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1ST INTERNATIONAL CONFERENCE ON LANDSLIDES RISK REDUCTION AND RESILIENCE - 2019

Thursday, 28th November 2019
The Ashok Hotel, New Delhi, India

ABSTRACT VOLUME

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NATIONAL INSTITUTE OF DISASTER MANAGEMENT
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1st International Conference on Landslides Risk Reduction and Resilience-2019

Thursday, 28th November 2019, Banquet Hall, 3rd Floor,
Hotel The Ashok, New Delhi

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GOVERNMENT OF INDIA

MESSAGE

Landslides have fetched global concern in recent years. The ubiquitous hazard has the potential to cause catastrophic disasters and wreck havoc on community, human settlements, livestock, livelihoods and environment leading to colossal losses and damages directly or indirectly in a cumulative way. The economic losses plunged by landslides are not only associated with devastation of structures and infrastructures such as buildings, roads, railways, bridges, dams, communication systems and ports but also cultural and natural heritages that are invaluable and irreplaceable for dwellers of the regions and others. Though the disasters don't discriminate against the boundaries crafted by Homo-sapiens on the globe, yet the developing countries are most affected by disasters in terms of socio-economic and life losses.

The need of hour therefore is to address the multidimensional aspects of the landslides through productive collaborations in international, national, state and district level platforms. I am delighted to note that many stakeholders have submitted abstract papers for this international conference and shared information about their works and experiences related to landslides risk reduction and resilience. I am hopeful that this conference will provide a roadmap for such collaborations by sharing of wisdom, expertise and indigenous knowledge in the field of landslides risk reduction and resilience.

I welcome all delegates from international and national organisations to this 1st International Conference on Landslides Risk Reduction and Resilience-2019 and would like to congratulate them all for their contributions to this field.

(G. Kishan Reddy)

25th November, 2019
New Delhi

FOREWARD

National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Government of India is a premier institute and a Statutory Body (under Disaster Management Act 2005) for training, research, documentation, awareness and capacity development of human resources in the field of disaster risk reduction and resilience. The Institute has been organizing various training courses and conducting seminars / workshops / conferences covering wide spectrum of themes at the national and international levels besides publishing several training modules and other documents including case studies, templates and disaster reports.

The International Conference on Landslides Risk Reduction and Resilience will be directed towards understanding past and present processes to ensure landslides risk reduction and resilience through effective and successful strategies and approaches with focus on enhancing human capacity. The conference will also discuss about various issues of landslides with reference to Sendai Framework for Disaster Risk Reduction (SFDRR), Sustainable Development Goals (SDGs), Urbanization Agenda, Climate Change and 10 Points Agenda for DRR suggested by Hon'ble Prime Minister of India during Asia Ministerial Conference on DRR (2016) in context of plans, policies, procedures, guidelines and strategies for landslides risk reduction and resilience with multi-hazard perspective.

It will surely provide an ideal environment to national and international delegates including experts and relevant functionaries from the government and non-government agencies, academics & research institutes and media for exchanging innovative scientific and indigenous, short-term, medium-term and long-term solutions for eliminating or reducing the landslides risks and obtaining sustainable growth and development of human and ecosystem.

I also thank all the authors for contributing their latest work in the abstract volume of the said conference. Special thanks go to advisory committee for their valuable direction and to knowledge partners for supporting the cause of International Conference. I express my sincere gratitude to all the organizing committee members and NIDM staff for their immense support in bringing out this International Conference possible within a very short period of time.

Major General Manoj Kumar Bindal, VSM
Executive Director

PREFACE

Landslides are one of the potential hazards that cause catastrophic disasters and wreck havoc on community, human settlements, livestock, livelihoods and environment leading to colossal losses and damages directly or indirectly in a cumulative way. The economic losses plunged by landslides are not only associated with devastation of structures and infrastructures such as buildings, roads, railways, bridges, dams, communication systems and ports but also cultural and natural heritages that are invaluable and irreplaceable for dwellers of the regions and others.

The disastrous phenomenon have a broad spectrum of magnitude and types that can be triggered by other disasters such as earthquakes, unprecedented precipitation, wildfires, cyclones, floods, glacial lake outburst floods, cloudburst and anthropogenic activities viz., unregulated cutting of hillsides, haphazard constructions of buildings and roads on fragile slopes and mining. In Kiryu, Japan, 2012, an International Symposium on Earthquake-Induced Landslides was organised especially to brainstorm the research area of earthquake induced landslides

Landslides are also responsible for inducing hazards like flash floods and tsunami. Collapse of landslide dammed lakes can generate devastating flash floods. Similarly, episodes of submarine landslides are enough capable of producing huge tsunamis in coastal areas that can be potential threat to community and coastal ecosystem (e.g. Indonesia Tsunami 2018).

The climate change and its adverse impacts on temperature and precipitation will further flame the quotient of landslide disasters and will be constantly challenging our strategies of landslides risks reduction and resilience. An International Conference on Landslides and Climate Change was held at Ventnor, Isle of Wight, United Kingdom in May 2007 to understand the relationship between climate change and landslides.

National Institute of Disaster Management endeavours to convoy expertise and wisdom on landslides risks reduction and resilience around the globe under one single umbrella by organizing "International Conference on Landslides Risk Reduction and Resilience" to launch a wider and stronger landslides risk reduction and resilience network (both national and global) by the delegates/resource persons and to combat the impending risks of landslide hazards.

The active participation of the international, national and local delegates will certainly fabricate an excellent platform for meaningful deliberations and road map for reducing landslides risks and strengthening the resilience against the disasters.

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- Department of Science & Technology
- Central Building Research Institute
- Sikkim State Disaster Management Authority
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- Guru Gobind Singh Indraprastha University
- Revenue (RR&DM) Department, Government of Tripura
- ICLEI – Local Governments for Sustainability
- Mahatma Gandhi Kashi Vidyapith, Varanasi
- Indian Institute of Technology, Bombay
- Odisha State Disaster Management Authority
- National Geophysical Research Institute

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ACTIONS AND INITIATIVES FOR LANDSLIDES RISK REDUCTION AND RESILIENCE

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ABSTRACT
Landslides have posed serious threats to life, economy, infrastructure, environment, resources, services and the society. Despite all efforts, the damages and losses from landslides could not be reduced well in several countries like India, Nepal, Pakistan, Bhutan, Sri Lanka, Vietnam and China. It required introspection into the actions and initiatives being taken to deal with the challenges and threats of landslides vis-à-vis strategies and opportunities to reduce the risks and make the communities resilient against landslides. An attempt has been made to study the various efforts being made by different stakeholders in a systematic manner to enhance human capacity through better understanding of the phenomena and efficient management practices including the elimination or reduction of the landslide risks as well as preparedness measures to respond and recover from landslides. The study revealed numerous such actions and initiatives taken by the government, concerned line departments and communities in terms of public policies, plans, procedures, guidelines, regulations, byelaws, codes, standards using different tools, techniques and technologies.

The paper briefly discusses the actions and initiatives taken by Government of India and the International organizations with a view to highlight the gaps in the field and proposes a potential road map for reducing such gaps and strengthening the efforts towards landslides risk reduction and resilience in a holistic integrated manner. Some of these suggestions include education, training, research, documentation, advocacy, networking, linkage, coordination and collaboration for sharing and exchange of knowledge, experiences, expertise, innovations, ideas and good / bad practices for landslides risk reduction and resilience.

Keywords: Landslides, Networking, Education, Innovation, Advocacy

ROCKSLIDE DAMS - POTENTIAL SOURCE OF THE TRANSBOUNDARY DISASTERS

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ABSTRACT
Large rockslides, most of which can be classified as rock avalanches, often form natural dams whose breach might be much more disastrous that rock slope failure itself. Sudden release of large amount of water stored in the dammed lake can devastate the entire river valley destroying settlements, roads, lifelines, and arable land not only in the country or province where it initiates, but also in the neighboring territories. Such cross-border disaster, besides obvious economic, social and environmental losses, might have negative political consequences. Cross-border outburst floods caused by the breach of rockslide dams occurred in 1966, 1977 and 1998 in Central Asia. Breached dams were located in Kyrgyzstan, while outburst floods reached the densely populated Ferghana valley in Uzbekistan. Similar disaster occurred in eastern Tibet in the Tsangpo-Brakhmaputra basin in 1900 and 2000. Breach of natural dams in the Yigong River affected not only the Chinese territory, but also India more than 400 km downstream. In 2004, the same transboundary catastrophe occurred in the Pali River in Western Tibet in China and in the neighboring part of India downstream. Traces of several enormous prehistoric outburst floods caused by breach of rockslide dams and numerous sites with evidence of the ongoing large-scale slope instability were river damming can be anticipated were found in Central Asia and in other parts of the World. Tight cooperation between researchers studying such phenomena on both sides of the state boundaries is necessary to avoid such catastrophes or, at least, to mitigate their most disastrous consequences.

Keywords: Rockslide dam; Outburst flood; Transboundary catastrophe; Slope instability; Mitigation

AN OVERVIEW OF GEOPHYSICAL HAZARDS IN SHILLONG CITY, MEGHALAYA, INDIA

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ABSTRACT
Shillong city is exposed to two key geophysical hazards - earthquake and landslide. As per seismic zoning map of India, the city lies in the highest seismic zone V on the Shillong Plateau. The Shillong Plateau experienced the 1897 Great Assam Earthquake (also known as 1897 Great Shillong earthquake) of magnitude 8.1 and experienced heightened seismicity from 1869 to 1950. Since 1951, the city and nearby areas have been experiencing moderate to high level of seismicity. In spite of the moderate to high levels of seismicity observed in and near Shillong in the last 65 years, it cannot be said that higher intensity earthquakes (VIII and above) are unlikely as the region has a potential for large to great magnitude earthquake. The city is less prone to landslides as compared to its neighboring areas, including the approach roads to the city. The city experiences most of the landslides during the monsoon that cause damages to houses, roads, and sometimes to agricultural land. However, the potential of earthquake-triggered landslides cannot be ruled out, as the region has a potential for very strong earthquakes. This paper presents an overview of geophysical hazards that city is exposed to and suggest measures for disaster risk reduction.

Keywords: Earthquake; Seismicity; Seismotectonics; Intensity; Magnitude; Landslide

SURVEYING AND MAPPING OF LANDSLIDES IN INDIA USING EMERGING TOOLS AND TECHNOLOGIES: CURRENT PRACTICES AND POLICIES

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ABSTRACT
India has 15% of its land area prone to landslides in different hilly terrains. The occurrences are by and large in Himalayas, the Northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhyas. Multiple investigation agencies are involved in the study of the landslides. In order to provide effective remedial measures, it is important to map the occurrences of landslides in a medium scale followed by a large scale surveying and mapping of individual or a cluster of slides.

Conventionally, remote sensing techniques are used for large scale mapping of the area and Total Stations (TS) and Differential Global Positioning Systems (DGPS) are being used by the investigators for surveying critical individual landslides. Globally the usage of Unmanned Aerial Vehicles (UAV) and LiDAR (Light Imaging, Detection and Ranging) data for landslide studies is on rise. Cost effective techniques are available for generation of High Resolution Digital Elevation Models (HRDEM) and other thematic geospatial layers. Disseminating the 3D geospatial datasets and models over web requires specialized 3D visualization and analysis software tools.

This paper will describe modern geospatial tools and techniques which are emerging in the geospatial industry for landslide surveying, mapping and dissemination of datasets over web environment. The paper will also describe the mapping policies as relevant in India for data acquisition, processing and dissemination of 3D geospatial datasets in web environment for governance and for offering citizen centric services.

Keywords: Landslide; UAV; LiDAR; Maps; DEM; 3D

APPLICATION OF CONVENTIONAL METHODS AND KINEMATIC ANALYSIS IN IDENTIFICATION OF SLOPE FAILURE

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ABSTRACT

Landslide is a common phenomena in hilly terrain which disturb the transportation system as well as damage the livestocks. The rock falls and wedge failure is generally observed in and around Markundi hill, Chopan, District- Sonbhadra. An attempt has been made to identify and demarcate the probability of slope failure/landslides in and around Markundi hill in District Sonbhadra (U.P). The conventional methods applied during the present study are Rock Mass Rating, Slope Mass Rating and Continuous Slope Mass Rating. The Kinematic Analysis has been conducted to understand the different modes of failure on the base of joint data. Nine locations (1-9) have been considered for the study. On the basis of RMR classification, the location-1, location-2, location-3, location-4, location-5, location-6, location-7 and location-9 belong to Fair rock mass and location-8 belongs to Poor rock mass. On the basis of SMR study, the location-1, location-2 and location-8 are belonging to completely unstable. The location-3, location-7 and location-9 are belonging to unstable conditions. The location-4, location-5 and location-6 are belonging to partially unstable condition. As per kinematic analysis, the location-1, location-2, location-3 and location-5 shows wedge failure in critical zone towards North-East direction but location-7 shows wedge failure in critical zone towards South direction. The location-4, location-6, location-8 and location-9 shows the wedge failure in failure envelop. The entire section needs preventive measure at high priority.

Keywords: RMR; SMR; CSMR; Kinematic Analysis; Markundi

EXPLORING SPATIAL DISTRIBUTION OF LANDSLIDE SUSCEPTIBILITY OF DARJEELING HIAMALAY, INDIA: A MODEL BUILDING APPROACH TOWARDS LANDSLIDE HAZARD MANAGEMENT

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ABSTRACT

The present study is dealt with the application of weight of evidence model, index of entropy model and statistical index model to explore the spatial distribution of landslide susceptibility in Darjeeling Himalaya. To perform all the models and to prepare landslide susceptibility, fifteen landslide causative factors were taken into consideration and categorized further into six groups viz. geomorphologic factors (elevation, aspect, slope, curvature), lithological factors (geology, soil types, lineament density, distance to lineament), hydrological factors (drainage density, distance to drainage, SPI, TWI), triggering factor (rainfall), protective factor (NDVI) and anthropogenic factor (LULC) and corresponding data layers were being made. Various data i.e. Google earth map, high resolution sentinel-2 imagery, arc map high resolution world imagery, Survey of India (SOI, Kolkata) covering topo-sheet no. 78A/4, 78A/8, 78A/12, 78A/16, 78B/1, 78B/2, 78B/5, 78B/6, 78B/9 and 78B/13, SRTM DEM, Geological map and soil map from Geological Survey of India (GSI), soil map from NBSS (National Bureau of Soil Science) & LUP (Land Use Planning) Regional Centre, Kolkata were being processed to prepare data layers on GIS environment. Three Models such as Weight of Evidence Model (WoEM), index of Entropy Model (IoEM) & Statistical Index Model (SIM) were applied to integrate all data layers and to develop landslide susceptibility map of Darjeeling Himalaya. Finally, a comparison has been made between three model based on the accuracy result derive from ROC analysis. The study identified the risk prone areas of Darjeeling Himalaya considering the existence of risk elements in connection to landslide susceptibility.

Keywords: Darjeeling Himalaya; Landslide Susceptibility; Weight of Evidence Model (WoEM); Index of Entropy Model (IoEM); Statistical Index Model (SIM); ROC Analysis

GIS-DATA DRIVEN MODEL FOR LANDSLIDE SUSCEPTIBILITY ANALYSIS ALONG THE TEHRI-GANGOTRI HIGHWAY CORRIDOR, GARHWAL HIMALAYAS (INDIA)

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ABSTRACT
This paper is an attempt to investigate the characteristics of shallow translational debris fall and sliding that occurred along the Tehri to Gangotri highway corridors in the Garhwal Himalayas. Apart from the field investigation, LISS IV and Landsat 7 ETM+ and Landsat 8 OLI satellite images were used to prepare landslides inventory of the study area. We have delineated 103 landslides on the 178.2 km road stretch; and 194 along the streams and other slopes. The geometry of these landslides shows that some of them are more extensive; having a volume of the displaced surface is more than 400 m^3.The road corridor, which was under construction for the past five years, suffers more, which aggravated the situation due to cutting into the bedrock or crossing areas affected episodically by debris slides, earth flows, debris flows, and rock slides. A complete landslide inventory is prepared for the study area that also comprises a spatial database, including associated parameters that influence the incidence of landslides. Aster v.2 digital elevation model has been used to analyze slope and associated topographic variables for the study area. In order to assess the landslide susceptibility, a 5 km buffer has been created along the roads. GIS plays a crucial role in analyzing the factors that significantly trigger landsliding in a region. The factors such as lithology, slope angle, aspect, curvature, relative relief, topographic wetness indices, distance from drainage, distance from the road, NDVI, and land use has been used as predictive variables. Land use/ land cover and Normalized Difference Vegetation Index (NDVI) are extracted from Landsat 8 images. In this study, the weight-of-evidence model is used to calculate the weights of predictive variables. Landslide Susceptibility Indices (LSI) values were categorized into five zones based on the probability of occurrence. The model result is validated with test set data of landslides, and the success ratio of the model was 84.2% that shows the satisfactory association between the landslide susceptible area and the existing landslides. These landslide susceptible zones can be used to demarcate hazard-prone areas on the highway corridor for the appropriate mitigation measures.

Keywords: Landslide Susceptibility; Weight-of-Evidence; GIS; NDVI; Vulnerability; Garhwal Himalaya

IMPLICATIONS OF CLIMATE CHANGE ON LANDSLIDE HAZARD - A CASE STUDY OF MALIN LANDSLIDE IN ECO-SENSITIVE AREA, A PART OF THE WESTERN GHAT, INDIA

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ABSTRACT
The Western slopes receive intense south west monsoon rains totally around 350 cm per annum. The catastrophic landslide caused by extreme rainfall events that are triggered by climate change. The cumulative antecedent rainfall from July 22nd to 28th was 127 mm followed by 108 mm rainfall on 29th July and 48 mm rainfall on 30th July, which led to oversaturation of unconsolidated debris material and rises in groundwater level. A cumulative rainfall of 283 mm for short period during consecutive 9 days has resulted into reduction in pore pressure of the debris material over the slope area triggered slope failure and landslide on 30th July 2014. This disastrous landslide triggered by accumulated heavy rainfall since 22 July 2014. Very high intensity rainfall is an implication of climate change, has a great potential in slope failure in hilly terrain and threats to local community. The amount and duration of rainfall can initiate slope failures in hilly terrain. As per IPCC report, heavy rain events are projected to become more intense, its frequency and intensity of heavy rains are likely to increase. As a result, there is higher likelihood of landslides incidences.

The Malin village is characterized by rugged hills with steep slope associated with loose unconsolidated soil. Malin village is located in the Sahyadri foothills, a part of the Western Ghats, situated in the Ambegaon Taluka of the Pune district, Maharashtra State. A tragic catastrophic landslide event took place in Malin village on 30 July, 2014 at 7.45 am while most of the people were in sleep. This disastrous event killed 151 people, buried 45 houses, affected 40 families, destroyed 120 m length of road section and affected 44,245 sq. m. of land area. There was no early warning and community awareness regarding landslides in this region which ultimately led to catastrophic landslide in Malin village.

The early warning, dissemination of the Early warning, community awareness, Do's & Don'ts, sharing of IEC material in local language and pre-disaster training at the community level can remarkably reduce the impact of landslides and finally help in making landslide disaster resilient communities.

Keywords: Western Ghat; Ecologically Sensitive Area; Economic Development; Climate Change; Early Warning, Community Awareness

SENDAI FRAMEWORK, DISASTER RISK AND RESILIENCE: SDG'S IN A REGIONAL CONTEXT

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ABSTRACT
The well acclaimed Sendai Framework is the successor instrument to the Hyogo Framework for Action (HFA) for a period of 2005-2015. It primarily focuses on building the resilience of Nations and communities to disasters. It is the major outcome of stakeholder consultations that was initiated in March 2012 and inter-governmental negotiations held from July 2014 to March 2015. It received pivotal support from UNISDR and has been tasked to support the implementation, follow-up and review of the Sendai Framework in continuum.

It mainly aims for the focused outcome as; substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. Disaster risk reduction cuts across different aspects and sectors of development. The perspective as to how disaster risk reduction and resilience is reflected in the outcome document and outlines what disaster risk reduction means for the SDGs in a regional context of South Asia and India in particular.

The framework provides a methodology for developing a Community Resilience Plan that accounts for social aspects of resilience when setting performance goals. The envisaged policy and its broad framework with four cardinal strategies provides the opportunities to reduce disaster risk, build a resilient future and achieve the goals and targets through the implementation of both the 2030 Agenda for Sustainable Development and the Sendai Framework.

Keywords: Sendai Framework, Disaster Risk, Resilience, Sustainable

INTEGRATED METHOD FOR LANDSLIDE SUSCEPTIBILITY MAPPING IN RUPIN WATERSHED OF TONS VALLEY, GARHWAL HIMALAYA, UTTARAKHAND

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ABSTRACT

The study area is bounded between 31°21'23" N to 31°21'54" N latitude and 77°57'39" E to 78°18'36" E longitude covering area of 545 km^2 which is part of Lesser and Higher Himalaya. Rupin River is important tributary of Tons river, originates from a glacier Jaundhar Bamak and Bandarpunch at head of the famous Har-ki-Dun valley in the north-eastern part of the Tons catchment. Geologically, the rupin watershed comprise of Vaikrata, Almora, Dudhatoli Jaunsar and Garhwal group containing granite, quartzite, limestone, shale, phyllite and basic rocks. This research work is focused on Landslide mapping, change detection and the preparation of landslide inventory, using geospatial approach. In this work, weighted overlay method is used for landslide susceptibility mapping considering parameters such as thematic layer geology, geomorphology, lineament density, drainage density, drainage frequency, drainage texture, land use/land cover, NDVI, slope, slope aspect, curvature, built-up, road etc. A landslide inventory is being prepared on the basis of pre and post Uttarakhand disaster of 2013 using high resolution satellite data (LISS-IV). A total of 150 landslides were identified in pre-disaster situation through (2011) and 221 were identified in post-disaster (2014). Damage assessment emphasized was carried out with respect to settlement, road and agricultural land. Landslide susceptibility map shows very low (37%), low (36%), high (21%) and very high (6%) susceptibility zones while vulnerability map has very low (33%), low (26%), high (35%) and very high (6%) classes. The final risk was obtained by multiplying the susceptibility and vulnerability map in the raster calculator of Arc GIS. There are four risk zones as identified from the map namely very low (58%), low (31%), high (7%) and very high (4%). Landslide susceptibility zonation (LSZ), vulnerability and risk mapping are important for disaster management and planning development activities in the Himalayan regions.

Keywords: Garhwal Himalaya; Landslide Susceptible Mapping; LISS-IV; Damage Assessment

KINEMATIC ANALYSIS OF NOKLAK TOWN LANDSLIDE, NAGALAND

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ABSTRACT
A very complex landslide has plagued Noklak town in eastern part of Nagaland for more than two decades.The magnitude of the landslide has grown both in its influence and coverage area of 1.84 sq. kms in last few years affecting the only route connecting the International Trade Centre at Pangsha (Dan), uprooting many households, cultivated areas and also posing a threat to nearly one-fifth of the town population presently. It is incorporated in SOI toposheet no. 83 N/4 and lies in 95^{0}00'39" E longitudes and 26^{0}11'52" N latitudes.The present study aims to identify the causative factors of this land instability by employing the method of kinematic analysis of the slope material to determine potential mode of failure.This analysis were performed from 1,195 joint attitudes collected from in-situ rock exposures in the field to determine the dominant joints that controls the instability in the area.The strength of the rocks were calculated by Point Load Test data on 50 rock samples. Both Rock Mass Rating (RMR) and PLT value indicates poor rock quality and low values for the rocks. SMR (Soil Mass Rating) values for this slope fall in Class IV and results from the kinematic analysis shows both planar and wedge type of failure indicating several micro-slips within the study area and absence of firm bedding.

Keywords: Noklak; Nagaland, Kinematic Analysis; RMR; SMR; Landslides

LANDSLIDE RISK ASSESSMENT AND COMMUNITY BASED LANDSLIDE DISASTER MANAGEMENT STRATEGIES: A CASE STUDY OF KANDEY VILLAGE, CHAMOLI DISTRICT, UTTARAKHAND

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ABSTRACT
Landslides cause widespread damage in the Himalayas. In the recent past, cloud burst events are on rise causing huge loss of life and property, may be attributed to climate change and extensive anthropogenic activities in the mountain region. Despite the growing scientific and technological advances, it has been difficult to reduce the impact of natural hazards as experienced in case of 2013 Kedarnath Tragedy. Therefore, systematic scientific risk assessment is required where people living in the hazardous terrain to minimize the disaster risk reduction and disaster loss.

In the present study, Kandey village near Gopeswar town of Uttarakhand has been considered for Landslide Disaster risk assessment. The villagers are living close to a landslide, which has gradually taken a gigantic shape over the last 70 years. In this study, landslide hazard, risk and vulnerability maps have been prepared using integrated remote sensing-GIS technique through analysis of various secondary and primary thematic information. Data integration was carried out using the weighting rating technique to give a Landslide Risk Index (LRI) value. The breaks in the LRI frequency diagram were used to delineate various landslide risk zones, namely, very low, low, moderate, high and very high. Field data on landslides were employed to evaluate and validate landslide risk zonation map. Therefore, the community based disaster Risk Management process applied for disaster management strategies for disaster risk reduction. The methodology is basically proposed in two phases: Assessment of the community vulnerabilities, capacity of multiple hazards in selected village by Community engagement and Community participant characterized by training and skills development for multi hazards and disaster risk mitigation.

Keywords: Landslide, Himalaya, Risk Assessment, Risk Index, Community based Disaster Management, Community Participation

NATURE BASED SOLUTIONS (NBS) FOR LANDSLIDE RISK REDUCTION STRATEGY

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ABSTRACT
Landslide risk reduction involves a series of activities that include landslide susceptibility mapping, risk evaluation, landslide monitoring, forecast etc. Based on host of causative parameters, the landslide risk reduction scheme may be classified in four groups viz. modification of slope geometry, drainage, retaining structures and internal slope reinforcement. These structural solutions of landslide mitigations are diversified into a range of sophisticated techniques such as passive piles and piers, cast-in-situ reinforced concrete walls and reinforced earth retaining structures, ground anchors etc.

Over the last few decades, there has been a increasing interest in non-structural solutions and host of Natural Based Solutions (NBS). The concept of NBS involves use of local natural materials, plants that binds the soil and improve surface drainage. Such biotechnical slope stabilization, are not only cost effective but also increases environmental compatibility. These nature-based solutions provide sustainable alternatives and restore modified ecosystems and adapt impacts of the climate change. The vegetative cover has a beneficial effect on slope stability by the processes of interception of rainfall, maintaining drier soils and enabling some reduction in potential peak groundwater pressures. Except the hydrological effects, vegetation roots reinforce the soil, increasing soil shear strength while tree roots may anchor into firm strata, providing support to the upslope soil profile through buttressing and arching. A small increase in soil cohesion induced by the roots has a major effect especially on shallow landslides. These nature-based 'green solutions' provide sustainable alternatives, restore scared ecosystems and adapt impacts of the climate change.

Keywords: Landslide Susceptibility; Risk Reduction, Structural Solutions, Non-structural Solutions, Nature Based Solution, Shallow Landslide

PROBABILISTIC ANALYSIS OF SLOPE STABILITY AND LANDSLIDE RISK ASSESSMENT

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ABSTRACT
Provision of social and economic safety is one of the main concerns during territory development with high risks of landslides activities. This issue requires geological risks assessments. Probability evaluation of landslides activity is one of the main parameter in quantitative evaluation of geological risk.

For performing risk assessment, an application of probability analysis for quantitative evaluation of slopes stability is suggested. This allows to characterize threats by the means of quantitative evaluation. The substantial idea of probability analysis is probability function determination of factor of safety (FOS) that depends on initial probabilistic physical and mechanical soil parameters of the analyzed slope, as well as other slope activity factors.

This article shows the results of slope stability probabilistic analysis. Also, at the next stage, for the researched construction site, the quantitative risk assessment of landslide activity was performed. For the implemented risk analysis, an assumption was made that economic losses depends primarily on the deformation level of the structure foundations.

Keywords: Slope Stability; Probabilistic Analysis; Landslide Risk Assessment

SUSTAINABLE HOUSING CONSTRUCTION AND RESCUE DURING LANDSLIDES

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ABSTRACT
With close to 11,000 deaths due to landslides in 12 years, India tops a global list of nearly 56,000 deaths from 4,800 landslides around the world between 2004 and 2016. India not only accounts for 20% of global landslide deaths but also has the dubious distinction witnessing the fastest rise in human-triggered fatal landslides in the world (Deccan Herald, 2018). Unplanned expansions & constructions often block rescue operations during disaster. It is important to consider disaster hazards during housing construction and design planning. Further, critical infrastructure should be planned properly. Of many, one such disaster is landslides which are quite prevalent in various parts of India. India being the developing country where there is lot of housing demand and increased urbanisation posing threat to human life and environment, it is imperative to focus on sustainable construction practices to prevent Triggering of disasters, maintenance of existing infrastructure and disaster risk reduction (DRR) plan for post-disaster situations. The paper also addresses the importance of process of rescue operations in landslide affected housing sectors.

Keywords: Sustainable Landslide Constructions; Rescue Operations and DRR (Disaster Risk Reduction) in housing

CHARACTERIZATION OF LANDSLIDE POTENTIAL ZONE THROUGH INTEGRATED SATELLITE REMOTES SENSING AND GEOPHYSICAL TECHNIQUES (ELECTRICAL RESISTIVITY TOMOGRAPHY AND GROUND PENETRATING RADAR) STUDIES AT MANDI, HIMACHAL PRADESH, INDIA

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ABSTRACT
A comparative study has been done to delineate and characterize potential landslides zones with the help of two cost-effective and non-invasive techniques i.e. Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT) and satellite Remote Sensing data at Garpa, Mandi, Himachal Pradesh. Two ERT profiling (on above and below the slope) and One GPR profiling (below the slope) has been carried out at the slope below to characterize water saturation induced landslide potential zone. The GPR radargram profiling acquired with two different frequency channels having different depths of penetration i.e. 600 MHz and 200 MHz respectively which complemented with 40 m ERT profiling of Wenner-Dipole-Dipole and Dipole-dipole configuration below the slope. The GPR radargram results (600 MHz and 200 MHz) depicted a bowl-shaped structure near the surface with strong reflection as outline of 13 m to 26 m of depth 1m to 3.5 m. Analogizing with ERT results shows low resistivity values (10 ohm to150 ohm) from 21 m to 31 m at depth of 3.5 m to 6.75 m. The present study reveals that in the future there are high chances of large-scale landslide, which might affect the guest house of IIT Mandi and road connecting the area. Integrated study of satellite remote sensing and geophysical techniques along with ground site observations can perfectly delineate and characterize the water-saturated landslide potential zones. This study reveals the significances of earth observation tools and geophysical techniques in landslide hazard risk assessment.

Keywords: Satellite Remote Sensing; ERT, GPR; Water Saturation; Landslide Risk Assessment

DECODING THE IMPACTS OF MASS MOVEMENTS IN THE CONFINED RIVER SETTING ON THE CIVIL ENGINEERING STRUCTURES-A CASE STUDY FROM THE JAMMU LESSER HIMALAYAS

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ABSTRACT
The rivers draining the Himalaya are characterised by high discharge and sediment load and the former is direct function of catchment area and precipitation. While the latter is controlled by the discharge and geology (structures and lithology). The river has the natural mechanism of dealing with both at different reaches of the river by erosion, sedimentation through transportation. But, the problem accentuates when the river reaches are modified by anthropogenic activities. The landslides whether seismically induced or by the intense rainfall events, contributes anomalously high sediment load to the downstream dammed reservoirs.

In the present study, the unstable slopes upstream of the Baghliar dam reservoir located in the valley margin confined reaches of the Chenab river basin. The landslides are witness in the Salkhala Group of Lesser Himalaya and the schists and phyllites belonging to the group are crushed in the tectonically active terrain. The non-cohesive soils derived from the rock are prone to sliding and causes anomalous sudden addition of sediment load to the reservoir.

The Korapani landslide has been investigated using the geophysical and geotechnical surveys coupled with geological and structural data to comprehend the stability/instability of the slopes and the impact on the downstream reservoir. The results shows that the extreme rainfall events and subsequent discharge and sediment load are a threat to the downstream reaches and can be treated as a replica of the building up of the disasters. However, the role of humans cannot be averted as they alter the slope stability conditions to a great extent.

Keywords: Mass Movement; Lesser Himalaya; Anthropogenic Activities

APPLICATION OF REMOTE SENSING AND GIS IN LAND USE AND LAND COVER MAPPING IN GARHWAL REGION

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ABSTRACT
In this study, Land use and land cover changes are investigated by using Remote Sensing and Geographic Information system in Uttarkashi district. For this firstly, unsupervised classification is applied to the Landsat images acquired in 2000, 2008 and 2017. An Unsupervised maximum likelihood classification was implemented for the three images and the final classification products provide an overview of the major land use / land cover features of study area for the years 2000, 2008 and 2017. This paper also focusses on land use and landcover changes that have been done by change detection method (digital overlay method). This work presents an investigation for identification of changes in land use / land cover (LULC) classes of the study area over a period of 17 years (from 2000 to 2017) using remote sensing techniques.

Keywords: GIS, Land Use and Land Cover Changes; Landsat Imagery; Remote Sensing Techniques

STUDY OF POWARI LANDSLIDE, KINNAUR DISTRICT, HIMACHAL PRADESH & SUGGESTIVE CONTROL MEASURES

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ABSTRACT
This paper illustrates the study of a landslide that occurred near to the Satluj river between Powari and Peo, Kinnaur district, in Himachal Pradesh. The Powari landslide is a destructive debris flow, which affects the area very much. For that first, we adopt the Limit Equilibrium Method (i.e. Geo Slope software is used) for slope stability analysis in terms of factor of safety at this location. And second, to provide a control measure, a Staad pro software is used to design a retaining wall with the help of stress value found in the finite element method (FEM). After taking the soil samples, they passed through various lab tests for finding the parameters of soil. The parameters obtained after testing the soil is used as the input parameters in Geoslope (based on LEM). LEM is commonly used technique for slope stability studies. This method obtained some fine slices by cutting the slope, these slices called slip surface slices. From all of the above slices, the critical slip surface is slice 4 having the lowest factor of safety (0.940). Plaxis and Staad pro software is used to design the retaining wall as a control measure for this site. We used the obtained maximum stress due to soil and load in FEM analysis as the input load value in Staad pro. By using the stress value 553.9 kn/m^2, we design the retaining wall in Staad pro. Keeping in view the high vulnerability of the area to landslides, there is an urgent need for restorative measures along with the Corridor. Proper drainage network and suitably designed retaining walls should be constructed in all the places where road cutting has rendered the slopes unstable. Proper disposal of slope cut debris material should be ensured in order to avoid the initiation of new slide zones from the large heaps of slope cut debris material and installation of rain gauges in Satluj and Spiti valley at regular interval should be needed.

Keywords: Landslide, Powari, Slope Analysis, LEM, FEM, Staad Pro, Retaining Wall

HILL SLOPE INSTABILITY IN PARTS OF NEOTECTONICALLY ACTIVE GARHWAL HIMALAYA, INDIA

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ABSTRACT
Alaknanda valley in Chamoli Garhwal is marked by frequent landslides and neotectonic activity. NNW-SSE and NE- SW lineament pattern indicates strong control of tectonic on the drainage architecture. High topography, prominent breaks along longitudinal profiles of Alaknanda River, prominent south facing escarpments, river pounding, steep gorges and incised river is indicative of ongoing neotectonic activity. Piedmont deposits of Kalpeshwar temple, Fault scarp at confluence of Karmasa and Kalpa Ganga at Helong, Subsidence of Dangri village, Ponding of Hanuman chatti, off set of talus mass of Pandukeshwar and seismogenic landslide of Titari village along bank of Virahi Ganga are the prominent sites where upliftment is noticed. Study of longitudinal profile of Alaknanda River suggests that rejuvenation and channel sedimentation phases are operative in this region. OSL dating of Alaknanda terraces at Pipalkoti also suggest upliftment. Values of morphometric parameters related to stream gradient index, drainage basin asymmetry factor, mountain front sinuosity also give evidence that the region is experiencing the dynamic rejuvenation phase.

Keywords: Landslides; Lineament; Tectonic; Morphotectonic

LANDSLIDES EDUCATION, ADVOCACY, RESEARCH AND NETWORKING (LEARN)

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ABSTRACT
Landslide disasters have fetched global concern in recent years. The ubiquitous disaster cost enormous human fatalities and economic losses of billions of dollars around the world. The actual losses due to landslides are still the topic of debate as in the role of secondary player after primary disasters such as earthquakes, floods, glacial lake outburst floods and others. Landslides are not given their due in number of deaths, socio-economic losses and constraint in response, rescue and recovery phase of disaster management. For example, 2015 Gorkha earthquake of Nepal induced numerous landslides which caused major damage to settlements and infrastructure and also hampered the post disaster activities. Further, researchers have authenticated the adverse impact of global warming and climate change in increasing the frequency and magnitude of landslides. Apart from the natural exaggerators, the development activities such as construction of structures and infrastructures in vulnerable areas, deforestation for expansion of urban boundary, negligence of proper slope management will increase the window of number of population exposed to the risk of landslides.

Consequently, there is a need for the International Network, convoying expertise and knowledge of global and national resource persons, key stakeholders and key line departments such as roadways, railways, urban development etc that pursue the multi-hazard spectrum of landslides, advocate education, awareness and participation of community to reduce the risks of landslides. Moreover, to execute the commitment and carry forward the inheritance of Sendai Partnerships 2015-2025 for Global Promotion of Understanding and Reducing Landslide Disaster Risk and Kyoto Landslide Commitment 2020, India being one of the worse landslides affected region in the world will be an ideal platform for establishment of such network.

Keywords: International and National Network; Landslides Education Advocacy; Research; Multi-hazard

ECOLOGICAL ASSESSMENT OF THE RELATIONSHIP BETWEEN LAND-USE AND LAND-COVER AND LANDSLIDES DURING AN EXTREME RAINFALL EVENT IN THE PART OF SOUTHERN WESTERN GHATS, KERALA

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ABSTRACT
A case study of rain-fall triggered landslides in the south Western Ghats are presented. Numerical analyses and field observations have identified Rainfall-triggered landslides represent for the greater major cause of number of victims and damages to structures, facilities and lifelines resting on or in the vicinity of the slope of the Kavalappara, Kerala. An accurate estimation of rainfall thresholds which can reactivate quiescent landslide or increase the ground movement rates of active landslides is a crucial aspect in the context of hazard assessment and risk mitigation, especially for prevention and warning activities.The paper presents a case-study of a landslide-prone slope in the Pathar- Kavalappara, Malappauram District of Kerala. The recent landslide has recorded a death toll of 57. From 7 to 8 of August 2019, high precipitation occurred related to a cloud burst. The river Chaliyar was strongly affected by 200 mm of rainfall in 24 hours, an extreme hydrological event. As a result, slope failures happened in many of locations and rivers overtopped with water and debris of considerable size that caused material damage and the human losses mentioned above. This study set out to answer the question of how land-use and land-cover (LULC) was related to the occurrence of mass movements during an extreme rainfall event. Land use planning by creating fool proof mechanism in water usage utilities, control blasting operations/debris in nearby areas, creation of better alternative living environment in proximity to work places are to be followed in this kind of remote places. The probabilities of incorporating multistake holder approach to minimize the impacts are discussed.

Keywords: Landslide; Rainfall; Land Use and Land Cover; Western Ghats; Kavalappara

OBSERVATIONS ON LANDSLIDES: A CASE STUDY FROM NEOTECTONICALLY ACTIVE NAINITAL AREA, UTTARAKHAND

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ABSTRACT
Southern portion of Nainital is characterized by rugged topography with rising hills from 360 m to 2600 m. The area forms a part of Proterozoic-Cambrian rocks of Krol belt which has been thrust over by Amritpur Granite along the Salari thrust and Neogene sedimentary rocks (Siwalik Group) along the Main Boundary Thrust. A number of geomorphological and morphotectonic parameters in conjunction of geology are studied to evaluate the occurrence of different types of landslides. The various geomorphic features suggest the neotectonic activity in the region. Landslides in the area have been studied in context to geology, tectonic activity and presence of lineaments, slope, drainage conditions and lateral erosion by streams. Mapping of landslides, natural springs, drainage network, terraces etc. have been carried out to arrive at morphotectonic map indicating the areas of neotectonic movements.

Keywords: Landslides; Neotectonic; Drainage; Slope

CHANGING CLIMATE AND URBANISATION: MAJOR AGGRAVATING FACTORS FOR LANDSLIDE RISK IN FUTURE

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ABSTRACT
Now-a-days as a consequence of climate change humid tropical countries are subjected to high intensity and high duration rainfall events. Worldwide population is expected to reach 8.5 billion in 2030 with half of the population will be concentrated in urban areas. So, in the coming years, combination of unplanned urban development with climate change could affect the landslide occurrences in the humid tropical countries. India also experiences this extreme phenomenon in terms of this year flood and landslide hazards in Kerala (21 cm rainfall in one day) and Karnataka. Deforestation and cut slopes, typical of the urbanisation process are known to increase the incidence of landslides, altering hydrological processes and shear-stress distribution. In addition to low quality houses, resulting from rapid urbanisation enhances the landslide risk because of their vulnerable location associated with obsolete drainage network. This research is addressed to comprehensive risk analysis in Sikkim Himalaya by bridging up the research gap between climate changes, urbanisation vis-a-vis landslide risk. Ranges of preparatory factors, triggering mechanisms and aggravating factors are evaluated to identify the possible vulnerable areas. Thereafter, variable rainfall and future urbanization scenario is superimposed in a GIS platform to identify high landslide susceptible areas. Based on physical model effect of single house and the single drainage network on soil hydrology and stability mechanism are evaluated and thereafter outcomes are projected to denser network in order to make an outline of a detail risk map, which will be a tool for decision making process to prevent and mitigate landslide occurrences.

Keywords: Climate Change; Urbanisation; Physical Based Mode; Landslide; Sikkim Himalaya; India

EVALUATION OF SAATY RATIO SCALE IN LANDSLIDE SUSCEPTIBILITY ZONATION IN NORTH KASHMIR ALONG HIGHWAY FROM BANDIPORA TO GUREZ, JAMMU & KASHMIR

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ABSTRACT
The state highway from Bandipora to Gurez is known as one of the most landslide susceptible areas in Kashmir division. Landslides are among the great destructive factors which cause lots of fatalities and financial losses all over the world every year. The aim of this research is to generate a landslide susceptibility map using Analytical Hierarchy Process in GIS environment. Ten landslide influencing factors which are investigated to form the probable AHP matrix that is slope angle, lithology, rainfall/precipitation, landuse/landcover, distance to road, distance to fault, distance to river/drainage, altitude, soil and slope aspect. Furthermore, more than 300 number of landslides were mapped along Highway using the historical records of the Border Road Organisation (BRO) of Srinagar, Bandipora and Gurez, as well as Landsat 7 ETM plus and Google maps were used due to their higher resolution and available GCP's which enables to identify the landslides precisely. An extensive field survey was conducted in course of the study in which the location and measurement of landslides were carried out using the hand held GPS and Tape. The results show that the area of 623 Km^2 is covered by very high and high landslide susceptibility zones constituting 38 percent of the study area. The villages which fall under these zones are Bandipora, Razdan Pass, Bufflias and Gurez and thus are highly prone to landslide

commotion. These are the most tortuous and rugged zones with high occurrence and impact of landslides. There is a frequent incidence of traffic disruptions along the road. Thus, there is an urgent need to mitigate the landslide hazard particularly to avert the disruption from Bandipora to Gurez road which causes huge inconvenience, economic and human losses.

Keywords: Landslide; Susceptibility; GIS Environment; Highway; Bandipora; Gurez; Satty Ratio Scale

LANDSLIDE ANALYSIS THROUGH GEOLOGICAL AND GEOTECHNICAL APPROACHES: IDUKKI DISTRICT, KERALA, INDIA

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ABSTRACT
Idukki district, in central Kerala, is one of the major landslide prone areas in the Western Ghats. The landslides in August 2018 claimed 46 lives, destruction of houses, loss of belongings agricultural area loss, destruction of roads etc. In general, majority of the landslides studied are located in the fringe slopes of rugged hill bordering the Munnar plateau of the Western Ghats. Regional lineaments with NNW-SSE and NNE-SSW orientations are observed in the area. The hydrostatic thrust along the regolith-rock interface caused by seepage and infiltration after heavy rainstorms is the immediate triggering factor causing landslides. Major part of the study area is characterized by the outcrops of hornblende gneiss and granite gneiss. Hornblende gneiss and granite gneiss show CIA values of 69.50 and 59. 30 respectively indicating the significant weathering condition in the area. The mean CIA value of lateritic soil and forest loam in the area are 93.56 and 81.15 respectively, indicating the high extent of chemical weathering. XRD analysis showed that Kaolinite and Gibbsite are the major clay minerals. Slope stability analyses were performed by determining Factor of Safety values using GEOSLOPE. Maximum value of Factor of safety obtained is 1.35 and minimum is 0.25 and slope stability analysis indicate that most of the slopes in the study area fall in unstable category which requires immediate remedial measures for slope stabilization.

Keywords: Western Ghats; Landslides; CIA index; Factor of safety

THE EFFECTIVENESS OF WARNING DISSEMINATION AND COMMUNICATION IN LANDSLIDE

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ABSTRACT
In every early warning system, warning services lies at the core. Effective working and reliable technology are essential for real time or near real time detecting and monitoring of landslide and providing warning and forecast 24 hours a day, throughout the year. For establishing operational landslide warning system, landslide requires attentive planning, involvement of differential departments and should emphasis on highlighting the vulnerability of the population at risk, analyzing barriers in effective implementation of early warning and understanding the meteorological and geological conditions affecting landslide. Monitoring is crucial part in landslide early warning system which includes installation of instruments, data collection, data communication, analysis and interpretation. The operation, maintenance and monitoring of these system also demands trained, experienced and qualified staffs. Generation of real time early warning requires continuous monitoring of landslide parameters. It is very essential for the early warning system to be multi-hazard perspective since one factor can cause more than one hazards e.g., heavy rainfall can trigger landslide and flood. The warning system should be well coordinated and interconnected among various institutions and concerned organization to allow exchange of data at the earliest. Warning messages issued for the people at risk should be simple, clear and usable to ensure proper response and preparedness from organizations, communities and individual level securing lives and livelihoods. Regional, national, state and community communication systems must be pre-identified with proper allocation of duty and powers.

Keywords: Early Warning System; Warning Dissemination and Communication; Landslide; Monitoring

ROLE OF EMERGING AEROSPACE-BASED TECHNOLOGY, GEOPHYSICAL INVESTIGATION AND NUMERICAL SIMULATION IN LANDSLIDE HAZARD MAPPING, MODELLING AND MITIGATION

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ABSTRACT
Some innovative methods were demonstrated for the first time to acquire data related to landslides and attempt modelling. The TLS of Riegl VZ 400 make was used for acquiring dense point cloud with average spacing of 1cm with an accuracy of 5 mm. DTM, hillshade, aspect and slope map of the landslide were generated, which were found very useful for detailed landslide mapping, modelling and analysis. UAV based ultrahigh resolution mapping has independently emerged as a complementary technique to satellite/aerial remote sensing in steep terrain and under heavy cloudy conditions. At Baliyanala landslide in Nainital, the technology was demonstrated to assist state government in acquiring authentic information on the extent of landslide in 3-D along with high resolution DEM and surface cover. Geophysical investigations can help to determine the slip surface and other sub-surface details, alternatively which can only be obtained by expensive and time consuming drilling. One such scarp of 600 m length was detected at Kunjethi (Kalimath) village (Uttarakhand) on satellite images during routine analysis to confirm the presence of landslide scarp, its dimension, depth and geometry of the slip surface using resistivity and GPR technology. Numerical simulation model has also been employed that predicts run out in three dimensions and provide velocity, momentum, height and pressure at Kaliyasaur landslide. These emerging technologies caters to high resolution terrain attributes essential for landslide modelling, designing remedial measures, to evacuate people and also help to simulate and understand the actual cause, process and mechanism of landslides.

Keywords: TLS; Baliyanala; UAV; Simulation; GPR; Kaliyasaur

LANDSLIDE SUSCEPTIBILITY ASSESSMENT IN NORTH KASHMIR ALONG HIGHWAY FROM BANDIPORA TO GUREZ, JAMMU & KASHMIR: USING FREQUENCY RATIO METHOD

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ABSTRACT
Landslides are among the great destructive factors which cause lots of fatalities and financial losses all over the world every year. The aim of this research is to produce a landslide susceptibility assessment using Frequency Ratio Method in GIS environment. Ten landslide geo-environmental factors which are investigated to form the plausible Frequency Ratio matrix that is slope angle, lithology, rainfall/precipitation, landuse, distance to road, distance to fault, distance to river/drainage, altitude, soil and slope aspect. Furthermore, above 300 landslides were mapped along highway using the historical records of the Border Road Organisation of Srinagar, Bandipora, and Gurez, extensive field survey and Google maps with high resolution. The smallest landslide that was identified in the field had an area of 77 m^2 at Gurez, while the largest one was 107 m^2, at Razdan Pass. The results show that the area of 555 Km^2 is covered by very high and high landslide susceptibility zones constituting 36 percent of the study area. The villages which fall under these zones are Bandipora, Razdhan Top, and Gurez and thus are highly prone to landslide movement. These are the most twisting and harsh zones with high occurrence and impact of landslides. There is a frequent incidence of traffic disruptions along the Razdhan Pass. Thus there is an urgent need to mitigate the landslide hazard particularly to avert the disruption from Bandipora to Gurez valley which causes vast inconvenience, economic and human losses.

Keywords: Landslide; Susceptibility; GIS Environment; Highway; Frequency Ratio; Matrix

INTEGRATED APPROACH OF GEOSPATIAL AND GEOSTATISTICAL MODELING OF LANDSLIDE SUSCEPTIBILITY PATTERN IN GANGTOK, SIKKIM

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ABSTRACT
In this research, comprehensive analysis is performed to quantify the landslide susceptibility for Gangtok city, Sikkim. Landslide inventory is developed based on LISS-IV satellite imagery, Quickbird, Google Earth and reported data of Geological Survey of India. Eleven landslide triggering factors viz. slope, elevation, curvature, aspect, LULC, geology, lineament, rainfall, soil type, soil thickness and water regime are incorporated as input data in the analysis in ArcGIS environment. Frequency ratio (FR) and Fuzzy logic (FL) techniques are used to generate landslide susceptibility map. The derived landslide susceptibility maps are classified into four hazard zones i.e., low, medium, high and very high. On validation FR and FL shows Area Under Curve (AUC) of success and prediction rate as 76%, 67% and 83%, 78% respectively. Comparative evaluation reveals that FL gives more accurate result. Present research gives helpful information for future planning and preparedness in the study area.

Keywords: Frequency ratio; Fuzzy logic; Landslide susceptibility; Success Rate Curve; Gangtok

LANDSLIDE RISK, RESILIENCE AND RESISTANCE: CONFRONTING COMMUNITY RESILIENCE WITH ECONOMIC BENEFITS IN LANDSLIDE PRONE AREAS IN KERALA

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ABSTRACT
Landslides are increasingly posing challenges to disaster risk management institutions in country like India. Unlike other disaster risk reduction measures including community bases resilience is a challenging task in the present context of development. Landslide prone areas in India are not just a risky geographical region with vulnerable people; instead these are 'emerging economic zones'. The economic value of these regions are displaces the risk and hence, state governments and central government often find it difficult to promote community bases resilience in landslide prone areas. The community often interprets resilience as resistance. Community based resilience in landslide prone area never follows the general theoretical position on resilience as ability to bounce back. Large-scale concentrations of quarry industries in the landslide prone areas of Kerala limit the community mobility as resilience. The idea of resilience converged into resistance in the landslide susceptible areas in Kerala. Resistance becomes an easy method rather than building resilience. Community's perception of resilience is never acceptable to government and investors and hence nobody promote community based resilience in these areas.

Keyword: Resilience, Landslide, Quarry Industries, Community Mobility, Movement

SHORTCUT PLANNING FOR SELECTION AND WIDENING OF HIGHWAY ALIGNMENT LEADING TO PERENNIAL LANDSLIDE HAZARDS IN HIMALAYA

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ABSTRACT
Over 60 thousand kilometers of the roads have been constructed in the Indian Himalayan Region (IHR) and most of them are affected by recurring landslide and other related problems of variable severity. One of the major reasons for such a state, undoubtedly is the non-consideration of the dynamic nature of Himalayan hills and mountains and their peculiar geo-environmental setting, inherent vulnerability due to its high and steep slopes, deep gorges, intense drainage work leading to constant and intense erosion, flooding, landsliding etc. Climate change resulting in increased events of extreme rainfall impacting the hill slopes have also been found ignored during planning, selection, construction/widening and maintenance of highways and roads of the region. The gaps in the process of selecting an alignment due to insufficient investigation lead to unending landslide and related slope processes post construction. As the highway slopes are generally left unmaintained after the construction of highways, mass wasting in the form of landslide and like process on the slope accelerates. The climate change in recent years has also uncovered some new slopes of which the vulnerability was not known so far; their sudden failure results in damage or blockade of highways at many locations resulting in huge loss of revenue on direct and indirect expenditures together with the hardship and threat to loss of life of the commuters. Socioeconomic and environmental challenges posed by lack of strategy or policy on slope management and mitigation require to be addressed emphatically for sustainable highway operation. In this article, a few of such examples of improper planning, construction and maintenance of highway and its slopes are discussed.

Keywords: Shortcut Planning; Himalaya; Highway Alignment; Climate Change

LANDSLIDE RISK MITIGATION USING REMOTE SENSING AND GIS TECHNIQUE - A CASE STUDY OF GANGTOK AREA, SIKKIM

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ABSTRACT
This study has process through the analysis of geo-environmental parameters related and responsible for landslides, one of the most frequently happening natural hazards in the Himalayan environment. The investigation is entire Gangtok area, in East Sikkim and total area is 30.25 sq. km. Remote Sensing and GIS technology involving integration of various thematic data layers in a rater GIS, is suitable for Landslide hazard zonation. The quantitative technique for landslide vulnerability mapping using geotechnical and geological parameters providers database system for Landslide hazard zonation. The study reveals that geomorphologic characteristic like landuse/landcover, slope, aspect, drainage density, rainfall etc. with high hazard scores play significant role in the happening of landslide. This study has given entirely a never type of information on Landslide Hazard Zonation Mapping and Mitigation through GIS. The review of inventory, susceptibility and hazard analysis has shown the wide range of studies and applications. Disaster Mapping is a tool for evaluating, storing, and assigning information on the geographical location of a disaster occurrence and the spread of the actual or likely effects of disasters.

The considered assessment of landslides and their thought when determining planning applications will help to reduce the impact of undesirable consequences such as risks to public safety, property damage, preventable costs to development, personal distress to those affected, degradation of the physical environment and loss of environmental resources. Emphasize of the study is to prepare the Landslide Hazard Zonation maps on 1:50000 scale. This map may be measured as the base map for preliminary identification of safe areas and areas prone to landslides. This map can be used by various departments for planning new developmental schemes in the region. The uses of these maps decrease the occurrences of landslides as significance of developmental activities and therefore ecological degradation will be reduced.

Keywords: Landslides; Landuse; Drainage; Hazard; Zonation; Mitigation

LANDSLIDES AROUND MAIN CENTRAL THRUST BETWEEN MANERI AND GANGNANI AREA DISTRICT UTTARKASHI, GARHWAL HIMALAYA, UTTARAKHAND, INDIA

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ABSTRACT
Landslides are one of the major natural disasters that cause huge loss of property in the hilly areas of Uttarakhand. Landslides not only occur as a phenomena of gravitational pull but also occur in conjunction with other hazards/events like earthquake, cloudburst etc. Present study has been carried out around Main Central Thrust between Maneri and Gangnani area district Uttarkashi. It was observed that after Earthquake of 1991 and kedarnath tragedy 2013 (heavy rainfall in Uttarakhand hilly areas) causes reactivation old landslides and new landslides were found near M.C.T. It was observed that lithology, structures, topographic and climatic factors are also responsible for landslides in the investigated area. Climate Change is the global phenomenon. Uttarakhand is a small developing state mainly with mountain terrain. Climate change influences the natural resources, bio-diversity, monsoon, earth processes, socio-economic activities and development of the countries.

The present paper deals with the study of few landslides like Aungi, Malla Bhatwari, Chadethi, Sunagarh and Gangnani. Main structural feature is Main Central Thrust which passes near Sainj along Kumaltigad. Main Cantral Thrust separates the rocks of lesser Himalaya from central crystallines. The main central thrust is very active and epicenter of maximum earthquakes occurred near MCT like Agora (1991) Bhatpara (2005) Kharsali (2007) and near Ranthal (2012) and number of landslides reactivated due to MCT. Engineering structures, forests, cultivated area, buildings and human settlement destroyed by peculiar climatic variation especially by heavy rain fall in the area. During last few years the events of cloudburst increases in Garhwal area which causes loss of property and life in the area. Cloud burst in the area during 2003,2007,2010,2012 and 2013 and Earthquakes frequently triggered the area, causes reactivation of landslides. Malla landslide, Bhatwari landslide, Chadethi landslides, Sunagarh landslide and Gangnani landslide are examples of reactivated landslide due to heavy rainfall and earthquakes. The construction of branched road, all weather road, tunnels, building, dam and unscientific construction of buildings are the factors of anthropogenic hazards. Construction of buildings around Bhatwari, Uttarkashi, Gangnani, Malla and roads accelerated the landslide activity in the area.

Keyword: Landslides, Earthquake, Rainfall, Main Central Thrust

GEOTECHNICAL CHARACTERIZATION AND SLOPE STABILITY ANALYSIS OF A LANDSLIDE IN THE KANGRA VALEY USING FINITE ELEMENT - SHEAR STRENGTH REDUCTION METHOD

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ABSTRACT
This study presents the numerical simulation of the slopes for stability analysis of a major landslide which occurred on 14th August, 2013 after a prolonged rainfall episode and affected the Tiralines village near Dharamshala city of district Kangra, Himachal Pradesh. The study is based on the field investigations for finding the cause and nature of landslide, geotechnical study of the slope material's index properties along with the shear strength parameters and numerical modelling of the slope using 2D finite element method (FEM). The lab study of the slope material involved the analysis of grain size, cohesion, permeability, angle of friction (Φ), optimum moisture content (OMC), field density and dry density. The numerical modelling involves the discretization of the slope into number of elements/zones. The forces are applied on the defined number of slope elements for finding the maximum displacement (m) at the critical strength reduction factor (SRF) of the slope sections. Three slope models were used with a material boundary between the underlying basement rock and the overlying quaternary debris cover. An external building load/force has been applied in slope model 1 of slope section A whereas for slope model 2 of slope section A, no external building load was used. The slope model 3 for section B is from the same landslide body representing the natural slope exposed after the first landslide episode. All the slope models were simulated for the critical strength reduction factor (SRF) beyond which the slope would fail. The results reveal a low critical SRF value 0.85 for slope model 1 at which the maximum displacement of 0.22m was computed for the lower portion of the slope A which looks vulnerable. The upper and the middle parts of the slope section A have stabilized due to debris accumulation on it from the first landslide event which decreased the inclination of the slope but near the toe the slope is steeply dipping which makes it vulnerable to failure. The SRF value 1.27 for slope model 2 and 1.15 for slope model 3 shows a comparative marginal stability theoretically but the field conditions indicate critical slope nature which requires monitoring and mitigation at vulnerable locations of the study area.

Keywords: Tiralines Village, Debris Landslide, Finite Element Method, Slope Stability Analysis

LANDSLIDE CHALLENGES DURING NATIONAL HIGHWAY-44 ROAD WIDENING PROJECT, UDHAMPUR TO CHENANI SECTION, J&K, INDIA

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ABSTRACT
Landslide is normal phenomena in hilly terrain. Various research works have been undertaken on landslide identification and mitigation measures. Government of India has started upgrading the road connectivity and accordingly proposed various road projects in Himalayan region. Jammu- Srinagar road National Highway 44 widening project (295 km long) is one of the precious projects, passing through Siwalik Himalaya to Greater Himalayan range and always in critical stage due to frequent landslide at various places. Udhampur-Chenani is part of Jammu-Srinagar NH-44 highway, about 22 km long section and belongs to outer Himalayan range with very poor geology and steep topography. Study area having thick cover of debris material with boulders, which is prone to landslide due to highly weathered and unfavourable joint orientation, geomorphological and hydrological factors. Study area having high rainfall and having large and old natural landslides zone. At the project feasibility stage, project authority has identified the landslide prone area and suggested precautionary measures but during the construction work various unpredicted landslide and ground sinking events happened which given trouble in road construction cost and project completion time. In this paper, the challenges faced due to landslides and ground failures due to reactivation of old slides adjacent to road construction, agriculture and residential ground failures at different altitude due to road construction, collapse of high tension towers in cut slopes, its impact on construction activities and project completion time, are discussed. It also talks about the suggested mitigation measures for unidentified landslide related challenges in view of case studies.

Keywords: Landslide, Geomorphological Factors, Hydrological Factors, Mitigation Measures

LANDSLIDE RISK ASSESSMENT FOR A PART OF COONOOR TOWN, TAMIL NADU

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ABSTRACT
Landslides are off-late a frequent and common hazard in the hill and mountain terrains all over the world. The changing climate pattern with increase in the number of extreme rainfall events have led to the increase in the frequency of landslides that disrupt the social and economic fabric of these hill and mountain regions. This scenario mandates a thorough analysis of the physical factors causing landslides in a particular geo-environment and the threshold of triggering factor that initiates the landslide activity. This information can be used to map the spatial propensity of the landslides and the temporal probability of its occurrence which can be expressed as the spatial distribution of hazard in the selected region. The hazard zonation map is a vital tool that can be used to identify the exposure of the region to the hazard. Risk is interpreted by comparing the hazard map and the land use & land cover map. Risk zonation can be used plan the developmental activities and strategies for mitigation. This is of particular interest when the region under study is has an economy based on tourism. Risk assessment can help suggest alternate economies and optimize tourist infra-structure in a hazard resilient and sustainable fashion.

Keywords: Landslides, Climate Change, Hazard, Risk, Tourist Economy

LONG TERM LANDSLIDE MITIGATION TECHNIQUE ILLUSTRATED- A CASE STUDY

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ABSTRACT
Landslide is the mass movement comprising of rock, debris or soil under gravity influence. The main slide triggering factors are rain and tectonic seismicity induced landslides occurring in Himalayan belt of Indian subcontinent. Anthropogenic activities like tunnel blasting for hydroelectric projects, unplanned excavations or cuttings of side for road widening purpose activates failure mechanism. On the other hand, continuous blasting and tunnelling weakens the rock joint layers. Based severity of rock joints and rock surface conditions, rock structures have been characterized in to different range of GSI chart. Thorough study and analysis is required to check the long term stability for these types of weak slopes with GSI range of 10 to 40 having fair, poor to very poor surface conditions lying close to important and sensitive structures. Present study reveals the effectiveness of preventive measure applied to the unstable slope stretch in the vicinity of Teesta stage III hydroelectric system. Finite element modelling has been carried out for the critical slide triggering stretch using Rocscience-Phase2 v8.005. Analysis has been carried out without and with stability measures. It has been observed that 50m vertical cladding wall having prestressed cable anchor with no base support survived the 2012 earthquake of 7 Richter magnitude scale with no signs of distress.

Keywords: Landslide, Himalayan Belt, Long Term Stability, Finite Element Modelling, Prestressed Cable Anchor, Teesta Stage III Hydroelectric System

QUANTITATIVE COMPARISON OF RAINFALL THRESHOLDS: A CASE STUDY FROM KALIMPONG, INDIA

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ABSTRACT
The increasing frequency of landslides has become a matter of prime concern in the context of Indian Himalayas. Massive losses are reported due to landslides every year, demanding the development of strategies to minimize the impact of such events. Kalimpong in the Darjeeling Himalayas is one among the landslide susceptible towns in India, where rainfall is identified to be the primary triggering factor for the occurrence of landslides. Attempts have been made in the past to develop local scale rainfall thresholds for the region using different approaches. Among the various methods, empirical methods are observed to be the simplest approach in predicting landslides. The procedure includes finding the relationship between rainfall and landslides happened in the past to predict the possible occurrence of landslides in future. In this work, three different empirical relationships derived for the region are compared to find the best suited method and to testify their applicability in an operational Landslide Early Warning System (LEWS).The Event Duration thresholds defined using an algorithm based approach is found to be performing better than the other two models considered in the analysis. It is observed that the empirical relationships have to be improved conceptually to be used as a tool for LEWS.

Keywords: Landslides, Rainfall Thresholds, LEWS

AN ADVANCED VERY HIGH RESOLUTION ENSEMBLE WEATHER PREDICTION SYSTEM SUITABLE FOR LANDSLIDE EARLY WARNING

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ABSTRACT
Landslide disasters have become a major concern in recent times in India primarily due to the colossal amount of casualties and property damages. This advocates the need for an accurate landslide prediction system in order to reduce the landslide disaster risk. A high resolution weather modeling system can become an important tool for landslide prediction which could predict the possible areas of heavy rain. In this regard ensemble based prediction systems could provide better weather forecast guidance. These forecasting systems, in the past two decades, have evolved from global scale to regional scale. The efforts to tackle the uncertainty at shorter time scale have led to the ensemble approach applied at convective scale resolution. The NCMRWF Regional Ensemble Prediction System (NEPS-R) is based on the regional version of Met Office Global and Regional Ensemble Prediction System (MOGREPS) with 12 members (1 control + 11 perturbed). The horizontal resolution of this regional ensemble prediction system is 4 km and there are 80 vertical levels up to a height of 38.5 km. There are 776 grid points in the East-West and North-South directions. The model domain extends from 670 E to 980 E and from 70 N to 380 N which covers the whole Indian region. The NEPS-R runs with initial and boundary conditions generated from the NCMRWF Global Ensemble Prediction System (NEPS-G) and provide probabilistic forecasts up to 3 days. The model uncertainties in NEPS-R are taken care by Random Parameters (RP) scheme.

NEPS-R has put up a credible performance in predicting the heavy rain associated with monsoon depressions and tropical cyclones. It has performed better than its global counterpart in predicting the maximum rainfall amount during the Kerala heavy rain episode of August 2018 and the Mumbai heavy rain event of August, 2019. It also performed well in predicting the rapid intensification of TC-FANI. So, convective scale ensemble prediction system such as NEPS-R could add immense value to landslide prediction and early warning system.

Keywords: Landslide Prediction and Early Warning System, Regional Ensemble Prediction System

PLANT-BASED SOLUTIONS FOR LANDSLIDES RISK REDUCTION AND RESILIENCE

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ABSTRACT
Landslides account for huge economic losses by destruction to both life and property. Vegetative engineering effort is one of the alternatives for preventing landslides, risk reduction and resilience. Plantation on susceptible slopes can reduce risk, while natural regeneration and planting trees on failed slopes can help in controlling after effects like, sediment release into rivers. Fast growing trees and shrubs are best suited to reduce erosion by increasing filtration, holding soil particles, stabilizing soil and slowing wind and water flow, however, socio-economic and conservation related factors of these plants should be considered. Tree species with low soil moisture requirement and capability to withstand unfavourable conditions are favoured. Suitable shrubs being chosen for landslide-prone area must have high quality to resist drought, high temperature and other adverse conditions, and grasses available round the year and surviving in wide range of climatic conditions. However, it is important that the plant species that are selected for such purposes are native to the region. Such species can produce best soil binding results. Establishing multiple vegetation cover on mountain slopes can reduce risk of landslides and rain induced erosion. Besides, plants provide stability to the slope through enhancing soil cohesion. When plants are removed from a slope, the slope become vulnerable to water and wind erosion leading to disasters.

Keywords: Plantation, Regeneration, Soil Erosion, Risk Reduction

LANDSLIDES IN SIKKIM - CASE HISTORY OF MANGAN LANDSLIDE

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ABSTRACT
Sikkim being located over fragile mountainous geological and geographical set up, it has much vulnerability through various types of physical and other hazards that may turn into disasters. The main physical hazards in the State are Landslide, Flash Flood, Earthquake, Forest and Household Fire, Thunder and Lightning, Snow and Avalanche and Glacial Lake Outburst Flood. Owing to both natural and man-made activities, landslides are the most frequent and cause considerable loss of life, property and damage to communication networks, human settlements, agricultural and forest land in Sikkim every year. The State has been perpetually afflicted by landslides.

Mangan town is the district headquarter of North Sikkim and is highly vulnerable to landslide. The area has experienced a number of landslides in the past. The situation has worsened after the jolt of 2011 earthquake and cloudburst of 2012. Protective works taken up along the Raffong Khola and Ramit Khola have been washed away, there has been heavy scouring of slopes and buildings along the North Sikkim highway are at high risk. The culvert constructed over Raffong Khola was washed away by slush and debris carried by heavy discharge during the year 2016. The area above Mangan was cut-off for several weeks. Mangan town in north Sikkim is particularly affected by several individual slides. The paper discussed site specific causative factors responsible for this phenomenon and the mitigation initiatives taken by the state government.

Keywords: Sikkim, Mangan Town, Landslides, Causative Factors, Mitigation Initiatives

NEED OF NATIONAL LANDSLIDE RISK MANAGEMENT STRATEGY FOR REDUCING LANDSLIDE RISK IN INDIA

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ABSTRACT

National Disaster Management Authority (NDMA), is the apex body for the disaster management in India under the Chairmanship of the Hon'ble Prime Minister, is mandated to lay down the policies, plans and guidelines for disaster management to ensure timely and effective response to disasters. India, is vulnerable to different landslides which cause significant destruction in terms of loss of lives and property. As per GSI, about 0.42 million km2 covering nearly 12.6% of land area of our country is prone to landslide hazards. At present, no Ministry/ Department of the Government of India (GoI) has formulated a national level landslide risk management strategy. In order to fill in this gap, NDMA formulated National Landslide Risk Management Strategy to adopt a holistic approach for mainstreaming landslide risk reduction, besides strengthening of the State machinery and providing all necessary technical support to the concerned States and UT's for addressing landslide problem in sustained manner. In this regard, NDMA had constituted a Task Force of experts from diverse backgrounds for the formulation of national and local level strategy for landslide risk reduction. The strategy is fulfilling the fifth target of Sendai Framework for Disaster Risk Reduction (2015-30) i.e., Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020. Strategy document released in the 15th Formation Day of NDMA on 27th September, 2019, addresses all the components of landslide disaster risk reduction and management such as hazard mapping, monitoring and early warning system, awareness programmes, capacity building and training, regulations and policies, stabilization and mitigation of landslide etc. The strategy document envisages specific recommendations for the concerned Nodal Agency, Ministries / Departments, States and other stakeholders, so as to avert or reduce the impact of future landslide calamities.

Keywords: Landslide, Risk, Mapping, Early Warning System (EWS), Awareness, Capacity, Building, Strategies

KINEMATIC ANALYSIS OF RAINFALL INDUCED ROCK SLIDE ALONG ROADCUT SLOPES – A CASE STUDY ON DHALLI LANDSLIDE, HIMLAYAN REGION

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ABSTRACT
Himalayas is one of the highly prone region for landslide disasters in the world. State and National Highways along the Himalayan region are unstable and are prone to various landslide disasters is of a major concern in the region. Unplanned excavation of the slopes has caused instability among the slopes leading to rock and soil failure. The current Research is focused on the studying Slope instability and Kinematic analysis of Rainfall induced Rock slide along NH-22 near Dhalli tunnel in Shimla town. Dhalli landslide which occurred in September, 2017 is a structurally controlled landslide that occurred along a Road cut slope without proper toe support. Kinematic analysis was performed to analyse the type rock failure in the study area. Four different types of joint intersections were found in which J1 and J2 forming intersection line dipping away from the slope indicating it is a wedge failure. Using Slope Mass Rating method (SMR) field based Geotechnical investigations have been carried out to study the attitude of excavated slopes and measurements of discontinuities present in the rock mass accompanied by collection of representative samples. The final output derived with a value of 45 indicates that the slope is partially stable. Based on the data collected from field and lab analysis the slope stability of the landslide is computed using SWEDGE model. The results computed the total wedge area of the joint 1 is 297.33 sq.mts and wedge area for the joint 2 is 1587.52 sq.mts. The total factor of safety of this critical slope is derived as 0.9 which is below required value. A suitable Economically viable measure been proposed like a Reinforced Wire Mesh Shotcrete as Slope Stabilization measure with an FOS value of 1.45 providing stability and support to negate the future occurrences of the slope failure.

Keywords: Dhalli Landslide, Slope Stability, Kinematic Analysis, Rainfall Threshold, SWEDGE

CLIMATE CHANGE INDUCED MASS WASTING: A GLOBAL PERSPECTIVE

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ABSTRACT
In the current scenario, the impact of climate change is not only on the human beings but also influences the pattern of rainfall, agriculture, seasonal variability, weather conditions besides accelerating natural disasters (such as Volcanic Eruption, Earthquakes, Landslides, Mass-wasting, Floods, Droughts, Cyclones, Tsunamis etc.). With the usage of various space technologies such as remote sensing and Geographical Information System with limited ground truth verification and laboratory analysis, one could help in proper planning and management of infrastructure, roads, railways, hospitals etc.

In this era of climate change, the erratic climatic pattern also induces the phenomenon of mass-wasting. After the rigorous analysis of climate change induced mass-wasting, the pattern for future suggests still stronger process of denudation in the hilly areas. It is the current need of every nation to work together against disaster risk mitigation and enhance the capacity building, knowledge and starting joint ventures for reducing the impacts of disasters globally. In this paper, the recently generated data on climate pattern has been analyzed for the present hypothesis of enhanced mass-wasting globally.

Keywords: Mass-wasting, Climate change, Environment, Management

A RAINFALL THRESHOLD-BASED LANDSLIDE EARLY WARNING SYSTEM, UTTARAKHAND

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ABSTRACT
A pilot rainfall threshold-based landslide early warning system for the Bhagirathi valley in Uttarakhand State was evaluated and partially implemented under the Swiss government's SDC programme, "Strengthening State Strategies for Climate Action (3SCA)". The program seeks to integrate climate actions into sub-national planning, which directly benefits communities affected by climate change.

The study area delineates the road section between Uttarkashi and Gangnani, which is part of an important route for transport, tourism and above all, pilgrimage to Gangotri: the origin of the Ganges River. In 2018, Indian and Swiss landslide experts together with USDMA and UNDP officials visited landslide sites in the study area to evaluate first-order requirements for a rainfall threshold-based landslide EWS. The landslide phenomena observed includes: 1) Landslides that have catastrophically failed and maybe subject to reactivation, 2) Failing slopes that are yet to catastrophically fail, 3) Rock fall prone areas adjacent to the road, and 4) Numerous gullies intersecting the roadway, which are potential sources for debris flow and/or flash floods. During a field visit in April 2018, the team experienced a cloud-burst, which triggered flash flooding and rock falls, leading to prolonged road closure. The incident provided valuable insight, and raised important questions about the interplay between landslide early warning and response intervention, and potential issues for enhancing public safety.

An efficient rainfall threshold-based landslide early warning takes into consideration the process interactions between vegetation characteristics, soil/rock properties and precipitation/ infiltration into the substrate. As all three factors may vary in space and time, approximations are essentially made between the amount of precipitation and the triggering of a landslide event. In this regard, landslide susceptibility analysis was applied to characterise landslide prone areas, however the relationship between selected thematic layers (e.g. Rainfall, lithology, slope aspect etc) did not unequivocally demonstrate a clear relationship between observed landslide events (along the roadway) and statistical weighting of thematic layers.

First order rainfall thresholds were calculated from TRMM satellite data and compared to observed landslide event registries maintained by the BRO. The correlation between calculated rainfall thresholds, detection of landslides (radiative signatures) and the actual timing of recorded landslide events was not conclusive. Rainfall data from AWSs implemented during the

project demonstrated a reliable continuous recording of rainfall events, however much work still remains to analyse correlations with landslide events and establish reliable thresholds for specific sections of the study area.

Integration of the AWSs and warning thresholds within SOPs of the existing incident response system has high potential for a functional early warning system. It will be necessary to create horizontal linkages between government line departments responsible for DRM, and incorporate local community as non-passive actors in the implementation of warning, evacuation and response systems.

Keywords: Landslide; Rainfall-threshold; Early warning

LANDSLIDES MITIGATION BY DRAINAGE CONTROLS & BIO-ENGINEERING SOLUTIONS

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ABSTRACT
India's hill roads and allied developmental issues have been in the perennial mode of reconditioning specially after rainy season. For geo-professionals it's a slope instability problem aggravated mostly by ill-conditioned drainages. For Geological perspectives landslides are the Nature's gift to mankind for not following soil characteristics. As preparedness measures, simple guidelines for crack repairs and treatment; restoration and strengthening methodology; applicability of some sustainable technology in landslides mitigation, including bioengineering methods for slope stabilisation, anchored earth and geosynthetics application, to name a few, are essential. Realizing that heavy rain fall induced flash flood carries everything that come on its way; it's high time to look into the reconstructions measures that must be sustainable. It is very much possible to adopt slope stabilization measures by combination of reinforced earth, soil nailing including bio-engineering measures by Vetiver grass.The use of vegetation as a bio-engineering tool for erosion and drainage control has been implemented for centuries but its popularity has increased in the last few decades. Many studies all over the world have shown that Vetiver as a hedge is the ideal plant to conserve soil and rehabilitate eroded land.This paper shall provide the application of Vetiver grass, which is primarily of Indian origin, but routinely used by more than 100 countries. Some of the potential applications in the North East part of India, wherein proper methodologies along with some successful and failed examples will be explained.

Keywords: Landslides, Bio-Engineering, Vetiver Grass, Mitigation

ABOUT THE INSTITUTE

National Institute of Disaster Management (NIDM) constituted on 30.10.2006 under The Disaster Management Act 2005 has been entrusted with the responsibility for planning and promoting training and research in the area of disaster management, documentation and development of national level information base relating to disaster management policies, prevention mechanism and mitigation measures. Re-designated from the National Centre for Disaster Management of the Indian Institute of Public Administration on 16th October 2003, NIDM is steadily marching towards the mission of making a disaster resilient India by developing and promoting a culture of prevention and preparedness at all levels.

FUNCTIONS

Under The Disaster Management Act 2005, the Institute, has been entrusted with the following functions:

- Develop training modules, undertake research and documentation in disaster management and organize training programmes
- Formulate and implement a comprehensive human resource development plan covering all aspects of disaster management
- Provide assistance in national level policy formulation
- Provide required assistance to the training and research institutes for development of training and research programmes for various stakeholders
- Provide assistance to the State Government and State training institutes in the formulation of State level policies, strategies, disaster management framework and any other assistance as may be required for capacity building
- Develop educational materials for disaster management including academic and professional courses
- Promote awareness among stakeholders including college or school teachers and student, technical personnel and others associated with multi-hazard mitigation, preparedness and response measures
- Undertake, organize and facilitate study courses, conferences, lecturers, seminars within and outside the country to promote the aforesaid objectives
- Undertake and provide support for publication of journals, research papers and books as well as establish and maintain libraries etc.

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