ArcGIS software version 10.2.2 has been used for generating different thematic layers & attribute tables. Raster calculator and excel sheet is used for calculating linear, areal and relief parameters of drainage basin. The obtained result indicates that Yamuna and Tons river basin have 6^{th} and 5^{th} order stream respectively, both have dendritic drainage pattern with moderate to good infiltration due to low sloped terrain.

Keywords: CARTOSAT-1 DEM, Arc-Hydro Tool, Morphometric Analysis.

MULTI CRITERIA EVALUATION FOR SOIL EROSION BASED ON GEOGRAPHIC INFORMATION SYSTEM: A CASE STUDY IN UPPER CATCHMENT AREAS OF TISTA RIVER

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Soil erosion is one of the important environmental degradation processes. Mapping and assessment of soil erosion vulnerability are important tools for planning and management of human and natural resources. The objective of this paper is to assess the vulnerability of soil erosion based on multi-criteria evaluation (MCE) in the upper catchment of the Tista River. In this study Rank Sum Methodhave been used to calculate the weights of the factors influencing soil erosion of upper Tista basin. Include: rainfall, vegetation, slope, soil, drainage density, land use and aspects of slope etc. GIS and remote sensing are used for derivation, integration, and analysis of geographic layers of each of the themes. The whole study resulted in four classes of soil erosion vulnerability− ranging with very high, high, moderately and low. The soil erosion scenario maps are important in planning conservation and controlling measures for soil erosion to prioritize the area according to severity of erosion. It is observed that more than about 50 per cent of the total area of the watershed is under severe risk of erosion (i.e. very high, high and moderately high soil erosion) and 48 per cent of the area shows slight to minimum risk of soil erosion.

Keywords: Catchment area, GIS and remote sensing, Soil erosion, Tista River, Vulnerability.

GROUNDWATER RECHARGE POTENTIALITY ZONATION OF DARJEELING DISTRICT, WEST BENGAL USING GEOSPATIAL TECHNOLOGY

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Water is one of the prime natural resources available on the earth. Water exists in different forms in different places of the world having different physicochemical properties. But the existence of human being is depends on the availability of freshwater. Groundwater holds a significant proportion of sub-surface freshwater and where the surfaced freshwater is lacking, peoples of those area are totally dependent on the groundwater. Although it is a renewable natural resource, the over exploitation of groundwater causing lot of crisis in the availability of drinking water in many parts of the world including India. Groundwater extraction for daily need and commercial purposes leading to lowering of sub-surface water level, because the extraction is surpassing the amount of recharge. Thus the identification of recharge potential zones for groundwater has become an important task to the hydrologists, which may help us to determine zones of suitable groundwater extraction and the alarming or restricted zones for groundwater extraction. The northern most district of West Bengal, Darjeeling has been selected to carry out the identification of groundwater recharge potential zones using an integrated Remote Sensing and GIS technique. As the recharge of groundwater depends upon various physical parameters and human activities, eight major criterion namely soil, geology, slope, elevation, lineament density, drainage density, rainfall and land-use / land-cover (LULC) have been considered to perform Weighted Index Overlay Method (WIOM) on ArcGIS 10.5. The relative weightage of different criterion have been assigned by Analytical Hierarchy Process (AHP). On the basis of overlay analysis 5 potential zones for groundwater recharge have been identified as very low (1), low (2), moderate (3), high (4), and very high (5). Study reveals around 58 % and 38 % of the total area of the district have moderate and high potentiality for groundwater recharge respectively.

OPEN CAST MINING AND ITS RELATION WITH LAND SURFACE TEMPERATURE AND AIR QUALITY STATUS: A GEOSPATIAL STUDY ON ADDA REGION, WEST BENGAL

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Mining activities have their intense effect on the adjoining areas. Open cast mining affects directly on the physical environment adjacent to it. This study was carried out in Asansol Durgapur Development Authority (ADDA) in West Bengal, analyzing such impact of open cast mines on the environmental issues specially the increasing Land surface temperature and air quality degradation, along with the gaseous pollutants and aerosols causing air pollution along some elongated tracts by either excavation or dumping. Monitoring of the spatial extension of open cast mines (1999-2019) in ADDA region and its relationship with the distribution of high intensity aerosol as well as the spatial distribution of the high Land surface temperature patches or heat islands using geospatial technologies is the core objective of this work. This can be useful for future planning and development strategies as, such degrading environmental issues create some non-survival condition for plants and human beings. This study seeks to examine the Aerosol Optical Thickness (AOT) using Moderate Resolution Imaging Spectroradiometer (MODIS) by Dark Target (DT) and Deep Blue (DB) algorithms and Land Surface Temperature using Landsat 4-5 (TM) and Landsat 8 (OLI & TIRS) temporal satellite data by Single channel algorithm. The outcome values of the environmental variables from the satellite data were validated with primary as well as secondary field information. The temporal changes in the distribution of mining sites were undergone a detailed correlation study with the spatial variability of these two environmental characteristics. The results indicate a significant positive correlation between the spatial distribution of Aerosol Optical Thickness, Land Surface Temperature and open cast mining areas with some discrepancies due to the emissions from existing industries.

UTILITY OF GEOSPATIAL TECHNOLOGY IN THE PERSPECTIVE OF INDIA

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Geospatial Technology has applicable in practically all walks of human existence. Every fundamental question about the functioning of the biosphere and its implications for the environment and human welfare cannot be manipulated neatly. This technology is relevant to multitude of sectors such as agriculture, telecommunications, oil & gas, forestry, environmental management, public safety, infrastructure, logistics etc. The inescapable fact is that the "Geospatial Technology Revolution" will continue at a fast pace which will require accommodation across multiple domains of research, education and government. The common perception regarding utility of Geomorphic Information System (GIS) is in the form of web applications, used for maps and directions, but there is one side aspect. These tools have several features which go beyond location based services. Geospatial technologies as a tool for decision making can add immense value to planning and development. This multifunctional technology can effectively support noble sustainable development, governance, assist in better management of business process as well as bring location based information closer to people. In India, towards the progresses industrialization and technological advancement, decision makers continue to face several challenges for effective governance such as rapid population-growth, scarcity of resources, environmental issues and security issues. It requires an efficient and advanced information and knowledge regime to brace itself for the envisaged economic growth. Geospatial technology with their unique ability for acquisition, integration and analysis of geographically-referenced spatial information, have in recent times been recognized as an effective tool for planning management and decision making locally and globally. Rather than various technologies Geospatial Technology proven capabilities for supporting decision making would be fundamental for information management in future with applications of social and national significance.

Keywords: Geospatial Technology, Sustainable Development, Global Positioning System (GPS), Geospatial Information System (GIS).

VULNERABILITY ASSESSMENT OF FORESTED LANDSCAPE TO CLIMATE CHANGE IN BENGAL DUARS USING GEOSPATIAL TECHNOLOGY

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Bengal Duars, a unique landscape enriched with forest resource and biodiversity located in the foothills of Himalayan. This region has experienced climate change over past several decades in terms of rising temperature and occurrence of more extreme events. Frequent flooding, degradation of forest resource and socio-economic backwardness are enhanced the degree of vulnerability. This study is analysed the level of vulnerability under the domain of exposure, sensitivity and adaptive capacity in the present changing climate. Multi-dimensional vulnerability is addressed here by using GIS based integrated model approach. It has been noticed that 61% of area of Bengal Duars is configured to be vulnerable to climate change. The most vulnerable areas are found in the forest divisions of Jalpaiguri, Baikunthapur, Wildlife-II, Wildlife-III and Buxa Tiger Reserve East and their surrounding landscape.

GEOSPATIAL TECHNOLOGY & ARTIFICIAL INTELLIGENCE BASED STUDY OF GEOMORPHOLOGIC VULNERABILITY

L. P. Sharma

The primary objective of the present work is to propose a technology based system that would cater to understand the geomorphologic study of landside and seismic vulnerability of the study area and propose a software based model for live prediction of hazards based on the depicted vulnerability. The scope of the research is to carry out accurate delineation of the landslide and seismic vulnerable areas and categorize them based on degree of vulnerability and to link them with threshold values of triggering factors within the selected study area. In order to achieve this objective, different geo-statistical techniques have been employed on ArcGIS platform to determine the impacts of various causative spatial parameters on landslide vulnerability. The governing parameters considered in the present investigation comprise various soil parameters such as soil depth, stoniness, hydraulic conductivity, soil drainage characteristics, soil erosion characteristics, surface texture and depth texture in addition to lithology, foliation, slope, drainage network, road network with land use and land cover pattern. Thirteen different geo-statistical techniques have been employed in order to assess the vulnerability of the different land parcels of the study area based on the Landslide Information Value (LSIV) computed for each land parcel. Among the thirteen techniques, nine techniques have been developed and implemented for the first time in the present investigation. Landslide inventorisation was carried out from the analysis and interpretation of the satellite data (QuickBird and Cartosat) and augmented through the field survey. The various causative parameters for landslides were derived from the published maps and Topo-sheets available with the different organisations. The performance of various geo-statistical techniques employed for landslide vulnerability zonation has been compared on the basis of the prediction accuracies that were computed as the percentage of landslides in the highest three vulnerability zones. However, the percentage of vulnerability that is computed as the percentage of area falling in higher three vulnerability zones and the landslide density computed for each vulnerability zones are also considered as potential indicators. Vulnerability zonation maps were then developed based on the prediction from the various models developed. Different threshold Values for rainfall and seismicity are proposed for each of the vulnerability zones. Finally a Geo-spatial Technology and Artificial Intelligence based model is proposed by linking the databases server, application server and the automatic weather stations.It is concluded that Rainfall threshold and magnitude of earthquake for triggering landslide in any slope can be defined based on the other existing geotechnical parameters.In case of landslide, live prediction is possible if a Geospatial Technology integrated software having fibre based or wireless connection with the automated weather station.Hence using an integrated technology in place, landslide can be forecasted and loss of properties can be avoided.In most vulnerable areas advance precautions like special protective walls and vetiver plantation can be done to avoid triggering of landslides.This further indicates that the loss of lives and properties every year is due to lack of correct human and technological intervention.Areas and slopes that can slide with the triggering of earth quake of a certain magnitude can be identified and segregated for further investigation and action.

CRITICAL ASSESSMENT OF DIFFERENT MODEL TO ESTIMATE SOIL EROSION SUSCEPTIBILITY OF HUMID TROPICS: A CASE STUDY OF THE SOBHA DRAINAGE BASIN OF A PART OF CHOTONAGPUR PLATEAU, INDIA

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Complex environment such as plateau fringe areas are highly susceptible to natural hazards particularly those that are trigger by the action of water such as flash floods and soil erosion. Among all the natural hazards, soil erosion is the most implicit hazard, which directly alters the vegetation and property of these regions. Hence, in this study, a strategic monitoring model has been establish to reduce the adverse impacts of soil erosion, which is of utmost importance to the planners for watershed management programme in these regions. This paper primarily demonstrates the use of satellite based remote sensing data coupled with the observational field data in a multi-criteria analytical (MCA) framework to estimate the soil erosion susceptibility of the sub-watersheds of the Sobha watershed(166 sq. km) falling in the western part of West Bengal and adjacent part of Jharkhand. In this study, morphometry and landuse/ landcover are used as an input to the MCA framework to prioritize the

watershed based on their different susceptibilities to soil erosion. Further, the output from the MCA resulted in the categorization of the watershed into low, medium, high and very high erosion susceptibility classes. A detailed prioritization map for the susceptible sub-watersheds based on the combined role of landuse/ landcover and morphometry is finally present. This model is not only applicable for the watershed management programmers but also taken as a tool to investigate appropriate measures of soil loss in the study area.

Keywords: LR (logistic regression), Land use and Land cover, Morphometry, RUSLE Model, Soil erosion susceptibility.

APPLICATIONS OF REMOTE SENSING IN GEOMORPHOLOGY

Narayan Dutt TIWARI, Puneet YADAV and Priyanka MAURYA

Geomorphology and remote sensing are closely related of enquiry their common interest in the five factors of environmental system as relief, climate, process material, organism and time. Remote sensing is the process of detecting and monitoring the characteristics of an area by measuring its reflected and emitted radiation at a distance from the target area. It captures the information by the special cameras with special platform like Airplane, Satellite etc. It have special capability to take information with multi - spectral and multi- thermal band in a short time. Geomorphology as a science deals with evolutionary process of the relief and helps to understand various processes of evolution of landforms. Remote sensing data provides large scale over observation data of all geomorphic features on the Earth's surface. It provide us capability to detect the minors/major changes on the planet geomorphic conditions and features It helps in land management, resources development planning as well as natural hazards management.

Keyword: Remote Sensing, Environmental, Radiation, Geomorphology.

SCARCITY OF FRESH WATER IN CLIMATICALLY VULNERABLE SUNDARBAN REGION OF WEST BENGAL WITH SPECIAL REFERENCE TO MATHURAPUR–II C. D. BLOCK

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Access to fresh water is considered as one of the basic needs of life. Yet, this vital resource for sustaining life is becoming increasingly scarce because of unavailability of sufficient fresh water. Mathurapur–II is a Community Development (C. D.) block of Sundarban region of West Bengal which is located in proximity of the tide dominated coastal part of the Ganga delta. It is criss-crossed by numerous tidal rivers thus experiencing soil and water salinity and problem of fresh water. Besides, improper management of fresh water resources in spite of abundant monsoon precipitation, in the context of high run-off, encroachment and breaching of embankments leading to sea/saline water ingression into ground and surface water bodies, flood, waterlogging, cyclone and sea-level rise enhance the problem. In this study peoples' perception regarding water demand and water availability, issues related to safe drinking water has been assessed through random questionnaire survey. Water demand has been estimated for household and agriculture sectors. Estimated annual drinking water demand of the block is found to be 0.33billion litres and that of domestic sector as 6.70 billion litres and irrigation water demand as 0.38billion litres. On the average, each pond –the main source of domestic water, having 0.10million litres of usable water available in summer can sustain many families, but except very few most of them are saline, polluted, eutrophied, however people are found to be using them have been suffering from many water borne disease. People of the region are very much depending on ground water, but fresh groundwater is only available below160m depth which is difficult for extraction properly because of water level falling drastically during non-monsoon months. Hand pumps are the major sources of drinking water provide yield at the rate of $90m^3$ per hour cannot meet the demand. To mitigate this problem of water shortage rainwater harvesting, water

taxing, effective implementation of the state sponsored 'Jal Dharo Jal Bharo' along with other community programmers may be recommended.

Keywords: Sundarban, fresh water scarcity, rainwater harvesting, Jal Dharo Jal Bharo.

URBAN GREEN SPACE- FINDING AVAILABILITY AND UTILIZATION PATTERN USING GIS

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India is urbanizing rapidly and its urban environmental quality is deteriorating even faster. Urban green space (UGS) is often called the 'Lungs' of the urban areas. They provide multifunctional utility to the urban dwellers plus to the urban environment. Apart from being the source of oxygen, people also utilize it for playing, taking walks, meditation, social mingling etc. It thus positively affects people's physical health and psycho-social wellbeing. But with rapid unplanned urbanization the amount of urban green space is decreasing day by day. Preservation of UGS is dependent totally on the perception of the urban dwellers about its value and utilization of it in reality.This study focuses on the availability and usage of UGS in Barasat, an adjacent city of Kolkata with a very high urban growth rate. The spatial distribution of UGS is measured using Q-GIS 2.8.1-1. Areas surrounding 0.5 km around the UGS were identified using buffer technique. People living in those areas have been surveyed to find out their perception on the role of UGS and pattern of utilization of the UGS.The UGS in Barasat are scattered spatially and the ward-wise distribution is highly variable. In Barasat, 12.5% area is consists of UGS. Among the 25 urban wards, ward no.07 has the highest proportion of UGs (90.6%) and ward no. 25 has the lowest proportion (2.8%). From the questionnaire survey, it was found out that the main importance of UGS was perceived as playground, place to relax, pollution free space etc. However in reality, inspite of living in proximity of the UGS, only about 52.4% people used the green space. Type of usage included playing, walking, chatting, exercising etc. the main reasons for not using UGS were reported as lack of time, overcrowding and inferior quality due to low maintenance of the UGS.

DELINEATION OF GROUNDWATER QUALITY ZONES FOR DOMESTIC AND AGRICULTURALPURPOSES IN UPPER KARHA RIVER BASIN USING GIS TOOL

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Water is essential resource for the survival of human being. The rapid urbanization in the urban and semi urban region resulted in steep increase of groundwater demand for the domestic utilization and agricultural use as well. An immeasurable mainstream of groundwater contamination problems causing today are mostly because of improper management of groundwater resources and over use of available resources, or by combination of both. Because ofinadequate knowledge about groundwater resources the population residing in the particular area faces the problem of water contamination for long period of time.The present study is of Upper Karha River Basin located inPune District Maharashtra State. The study area is upper part of Karha river basin started from origin of the river up to the Malhar Sagar water body. Study area enjoys monsoon rainfall and there is rapid increase in Urbanisation results in more demand of Groundwater for domestic and agricultural needs.In the

present paper the main objective is to study the quality of groundwater forthe estimation of suitable and non-suitable groundwater zones in the Karha river basin. For the delineationof groundwaterquality zones,various groundwater quality parametershave been taken in to consideration. Sample water wells are selected to collect water sample and those samples has been analyse in the laboratory. The results obtained by the analysis converted in to thematic layers and further weight has been assigned to each thematic layer by using Arc GIS environment with weighted over lay index method.There are three zones observed in the study area likewise Suitable, Non suitable and suitable in the critical condition. The villages Askarwadi, Chambhli, Patharwadi, Bhivri, Pimple, KhaladKhanavdi, Kothale and Naralicha mala facing the groundwater contamination problem as values of some samples exceeded the permissible limit prescribe by BIS. The pH value for these villages is less than 7 which is not suitable for drinking. Electric conductivity is also showing the higher concentration in these samples and it is>2366 Siemens/ml.All groundwater samples are showing good properties for Agricultural utilization. Groundwater quality zonation has been displayed in map.

Keywords: Urbanisation, Groundwater Quality, GIS tool.

WATERSHED MANAGEMENT USING QUANTITATIVE MORPHOMETRIC ANALYSIS OF BAITARNI RIVER SUB-BASIN, ODISHA

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Understanding the hydrological dynamics of a basin necessitates a detailed assessment of the geomorphological and topographical characteristics of the basin. GIS and Remote Sensing tools can be a useful and significant instrument for achieving this objective. Baitarni River is a part of Mahanadi-Brahmani river system which have history of annual frequent flooding. Quantitative morphometric analysis coupled with GIS technique can help assess the hydrological characteristics of the basin which can be useful for water resources assessment and flood management. In the present study, focus is made on Baitarni river sub-basin, Odisha which is located between 85°10’5’’E to 86°20’30’’E longitude and 22°15’N to 20°55’30’’N latitude. The watershed is demarcated using SRTM DEM 90m*90m data using ArcGIS and Hydrology tool under spatial analyst tool. The basin area is 10059 Km^2. Morphometry parameters like drainage density, stream frequency, bifurcation ratio, relief ratio, elongation ratio, form factor, etc. are calculated and analysed. Dendritic and semi-dendritic drainage pattern is prevalent in the Sub-Basin. From the morphometric analysis, the Sub-Basin is of 5^{th} order stream. The region has an area of moderate relief and moderate slope. Elevation range from 1092 to 7 metre msl. There are indications of structural control with moderately steep slopes. The Sub-Basin has low drainage density (0.26) which indicate that the area is permeable with good infiltration capacity. The Sub-Basin has texture ratio of 2.93 indicating a predominantly alluvial area. It is found that the Sub-Basin has an oval shape with an elongation ratio of 0.82 and a form factor of 0.414. This connote that the flow will take relatively moderate time to travel from the most extreme point to the outlet and the resultant hydrograph would be medium to high bell-shaped denoting the susceptibility to flooding.

Keywords: Morphometric analysis, Baitarni River, GIS, Flood, Water resource Management.

A STUDY ON LAND EVALUATION IN RAJGANJ BLOCK OF JALPAIGUROI DISTRICT BY USING GEOSPATIAL TECHNOLOGY

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In spite of extensive research and technological advancement, the study of land unit has remained more of a speculative and intuitive science, as there is no method to facilitate direct observation of land in inaccessible area. Its quality can only be inferred indirectly by studying the geological, topographical, existing land use and land cover, etc. Remotely Sensed data by virtue of its synoptic coverage and multispectral nature help in identification and mapping of most of the factors with selective ground checks in a cost-effective manner. An integrated analysis of the factors and the ancillary data in the GIS environment helps in identifying the various types of land. The objectives of the present study are to discuss about the origin and evolution of the soils of Rajganj, Jalpaiguri and the impact of relief on its formation. Our motive is to find the quality of the land of this particular block that how much the land is capable to serve the potentiality for use in specified ways, or with specified management practices. The efficient use of land is not solely the function of soil types but is dependent upon a number of factors of which the most important are the physical and chemical properties of soil and the relationship between soil and terrain. It has been revealed from the study that, texture, chemical productivity, weather retention capacity of the soil and the terrain characteristics together are the most important factors that influence the land capacity. Among the limiting factors slope gradient, rooting zone, stoniness and obviously soil erosion are most important, while drainage does not appear to be of any major problems, even under a moderate management. As the northern part is hilly forest tract there is almost entirely the nature is domain. In the N-Wn part, it is a plain area along the bank of River Mahananda. Here the transport facilities are very developed. As a result, the SMC (Siliguri Municipal Corporation) has developed. Beside the other tract is more or less plain with very insignificant gradient and here the main character of land is that it is sandy loamy alluvial type. Agriculture is the main use in this sector with number of isolated rural settlements. Agriculture in the Rajganj area, at present has developed with limited commercial importance. A few tea gardens and pineapple gardens are now under operation and a few portion of northern part of Rajganj P.S. is under natural forest cover. Hence, the future agricultural development must be economically viable. Therefore, the land capability classification may be utilised for delineating area that are suitable for commercial development.

Keywords: Land evaluation, USDA method, Geospatial Technology.

ENVIRONMENTAL URBANIZATION ASSESSMENT USING GEOSPATIAL TECHNOLOGY: A STUDY OF SILIGURI MUNICIPAL CORPORATION

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The rate of urbanization in the Siliguri Municipal Corporation is uncontrolled and is rapidly growing considering the area it encompasses. While in the modern world, urbanization is a way of life the quality of life in the urbanized world differs from that of the rural world. More to say there is also a difference between the urbanized places of the developing countries and the developed countries. While the urban places should be socially and economically sustainable, it is very much necessary to consider the environmental sustainability of the urban place. In this paper an attempt has been made to assess the performance of environmental urbanization in a sustainable form, for Siliguri Municipal Corporation as the study area. There exist various aspects to assess the environmental quality of the urban place and is also very complex in nature when required to be considered for decision making keeping the environment in mind. The parameters as taken are: Urban Housing, Traffic Congestion, Socio-Cultural Dimensions, Environmental Pollution and so on, then Analytical Hierarchy Process (AHP) method is used to determine the weights of the indicators. The required data has been collected from both secondary and primary sources, as well as have been extracted from images. The study reveals that the comprehensive urbanization of Siliguri Municipal Corporation is close to medium level.

DETECTING TIMING OF LAND CONVERSION ANOMALY IN RESPONSE TO URBAN GROWTH: A TIME-SERIES ANALYSIS

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Urbanization is an important driving factor that result in rapidly changing the existing land use, impact agricultural land conversion, climatic condition, environmental degradation, hydrological cycle etc., and often pose threat to the human society. However, these processes of land conversion have multiple steps that do not follow the simple linear conversion rules. Such anomalies in the timing and season of land conversion can be effectively detected by Breaks for Additive Season and Trend (BFAST) time series decomposition algorithm. A large number of Landsat derived spectral indices e.g., Normalized Difference Vegetation Indices (NDVI) has been used to detect the timing of land conversation of a small area of land in the fast growing city of Surat. Results indicate that the algorithm can detect the area of significant agricultural land conversion, and the timing of changes. The outcome of the analysis can help the policy makers to monitor and evaluate the historical land use change in response to the urban growth, the understanding of which will enable them to identify the forces of such conversion and thereby, implement the necessary policy implication.

Keywords: Urban land conversion, BFAST, time-series analysis, Landsat NDVI, Surat.

LAND SUITABILITY ANALYSIS FOR PADDY CULTIVATION THROUGH GEOSPATIAL TECHNIQUE: A CASE STUDY OF MALDA DISTRICT, WEST BENGAL

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Improvement and maintenance of land resource are the basic decision making tool for sustainable crop production. The production of paddy is happentually low and if there exists any deficiency of information on the best combination of influencing factors. With this view in mind, the main objective of this study is to evaluate the land suitability of Malda district using Multi-Criteria Evaluation (MCE). For developing the land suitability map variables of soil, climate and topography were considered. For ranking the different suitability factors an Analytical Hierarchical Process (AHP) was used and the subsequent weights were utilized to construct the suitability map layers in Arc GIS 10.1 (trial Version.) platforms. The IDW (Inverse Distance Weightage) interpolation method has been used to show the spatial distribution of the suitability site in the study area. The assessment reveals that most of the areas (more than 70%) of the district are highly and moderately suitable for paddy cultivation, though the maximum soils of the district are neutral and slightly acidic in character. Therefore, economic growth of agricultural sector can be attained by cultivating paddy crop in highly and moderately suitable areas and performing diversification of slightly suitable areas to crops other than paddy.

Keywords: Land suitability, Sustainable crop production, MCE, AHP, IDW

AN ASSESSMENT OF TERRAIN PARAMETERS F OR AGRICULTURAL DEVELOPMENT: A CASE STUDY OF TENGA RIVER CATCHMENT, WEST KAMENG DISTRICT, ARUNACHAL PRADESH

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An Assessment of Terrain parameters is an important step to detect the environmental limit on agricultural practices. In the present study, terrain characteristics of Tenga River Catchment were assessed to estimate the land suitability for agricultural development. Tenga River Catchment located in the central part of West Kameng District of Arunachal Pradesh is known for its agricultural production. The parameters taken into consideration were altitude, slope, aspect and land-use/land-cover. ASTER DEM of the area has been used to generate spatial variations in its altitude, slope, aspect and TWI parameters while Satellite Image has been classified to prepare land-use/land-cover map. AHP method was used to identify the weight of each parameter from the pair-wise comparison matrix. The land suitability map for agricultural development in study area was then generated using Weighted Overlay Analysis in GIS environment by overlaying parameter weights and sub-parameters weights. The study area has been classified into five categories viz. Highly Suitable, Moderately Suitable, Marginally Suitable, Currently Not Suitable and Permanently Not Suitable Areas (Rocky Structure). It was determined that substantial proportion of study area was under forest cover with high degree of slope. Highly Suitable Land for Agriculture was found along the banks of Tenga River on the valley floors, mid-slopes and crest zones.

Keyword: Terrain parameters, Tenga River, Land Suitability, AHP method, Remote Sensing and GIS.

YOUNG GEOMORPHOLOGISTS COMPETITION

MORPHOTECTONIC EVOLUTION THROUGH GEOMORPHIC PROXIES IN KALLAR WATERSHED OF ACTIVE TECTONIC AND HUMID TO SEMIARID REGIONS OF CAUVERY BASIN, INDIA

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Internal tectonic processes deform the lithosphere while external climate forcing shapes the surface topography. Any perturbation caused by these processes will shift a landscape from its state of dynamic equilibrium to a state of disequilibrium. In this scenario geomorphic proxies are useful insights into understanding long-term endogenic and exogenic response to erosion and landform uplift rates in Kallar watershed. By evaluating two major proxies i.e. areal proxies (asymmetry factor (Af), mountain front sinuosity (Smf), shape factor (Shp) hypsometric curve and hypsometric integral (Hi)); linear proxies (river sinuosity (R), stream length gradient (Sl) and Chi gradient (Mχ)) and longitudinal profile were calculated for each micro watersheds. The study aims to evaluate the relationship between basin maturity and geomorphic proxis; along with internal correlation within the geomorphic proxies and understanding of morphotectonic evolution in Kallar Watershed of active tectonic and humid to Semi-arid regions of Cauvery Basin, India. The North and northwest micro watershed display convex shape hypsometric curves indicating a youth stage and significant tectonic influence. Mid portion has high river sinuosity which indicates the mature meandering stage of Bhavani River. The low and moderate Smf values within the micro watersheds are indicative of mountain fronts witnessing a high level of tectonic activity.The recent resurgence of tectonism is not only reflected in the shifting of Trunk Rivers, but is also evidenced by seismicity and landslides/faulting. The areal and linear proxies are positively correlated each other in terms of erosion rate and faulting. Present study reveals the active tectonic and the upliftment of landforms in upper part and central portion experiencing higher erosion. Through this understanding of local to regional level of tectono-geomorphic activity, further leads to neotectonic level of study for better understanding in more tectonically active regions.

HYDRO-GEOCHEMISTRY OF GURUDONGMAR LAKE IN SIKKIM HIMALAYA, INDIA: EXAMINING SEASONAL VARIATION OF MAJOR IONS AND DISSOLVED HEAVY METALS

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High altitude lakes are especially vulnerable to climate change with increasing anthropogenic influences due to their small catchment area, less vegetal cover, thin soil profile and also low bedrock weathering rates. The present hydro-geochemical study was focused on one of the highest Himalayan sacred lake Gurudongmar Cho, situated at an altitude of 5154 m.a.s.l in Sikkim Himalaya, India. The survey was carried out in the ice-free conditions during the pre-monsoon (June) and post-monsoon (November) seasons in 2018. The water samples were collected from different sites (inlet, outlet, human influence sites and other littoral zones) to represent entirely the quality of the lake. The physical parameters such as water temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, turbidity and dissolved oxygen (DO) were measured on-site and major concentrations of cations and anions in the water samples were analyzed in the laboratory and their variation was observed using spatial distribution contour plots. The results indicated that the overall lake water is slightly alkaline pH, followed by low EC, salinity and PO_4^{3-} concentrations which signify that the lake is oligotrophic in nature. The increase in concentrations of most of the ions in the pre-monsoon time probably due to long-range atmospheric transported pollutants through dry deposition and more snowmelt runoff, whereas higher concentrations of NO_3^- and Cl^- in some sites reflect the localized impacts of nomadic settlement, tourist influxes and grazing. Carbonate weathering is the principal source of the major ions in the lake indicating that water chemistry of the lake is governed by bedrock geology. Thus, the lake water is classified as Ca^{2+} (HCO_3^-) water type. Hence, Gibbs plot also suggested the dominance of rock weathering in the region. In addition, the concentrations of heavy metals such as As^- and Pb^+ were above the WHO detectable limits in most of the samples. Hence, this study can be a preliminary database for the evaluation of future anthropogenic influence on the lake in the region.

Keywords: High Altitude Lake; Hydro-geochemical facies; Weathering; Seasonal variation; Sikkim Himalaya.

MODELING CHANNEL AVULSION POTENTIAL ZONES (APZ) USING ANALYTICAL HIERARCHY PROCESS WITH FUZZY LOGIC METHOD OF CHEL RIVER, NORTH BENGAL (INDIA)

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Channel avulsion process indicates the diversion of flow from an existing channel onto the floodplain, eventually resulting in a new channel belt. It causes new braiding pattern within the existing channel. On the piedmont surface (North Bengal), the avulsion process follows annexation of previous channels by new channels. On the proximal fan surface, the process is dominated by rapid reoccupation and abandonment process. The major avulsion events and dynamic transformations of channel planform mostly occurred during the catastrophic rainfall events of 1992, 1996, 1998 and 2000. The paper aims to find out various geomorphic and anthropogenic parameters which are most likely to influence avulsion process in this river. The multi criteria decision making process (MCDMP) schedule has been prepared after checking the results of Factor analysis. In framing pair-wise comparison matrix of Analytical Hierarchy Process (AHP), we dropped X1 variable (S_{cv}/S_{dv}) as less explained by the resultant factors. The pair-wise comparison matrix checks the relative preferences of various 'decision factors' involves in the preparation of Avulsion Potentiality Zonation (APZ). The Fuzzy AHP model

finds- a. Sinuosity parameter (P) and b. Braid Channel Ratio (BCR) having significant normalized weights to map APZ alternatives.

Keywords: Avulsion, Triangular fuzzy number, Pair-wise matrix, Criteria Weights, Analytical Hierarchy Process, Braid Channel Ratio.

MULTI-INDEX APPROACH FOR CHARACTERIZING RIPARIAN VEGETATION QUALITY AND STREAMBANK STABILITY ASSESSMENT ALONG THE RIVER DULUNG, EASTERN INDIA

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Riparian vegetation exerts a significant control on the general morphological quality of river channels and streamside vegetation strips are widely used in river management to increase streambank stability. While site-specific differences do exist due to multiple factors, dense good quality riparian vegetation is generally an indicator of lateral stability in river channels. The assessment of riparian vegetation therefore assumes great significance for sustaining river health. In this paper, we examine the relationship between the riparian vegetation cover, channel stability and bank erosion along the River Dulung, which flows down the eastern fringes of the Chotanagpur Plateau. Reach-scale assessments have been undertaken for all parameters at 54 sites, with an average reach length of 2 km each along the entire length of the river. The quality of riparian vegetation was quantified using the Qualitat del Bosc de Ribera (QBR) Index and the Riparian Strip Quality Index (RSQI) around a 50 metre riparian buffer zone. The QBR Index encapsulates attributes of riparian vegetation like coverage and structure and anthropogenic modifications while the RSQI considers the land use pattern of the riparian zone. For vertical and lateral channel stability assessment, the Pfankuch Channel Stability Index, a multimetric rapid assessment technique was used, that determines the stability based on 15 indicators which encompass channel dimensions, bank angle, presence of vegetative surface protection and bed sedimentation and degradation. Bank erosion rates were predicted using the Rosgen BANCS model comprising of three components- Bank Erosion Hazard Index (BEHI), Near-Bank Stress (NBS) and observed rates of bank retreat. The results showed that a negative relationship exists between QBR-RSQI and both channel stability index and bank erosion rates. This implied that the better the quality of the riparian strip, the lower were the bank erosion rates and greater the stability of the river channel.

AN EARLY HOLOCENE FLOOD EVENT OF THE SOM RIVER FROM WESTERN INDIA

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The Som River is a major tributary of the Mahi River which rises in the eastern slopes of the Aravalli Hills. The length of the river is 121 km with drainage area of 8707 km². Investigations were carried out for palaeoflood along 8 km long reach of the Som River cut through ridges. A single-stacked slack water deposit (SWD) was identified at the beginning of the ridges cut reach. The SWD has been preserved at bottle neck of the reach influenced by back-flooding. The slack water sediment is deposited on the quaternary sediment in high-standing bench with 1.5 m thick and about 9 m above the river thalweg. The SWD is dated by using optically stimulated

luminescence (OSL) representing a single flood event covering ~ 8.2 ka of Holocene period. The magnitudes of the palaeoflood and a historical flood of 1973 are 3287 m^3/s and 4233 m^3/s respectively calculated by using slope-area method. A cursory examination of the causes of floods indicates that majority of floods on the river are produced by heavy downpour due to low-pressure system (LPS). Incidentally, the 1973 flood was the result of a LPS. Strengthening of summer monsoon and related high precipitation occurred during Early Holocene between 9.5 Ka and 5.5 Ka. Discharges and sediment inputs to the Arabian Sea from the Peninsular Rivers increased significantly during this Early Holocene monsoon optimum. It is, therefore, reasonable to conclude that the palaeoflood on the Som River was probably produced due to LPS. It, further, implies that the recent flood is slightly higher in magnitude than palaeoflood. Sediment deposition was more dominant during palaeoflood event and preserved at an ideal site on the Som River. The dated flood event is associated with Early Holocene period of related high precipitation and subsequent floods.

A PRELIMINARY STUDY TO RECONSTRUCT PALAEOCLIMATE IN THE CHANGME KHANGPU VALLEY, SIKKIM HIMALAYA

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The Changme Khangpu (CK) valley in Sikkim Himalaya has been taken to study the palaeoclimate through the proxy of glacial landforms and glacigenic sediment assemblages. The N-S trending valley of CK in the Sikkim Himalaya lies at the intermediate zone of the South-West Monsoon and North-East retreating Monsoon wind. Lack of previous studies and abundant spectacularly preserved landforms within the 4.5 km downstream from the present glacier snout raises the importance to reconstruct the palaeo glacier extents and glacial land system. The analysis of the satellite data (SRTM DEM, Sentinel-2A satellite imageries), field-based sediment-stratigraphically analysis (grain size, facies contact, clast fabric, etc.), and the 14C isotope AMS dates assist in reconstructing the palaeo glacier extent and glacial landform-sediment assemblages. At present the debris-covered CK glacier is restricted at 5900 to 4810 m a.s.l. altitude (27.9583 N, 88.6844 E) that is surrounded by the Phase-IV latero-frontal moraine and an active paraglacial land system. The Phase-III hummocky moraines terminated at the palaeo-lacustrine sedimentation. This rhythmist archive situated at 1.7 km from the present glacier snout, and was dated to be 31.47 ± 0.15 Ka Cal BP. Chronological analysis of glacio-fluvial archive from a trench in the palaeo-ablation valley indicate towards oscillating nature of environment from 14.05 ± 0.17 to 3.45 ± 0.06 Ka Cal BP. This study suggests that valley slope derived paraglacial processes inhibited the preservation of primary glacial sediments and geomorphic features in such environments. The Phase II significant glacier advance has left its imprint through the well-defined terminal moraine (stretches from 4740 m a.s.l. to 4540 m a.s.l.) that was terminated by the 100 m long Roche moutonnée. The ductile deformation of the tills on the open section of the Phase-II moraine throws glimpse on the subglacial environment.

BANK EROSION VULNERABILITY ZONATION: A CASE STUDY OF RIVER MAHANANDA IN DARJEELING HIMALAYA

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In this paper, bank erosion vulnerability zonation has been done to know the probability of occurrence of bank erosion of river Mahananda in the foothills of Darjeeling Himalaya. 32 sites have been selected for this analysis. The method uses some parameters, such as rainfall, near bank velocity, bank slope, vegetation cover, bank

material characteristics, position of thalweg, anthropogenic activities in terms of bed material extraction activities, unscientific construction activities etc. Field surveys have been done for the measurement of different hydraulic parameters of the river and the bank erosion rate from the year of 2016 to 2018. Topographical maps, ArcGIS Living Atlas, DigitalGlobe image, Cartosat DEM etc. have been used to determine different aspects of the zonation model. The individual value of each parameters gives a combined value for the selected sites. BEHI and NBS Model have also been applied on the selected sites and compared with the vulnerability zonation model to know its validity in the study area. The whole stretch of the study area has been divided into five hazard zone, i.e. very low, low, moderate, high and very high. The calculation of BEHI rating and the observed erosion rate shows a positive relationship. Out of the 32 sites, 7 falls under very high, 5 high, 9 moderate, 6 low and 5 very low vulnerable zonation respectively. 78% relationship have been found between the value of vulnerability zonation and observed bank erosion rate. Therefore, the method can be accepted to know the vulnerability of the bank erosion of the study area and may be of help to take any necessary measure to control the hazard.

Keywords: Bank erosion vulnerability zonation, Bank erosion hazard index (BEHI), near bank stress (NBS).

SIGNIFICANCE OF LOCAL COASTAL GEOMORPHOLOGY IN DETERMINING COASTAL VULNERABILITY- A VILLAGE LEVEL STUDY OF CANACONA, GOA, USING GEOSPATIAL TECHNOLOGY

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Global Warming is causing higher sea levels, which are coinciding with more intense storms which produces powerful storm surges consequently making coastlines vulnerable to coastal hazards. But not all the coastal regions are highly vulnerable. In this background this study aims to determine significance of local geomorphology on coastal vulnerability. Study area comprised 42 km long coastline of Canacona taluka of Goa, consists of 5 coastal villages. The methodology used 10 parameters and followed the procedure of study conducted by Kunte et al. (2014) along with Geospatial techniques to find physical vulnerability values. 10 parameters namely; Coastal slope, Coastal elevation, Sandy coast (%), Sand Dune density, Vegetation behind the beach, Rate of relative SLR, Shoreline erosion rate, Mean tidal range. Significant wave height, plausible storm surge height, which were ranked on a linear scale from 1-3 in order of increasing vulnerability. The PVI values of Villages of Cola, Agonda, Nagercem-Chaudi, Poinguinim and Loliem were 13.1, 27.8, 34.1, 16.1, and 5.3 respectively. High variations in PVI values are mainly influenced by local geomorphological settings. Sandy beaches, sparse sand dunes &Vegetation, estuary, low elevation and high coastal slope gave Nagercem-Chaudi the highest value, where world famous Palolem and Patnem beaches are located. On the other hand, with dominantly rocky coast and higher elevation Loliem got the lowest vulnerability value. Result showed that emphasis to grass-root level study should be given because coastal geomorphology plays significant role in affecting vulnerability values at any point along the coastline. It also implies that coastal settlement morphology mostly prefers coastal plains and proximity to the beaches which can add more vulnerability. Therefore, fragile landforms such as Sand dunes and Sandy beaches must be protected from non-sustainable anthropogenic activities as they act as the first line of defence from coastal hazards.

USING ECO-GEOMORPHOLOGICAL INDICES TO ANALYSE RIVER HEALTH AND CHARACTERISE STREAM FUNCTIONS: A CASE STUDY OF RIVER SILABATI, WEST BENGAL

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The inclusion of the term "Hydrogeomorphology" in the Water Frameworks Directive by the European Union has altered earlier perspectives of stream health analysis. Rivers are now viewed from integrative perspectives of channel morphology, hydrology and ecology for sustaining long-term restoration goals. This paper ascertains the morphological, hydrological and ecological health of River Silabati flowing through south-western West Bengal using a number of inter-linked eco-geomorphic indices. The channel has been segmented using Rosgen Natural Stream Classification system into 117 reaches, each of 2 km length. The morphological connectivity was analysed using the Morphological Quality Index (MQI) which takes into account 28 indicators to judge the overall state of the channel. The MQI results were compared with the site-specific Horton's Water Quality Index (WQI) which revealed the direct influence that channel morphology and water quality have on in-stream biota. Results were further validated using vegetation indices like Riparian Habitat Quality (QBR), Riparian Strip Quality Index (RSQI) and Normalised Difference Vegetation Index (NDVI), to pinpoint reaches that are in urgent need of restoration. The overall MQI score was 0.68 and the WQI was 83.4, which indicated channel health quality as being low. The QBR and RSQI scores also highlighted a seemingly degraded channel course. Strong correlations have been found between the morphological and hydrological parameters which helped in explaining some of the root causes of degradation. Flow and sediment disruption due to cross-structures, clear cutting of riparian vegetation for agriculture and intensive sand-mining activities in the middle course (MQI 0.63) while siltation, decreased carrying capacity, urbanization and incessant flooding in the lower course (MQI 0.69) have been identified as some of the major causes of stream health impairment. The upper course, though reflecting near-pristine conditions in a few reaches, also has some impairments resulting in a score of MQI 0.71.

Keywords: Riparian ecology, Stream morphological quality, River health.

In Collaboration with

Science and Engineering Research Board (SERB)
Department of Science and Technology (DST)
Govt. of India

Indian Council of Social Science Research (ICSSR)
MHRD, Govt. of India, New Delhi

Ministry of Earth Sciences (MoES)
Govt. of India, New Delhi

Siliguri Jalpaiguri Development Authority
Govt. of West Bengal, Siliguri

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UNIVERSITY OF NORTH BENGAL
Accredited by NAAC with Grade A

Published by : The Registrar, University of North Bengal
Printed at : The University Press, University of North Bengal

Acknowledgment to ISRO, Bangaluru for background image of Cover Page.