सत्यमेव जयते

A Selected Annotated Bibliography and Bibliography on Landslides in India

Surya Parkash
Anil Kathait

nidm
Towards a disaster free India.....

World Centre of Excellence on Landslide Disaster Reduction
National Institute of Disaster Management
Ministry of Home Affairs, Govt. of India
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Foreword

The document on ***"A Selected Annotated Bibliography and Bibliography on Landslides in India"*** has been prepared to provide a source of inventory of publications for those who are interested in the field of landslides studies, research and management. It is a compilation of the available literature and research work pursued on Indian landslides by different organisations and experts from the country or abroad. The document adopted the American Psychological Association (APA) citation style, which is one of the most used citation method for the referring the research work. The annotated bibliography and bibliography on landslides has been arranged in an alphabetical as well as chronological order .

I would like to congratulate Dr. Surya Parkash, Head, Knowledge Management and Communication Division, NIDM along with Mr. Anil Kathait who have successfully brought out this publication. It is divided into two parts: annotated bibliography and bibliography. The annotated bibliography provides a brief summary of the research work carried by the researcher while the bibliography gives only the reference information of the publications.

NIDM acknowledges the valuable support from all resource persons and institutes for providing technical inputs for the document and reviewing the same at various stages of preparation and publication.

(Dr. Satendra, IFS)

अगर उचित है आपदा प्रबंधन, तभी मिलेगा विकास को धन।

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Preface

The contemplation of available literature or research work carried out on any subject facilitates in understanding that particular subject. This document is equipped in an attempt to provide the relevant research works done on landslide hazard in India. Considerable literature and research works are available related to Indian landslides. The reason of designing this document on landslide is the severity of the hazard in India. Landslide hazard along with thousands of deaths in a year also cost huge monetary and environmental losses. The impacts of these hazards are felt for longer period of time after the disaster . The direct and indirect/delayed impacts of landslides include disruption in the communication network and economy, hardship for the local community, population displacement and negative effects on the natural environment. The document consists of annotated bibliography and bibliography of the publications made by different researchers and organisations.

Many international renowned citation styles of the research papers are available. These include American Psychological Association (APA), Chicago, Turabian, Modern Language Association (MLA) etc. Here APA citation style[1] has been used to refer the research work of the author(s). The annotated bibliography provides brief summary of the available research work carried out on Indian landslides. The sequence in which the annotated bibliography has been presented follows like this : author(s) name, year, title of the research, publication details, link of the source and a brief summary about the research. On the other hand, bibliography comprises author(s) name, year, title of the research and publication details. The sources of collected literature are different international and national journals, conferences and other related publications.

The aim of this documentation is to systematically organize a source of previous literature and research work on landslides for the interested researcher for their further research. It can also be helpful for those who have interest in knowing about the landslides publications of any particular area in the country.

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I take this opportunity to express my profound gratitude and deep regards to ***Dr. Satendra, Executive Director, National Institute of Disaster Management, New Delhi*** for his kind encouragement in preparing the document on ***"A Selected Annotated Bibliography and Bibliography on Landslides in India"***. I would also like to thank Mr. Anil Kathait, NIDM, who has supported me in completing this task successfully.

It is my sincere and humble duty to place on record my deepest sense of gratitude to Dr. R. K. Bhandari, Former Director, CBRI; Dr. Kishor Kumar, Chief Scientist, Central Road Research Institute; Dr. R. Dharmaraju, Dr. Shantanu Sarkar, Dr. Debi Prasanna Kanungo, Scientists from Central Building Research Institute and other professionals, academicans as well as researchers who have helped in preparation and publication of this document.

I would like to express my appreciation towards the faculty and staff members of National Institute of Disaster Management, New Delhi for their valuable cooperation during the period of this work. Particular thanks are due to Shri S. K. Tiwari, Librarian and Shri Ashok Kumar Sharma, Consultant and Shri T. K. Saha Roy, Consultant, NIDM.

Last but not the least, I would like to thank my wife Reeta and my daughter Rasika Gupta, without whose consistent moral and logistic support, I would not have been able to give due attention and time to this work. I am indebted for their tolerance to bear with me when I was busy with work related to this publication and could not give due attention and care to them.

Finally, I am grateful to the Almighty God without whose grace and kindness, I would not have been capable to carry this task successfully.

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Acronyms Used

ATES	-	Advanced Technical Engineering Services
ATI	-	Administrative Training Institute
BIS	-	Bureau of Indian Standards
BRO	-	Border Roads Organization
CBDP	-	Community Based Disaster Planning
CBLRM	-	Community Based Landslides Risk Management
CBDRM	-	Community Based Disaster Risk Management
CBO	-	Community Based Organizations
CBRI	-	Central Building Research Institute
CLRM	-	Comprehensive Landslides Risk Management
CRF	-	Calamity Relief Fund
CRRI	-	Central Roads Research Institute
DDMA	-	District Disaster Management Authority
DGBR	-	Director General Border Roads
DGCD	-	Director General civil Defence
DGM	-	Department of Geology and Mines
DMA	-	Disaster Management Act
DMMG	-	Department of Mines, Minerals and Geology
DoS	-	Department of Space
DST	-	Department of Science & Technology
ESF	-	Emergency Support Function
GSI	-	Geological Survey of India
GFDRR	-	Global Facility for Disaster Reduction and Recovery
HVCR	-	Hazard, Vulnerability, Capacity and Risk
ICL	-	International Consortium on Landslides
ILC	-	International Landslide Centre
IMD	-	Indian Meteorology Department
IIRS	-	Indian Institute of Remote Sensing
IPL	-	International Programme on Landslides
ISDR	-	International Strategy for Disaster Reduction
ISRO	-	Indian Space Research Organization
ITBP	-	Indo Tibetan Border Police
LHZ	-	Landslides Hazard Zonation

LMP	-	Landslides Management Plan
LRM	-	Landslides Risk Management
LSN	-	Landslides Schools Network
MHA	-	Ministry of Home Affairs
MoM	-	Ministry of Mines
MoES	-	Ministry of Earth Sciences
NCCF	-	National Calamity Contingent Fund
NDMA	-	National Disaster Management Authority
NDMRC	-	National Disaster Mitigation Resource Centre
NDRF	-	National Disaster Response Force
NDRF	-	National Disaster Response Fund
NGO	-	Non Governmental Organization
NHAI	-	National Highway Authority of India
NHPC	-	National Hydro Power Corporation
NIDM	-	National Institute of Disaster Management
NTPC	-	National Thermal Power Corporation
NRSC	-	National Remote Sensing Centre
PGCL	-	Power Grid Corporation (I) Limited
PWD	-	Public Works Department
QRT	-	Quick Response Team
SASE	-	Snow and Avalanches Studies Establishment
SDMA	-	State Disaster Management Authority
SDRF	-	State Disaster Response Fund
SDRF	-	State Disaster Response Force
SOP	-	Standard Operating Procedures
THDC	-	Tehri Hydro Development Corporation
UNDP	-	United Nations Development Programme
USGS	-	United States Geological Survey
VOs	-	Voluntary Organizations
WBI	-	World Bank Institute
WIHG	-	Wadia Institute of Himalayan Geology

CONTENT

1. Background

The vulnerability of India towards wide variety of hazards is well known. Landslides are among those hazards which now and then hammer the Indian Territory. India has a sensational record of catastrophes due to landslides. To name few such disastrous events are Mapla landslide, Alaknanda tragedy of 1970, Kaliasaur landslide, 2010 Cloudburst led flash mudslides in Leh of J&K etc. Many researchers had put their thinking cap in order to be familiar with Indian landslide. Ample research work has been carried out by different researchers on Indian landslides but hardship is that their work is not assembled in any one database which can facilitate current and future researchers to track these literatures. Therefore, its time to organize such a database source which is compilation of the research work conducted on the Indian landslides.

The inventory of annotated bibliography and bibliography on landslides in India, commenced at National Institute of Disaster Management is an attempt to provide users a database source of available literature/research on the landslide hazard. The document presents annotated bibliography and bibliography of the Indian researcher's work on Indian landslides. It includes research papers/ articles published in journals and conference proceedings.

Annotated Bibliography and Bibliography on Landslides in India

2. About Landslides

Landslide (Fig 2.1) is a collective term used to describe various types of movement of the slope forming materials i.e. rock, earth, artificial materials or a combination of these materials. It can be delineated as *"downward movement in the slope under the influence of gravity with a velocity ranging from very slow to very rapid".* Landslides are not an isolated phenomenon, they can occur virtually anywhere. Orthodox philosophy about landslide was that it only occurs in steep slopes but with passage of time and research it has been noticed that it can influence gentle slope too. One can experience this hazard on land as well as under the water. To understand landslides they are classified in many ways. The criteria used in classification includes, type of movement, type of material, rate of movement, activity, age of movement, morphological characteristics, size/ scale etc. The most adopted classification is that of Varnes and Cruden of 1996 which is a modified version of Varnes's 1978 landslide classification. This is based on two attributes, type of movement and type of material.

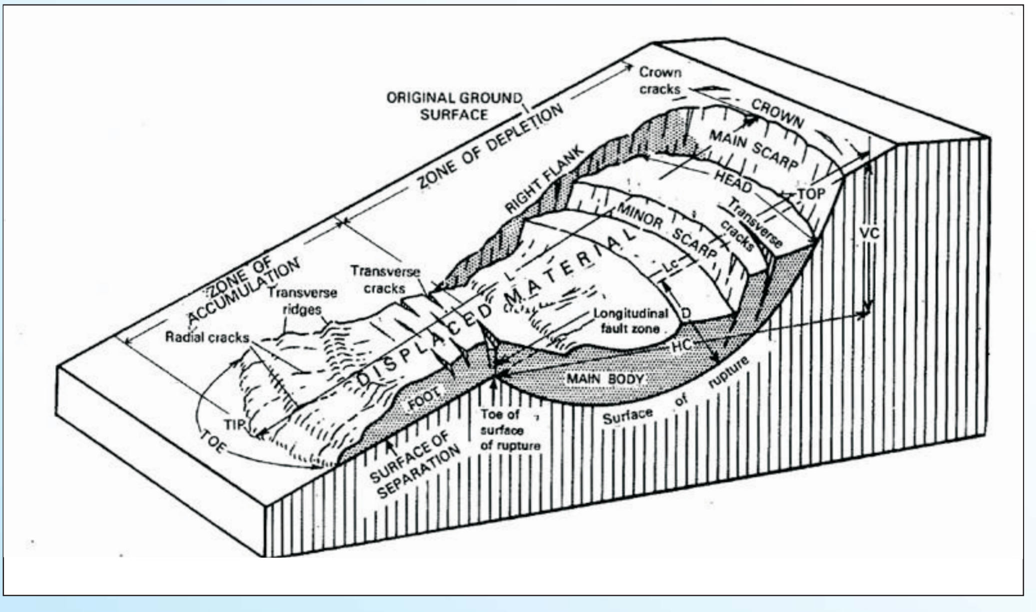

Fig 2.1: Block diagram of landslide and its features

Image source: http://www.bau.hsr.ch/(S(wpsr3wz4juhrmo45amnsljyf))/Print.aspx?Page=Characterizing_a_landslide

Fall

A fall starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends mainly through the air by falling, bouncing, or rolling.

Topples

Topples is the forward rotation out of the slope of mass of soil or rock about a point or axis
below the centre of gravity of the displaced mass. Toppling is sometimes driven by gravity exerted by material upslope of the displaced mass and sometimes by water or ice in cracks in the mass.

Slides

A slide is a downslope movement of soil or rock mass occurring dominantly on the surface of rupture or on relatively thin zones of intense shear strain.

Translational slide

In translational slides the mass displaces along a planar or undulating surface of rupture, sliding out over the original ground surface.

Rotational slides

Rotational slides move along a surface of rupture that is curved and concave.

Spreads

Spread is defined as an extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material.

Flows

A flow is a spatially continuous movement in which surfaces of shear are short-lived, closely spaced, and usually not preserved. The distribution of velocities in the displacing mass resembles that in a viscous liquid. The lower boundary of displaced mass may be a surface along which appreciable differential movement has taken place or a thick zone of distributed shear. Flows can be in the forms of debris flow, debris avalanche, earth flow and mud flow.

Complex movement

Complex movement is a combination of falls, topples, slides, spreads and flows.

Landslides can be caused by numerous factors. These factors have been categorized under different terms by different researchers/authors, ex. Natural factors/causes; controlling factors; anthropogenic factors/human activities; some instead of using natural factors differentiate it into geological factors, morphological factors etc. but the thing to remember is that the basic causative factors are same in all the classification. There are factors which make slope vulnerable to landslides and when a triggering factor enters in such area the hazard take place. Here, we have divided the causes of landslides into following two main groups:

1. **Preparatory factors** (which make the slope susceptible to fail)
   Example: inherent conditions of the slope (steepness, rock type and structure), weathering, erosion, deforestation, undercutting by river flow and human activities like unsupported cuts, slope loading (surcharge) by filling, and uncontrolled water discharges. The formation of earth dams, excavation and mining, irrigation, construction.

2. **Triggering causes** (which initiate the process of sliding).
   Example: intense rainfall, seismic activity and human intervention like construction activity that undercuts or overloads dangerous slopes, or that redirects the flow of surface or ground-water

Landslides also hold multi hazard title as it can be occurred as a by product of other hazards like, earthquake, cloudburst, flashflood.

Landslides are one of the overwhelming geological disasters, having broadened distribution. They adversely impact humans and their environment and their affects can be long lasting. Some of the negative impacts of landslides are:

- Fatalities and injuries to humans as well as domestic animals
- Destruction of infrastructure like road network
- Negative economic effects which includes loss to property, cost of rehabilitation and to repair structures, medical cost in the event of injury

- Loss of agricultural and forest cover
- Water pollution by increased sediments level in the water bodies
- Ecological disturbance by changing the landscape.

3. Overview of Landslide in India

India, due to its assorted physiographical, geo-hydrological, climatological conditions and dynamic tectonic plates houses areas which are vulnerable to different hazards. Landslide is one of the major hazards, widely spread in India and accounts for considerable fatalities and damage to highways/roads network, human settlements, agricultural fields and other natural resources. According to Geological Survey of India, out of total states and union territories of India 20 states and 2 union territories are vulnerable to landslide hazard (Fig 3.1). The most affected areas of the country are Himalayan mountain belt region comprising north and north eastern states, Western Ghats and the Nilgiris.

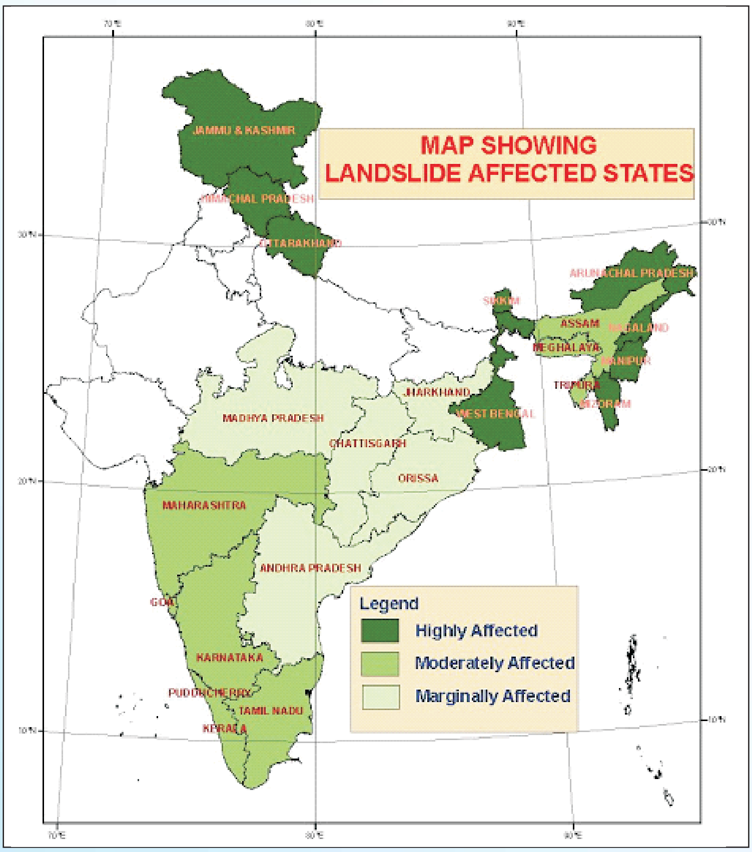

Fig 3.1: Landslide affected states of India

Image source:http://appscmaterial.blogspot.in/2012/02/disaster-management-landslides.html

A lot of efforts have been made by the researchers/investigators to understand the nature of Indian landslides. More than 450 researchers from all over the country have shown interested in the study of this devastating disaster. Various aspects of the landslides and other concerning to it have been studied, ex:

- Study of causative factors of landslides
- Landslide hazard zonation and mapping
- Landslide risk assessment
- Landslide database and inventory
- Effect of deforestation on landslides
- Earthquake induced landslides
- Geological, geomorphological, geotechnical investigations
- Instrumentation, monitoring and early warning of landslides
- Utilization of different softwares in landslide study, and many more.

Depending upon their valuable work we can step forward in the direction of making the most suitable mitigation and management strategies for our slopes. Table 3.1 presents some of the historical records of landslides in India, resulting in 15 or more casualties.

Table 3.1: Some of historical records of landslides in India

S N.	Location	Month/ Year	Damages
1.	Khurong Kewa Dara along \ Peling Dentam road, 15 km away from Geyzing, Tikjuk and lower Pelling, West Sikkim	23 June 2011	16 persons killed in multiple slides due to torrential rains b/n 8:30pm and 11pm, collapsed the entire connectivity, power and water supply
2.	Almora	19 Sept. 2010	31 died and 7 injured
3.	Shumgarh Landslide, Bageshwar distt	18 August 2010	18 school student between 5 and 12 years of age were buried alive, 12 injured, whole school destroyed
4.	Leh Distt, J&K	5/6 Aug 2010	145 killed, hundreds missing, villaged washed away, >25,000 people affected and became homeless
5.	Gulmarg, J&K	8 Feb 2010	17 killed in avalanche

6.	Udhagamandalam (Ooty),TN	10 Nov. 2009	43 killed, 600 houses destroyed, 1100 people homeless
7.	Madibagh of Kadwad in Karwar taluk, Uttara Kannda distt, Karnataka	2 Oct 2009	24 killed, 9 houses collapsed, NH-17 blocked. In total 21 landslide occurred on that day in Karwar hills
8.	Nachni, Pitthoragarh	8 Aug 2009	43 killed, 3 Villages Nachni, La and Jhekla were completely buried under landslides
9.	Kurseong, Darjeeling	28 May 2009	27 killed, 500 houses damaged
10.	Shimla, HP	21 Sept 2008	42 killed, 13 houses collapsed and road caved in
11.	Himachal Pradesh	15 June 2008	16 killed 6 injured
12.	Nehrukund, Manali	18 Mar 2008	25 Killed, Manali-Leh highway blocked
13.	Jammu Srinagar NH	8 Feb 2008	25 killed in avalanche
14.	Uri, J&K	10 Jan 2008	15 killed due to avalanche
15.	Dharla village, Shimla	30 Sept 2007	53 killed
16.	Sangla-Chittkul, Tangling-Purnavi near Recong Peo in Kinnaur and Ghanvi-Ladana-Sudana and Ghanvi-Pancha in Rampur sub-division of Shimla district	15 Aug 2007	65 killed, 14 houses destroyed and 13 damaged
17.	Kerala	18 July 2007	22 killed, 4500 homeless
18.	Dasgaon slide, Raigad distt, Mahatrashtra	26 July 2005	190 killed
19.	Budhakedar and Khetgaon Landslide, Bal Ganga Valley, Tehri	10 Aug 2002	29 people killed
20.	Amboori village	9 Nov. 2001	38 people died and 4 houses destroyed, damaged rubber plantation
21.	Phata and Byung Gad Landslides, Chamoli	17 July 2001	21 killed and several houses damaged
22.	Ukhimath, Rudraprayag	16 July 2001	28 persons killed

Annotated Bibliography and Bibliography on Landslides in India

23.	Barua Bhenti slide UK	19 Sept. 1998	15 people died, several livestock killed at about 8 km north of Okhimath along the left bank of Madhmaheshwar river
24.	Madhya Maheshwar, Rudraprayag	17 Aug 1998	40 persons killed and 10 livestock lost
25.	Malpa Landslide, Kali River	17/18 Aug 1998	Wiped out Malpa village with >210 persons killed
26.	Ukhimath Landslide blocked Madhyamaheshwar river (tributary of Mandakini)	12 August, 1998	109 deaths and 1908 families from 29 villages affected and 820 houses daamaged
27.	Chandighat Tea Estate, Assam	4 June 1998	22 persons killed
28.	Gangtok and its suburbs, Chandbari< tathangchen, Zero point, Gangtok Bhusuk Road	8 June 1997	50 people killed and damaged large number of houses. Killed a constable on duty and destroyed the institute of cottage industries and numerous vehicles. About 20 minor and major landslides occurred. In Changey Tar Basty, 1 dies and several houses and other properties destroyed
29.	Ratauri, Pitthoragarh	July 1996	16 killed
30.	Luggar Bhatti slide, Kullu, Himachal Pradesh	12 September, 1995	65 people died at about 2km north of Kullu along left bank of Beas river
31.	Deorali, Gangtok	1995	30 people killed and huge damages to properties
32.	Aizwal, Mizoram	May, 1995	25 deaths and roads damaged
33.	Varundh Ghat, Konkan Coast	June 1994	20 killed, breaching of Ghat road upto 1km at several places
34.	Nilgiri hills	November, 1993	Nearly 40 deaths and property worth several lakhs damaged
35.	Kalingpong, West Bengal	August, 1993	40 deaths and heavy loss to property
36.	Itanagar, Arunachal Pradesh	July, 1993	25 deaths, 2km road damaged and traffic disrupted

Annotated Bibliography and Bibliography on Landslides in India

37.	Ngopa, Champahi, Mizoram	(Year?)	55 families and 45 buildings affected by landslides
38.	Hlimen Slide, Aizawl	9 Aug 1992	66 killed and 17 houses destroyed
39.	Foot of Narkasur hill near Dispur, Guwahati	15 Oct 1991	15 persons killed
40.	Gopeshwar, Chamoli	16 Aug 1991	36 killed and 26 livestock lost in 6 villages
41.	Assam	July 1991	300 deaths, damage of roads and buildings worth million of rupees
42.	Nilgiris	October 1990	36 deaths and several injured. Buildings, roads damaged and communication disrupted
43.	Syari and Deorali, Gangtok	1990	25 deaths and considerable loss of property especially of the army cantonment
44.	Soldan Khad slide HP	1988	Flashflood in soldan khad killed 32 persons and 35 cattle, 200m road damaged on NH-22
45.	Landslides at Jakholi in Tehri Garhwal and Devaldhar in Chamoli	1986	32 lives lost
46.	Ukhimath Landslide	1979	39 persons killed
47.	Chamoli district	20 July 1970	Landslide formed an artificial lake in the upper catchment of Alaknanda river; affected 101 villages, >100 persons killed and 142 animals died; about 36 vehicles drowned by flashfloods; district headquarter of Chamoli devastated and subsequently shifted to Gopeshwar
48.	North district, Sikkim	1967	65 GREF workers killed
49.	Nainital Landslide	1880	Massive destruction , killed >150 persons
50.	Landslide at Chamoli Garhwal blocked Alaknanda river	1868	Swept 2 villages and killed 70 pilgrims

4. Annotated Bibliography

4.1 Agrawal, B. K., Singh, M. and Samadhiya, N. K. (2004). "A slip based constitutive model for rough rock joints". Proceedings of the ISRM International Symposium 3rd ARMS, Ohnishi & Aoki (eds) © 2004 Millpress, Rotterdam.

A constitutive model for the evaluation of rock joint deformation is presented. The model assumes a continuous slip along the asperity surface during shear, due to which the actual contact area decreases till the failure of asperity takes place. The actual contact area between the mating surfaces thus reduces, thereby increasing the normal stress on the asperity surface. The shear stiffness used in the model was determined by the equation of Yoshinaka and Yamabe (1986). It was concluded that the modified equation may be used to closely predict the deformations of rough dilating rock joints under low constant normal load conditions.

4.2 Anbalagan, R. (1992). "Landslide hazard evaluation and zonation mapping in mountainous terrain". Engineering Geology 01/1992; DOI: 10.1016/0013-7952(92)90053-2.
http://www.researchgate.net
publication222168592_Landslide_hazard_evaluation_and_zonation_mapping_in_mountainous_terrain

Landslide hazard zonation (LHZ) maps are of great help to planners and field engineers for selecting suitable locations to implement development schemes in mountainous terrain, as well as, for adopting appropriate mitigation measures in unstable hazard-prone areas. A new quantitative approach has been evolved, based on major causative factors of slope instability. A case study of landslide hazard zonation in the Himalaya, adopting a landslide- hazard evaluation factor (LHEF) rating scheme, has been presented.

4.3 Anbalagan, R. and Singh, B. (1996). "Landslide hazard and risk assessment mapping of mountainous terrains — a case study from Kumaun Himalaya, India". Elsevier Engineering Geology Volume 43, Issue 4, September 1996, Pages 237–246.

Landslides are studied systematically in order to evaluate the nature of hazard and the damages to the human life, land, roads, buildings and other properties. This can be expressed in terms of risk, which is a function of hazard probability and damage potential. A risk map will indicate the priorities for landslide hazard management. An approach to risk assessment mapping using a risk assessment matrix (RAM) is presented.

4.4 Anbalagan, R., Chakraborty, D. and Kohli, A. (2008). "Landslide hazard zonation (LHZ) mapping on meso-scale for systematic town planning in mountainous terrain". Journal of Scientific and Industrial Research Vol 67 July 2008, pp. 86-97. http://nopr.niscair.res.in/bitstream/123456789/1791/1/JSIR%2067(7)%20486-497.pdf

In present work, scope of regional scale LHZ mapping technique has been increased to accommodate more detailed aspects of inherent causative factors responsible for slope instability. This technique also incorporates effects of external causative factors such as seismicity and rainfall as correction ratings. This technique has been effectively applied to prepare a LHZ map on meso-scale in Nainital area; it will be useful for town planners to plan civil constructions in relatively safe zones. In addition, environmentally unstable slopes can be given adequate attention by planning suitable control measures.

4.5 Anbalagan, R. and Parida, S. (2013). "Geotechnical studies of reservoir area of Lakhwar Dam project, Garhwal Himalaya, India". International Journal of Emerging Technology and Advanced Engineering Volume 3, Issue 10. http://www.ijetae.com/files/Volume3Issue10/IJETAE_1013_66.pdf

The impacts of potentially unstable slopes on the water impoundment have been evolved. The paper discusses the stability of slopes around and above the rim of the reservoir which indicate that the slopes are stable in general. The most important consideration in developing and maintaining a reservoir is its ability to hold the water without endangering the stability of the rim area. The mapping of the reservoir has been carried out on 1:15,000 scale by undertaking extensive traverse mapping. In addition to mapping, 67 potential slopes for instability have been chosen for detailed analytical studies.

4.6 Anbalagan, R. and Parida, S. (2013). "Geoenvironmental problems due to harmony landslide in Garhwal Himalaya, Uttarakhand, India". International Journal of Emerging Technology and Advanced Engineering Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 553-559. http://www.ijetae.com/files/Conference%20ICERTSD-2013/IJETAE_ICERTSD_0213_84.pdf

A major landslide occurred in 1986 near Harmony village on left bank of Pinder River, along Karnaprayag - Gwaldam road in Chamoli district of Uttarakhand state. The Harmony landslide caused traffic blockade and consequent economic and environmental losses. In view of importance of this landslide, detailed Engineering Geological investigations were carried out incorporating relevant Geotechnical parameters. The entire landslide area had been mapped on 1:1000 scale and three Geological sections were prepared. The shear strength parameters were obtained with the help of in-situ samples collected from the site. The slope stability analysis to calculate Factor of Safety (F) was carried out using Circular failure charts.

4.7 Anbalagan, R., Kumar, R., Parida, S. et al. (2014). "GIS based post earthquake landslide hazard zonation mapping of Lachung Basin, Sikkim". International Journal of Emerging Technology and Advanced Engineering Volume 4, Issue 1, January 2014. http://www.ijetae.com/files/Volume4Issue1/IJETAE_0114_75.pdf

In the present study pre and post earthquake remote sensing data has been used to prepare landslide inventory. Geological features are analyzed using criteria such as colour, tones, topography and stream drainage pattern from the imageries. Digital elevation model data is used to generate primary topographic attributes namely, slope, aspect, and relative relief. For landslide hazard zonation (LHZ) different thematic maps such as land-cover map, slope map, relative relief map, structural map, lithology map, lineament buffer map, drainage buffer map, soil map, are assigned relative weight on ordinal scale to obtain landslide hazard index (LHI). Threshold values are selected according to breaks in LHI frequency and a LHZ map is prepared which contains very low hazard, low hazard, moderate hazard, high hazard and very high hazard zones.

4.8 Asthana, A. K. L. and Sah, M. P. (2007). "Landslides and Cloudbursts in the Mandakini Basin of Garhwal Himalaya". Himalayan Geology, Vol. 28 (2), pp.59-67. http://www.himgeology.com/himgeol/vol_28(2)/abstract6.htm

In the present study area of Mandakini Basin, the proximity of MCT and Vaikrita thrust are structurally weak zone making the rocks further weak in the study area of Mandakini Basin. The area suffers from large, medium and small landslides every year in monsoon season. Along with the inherent lithological and structural characteristics tectonic activity, climatic characteristics, deforestation and destabilization of slope due to construction have increased the probability of landslides in these fragile ecosystems. Construction of roads for developmental activity leading to removal of lateral support particularly in the dip slope faces of mountains has led to some massive landslides in the Mandakini Basin. High intensity rainfall and cloudburst are much frequent in the Mandakani Basin which accelerates the landslides and cause wide spread damages in the area.

4.9 Asthana, A. K. and Bist, K. S. (2009). "Basan slip zone: causes and mitigation measures, Yamuna valley, Uttarakhand". Indian Landslides Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf

Landslide and mass movement activities are very significant in the Himalayas. The Main Boundary Fault (MBT) is a structurally weak zone which makes the rocks further weak in the study area of Basan Slip zone due to their proximity. The toe cutting of fast flowing Yamuna river is making suitable conditions for the slip zone to remove the debris from the lower areas. Construction of road for the developmental activity leading to removal of lateral support particularly in the dip slope faces of mountain has led to massive landslide in the area. High intensity of rainfall during monsoon season accelerated the landslide and cause widespread damages in the area of Basan slip zone.

4.10 Avasthy, R. K. and Kumar, H. (2009). "Landslide hazard zonation mapping along Chamba - Bharmaur Road, Chamba District, Himachal Pradesh". Indian Landslides Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf

The landslide hazard zonation is carried out in parts of Ravi catchment, Chamba District, Himachal Pradesh with the objective of identification of old landslides, preparation of inventory and demarcation of landslide prone zones. The methodology adopted is based on Probabilistic approach for the determination of failure probability value (Pv) of various slope classes in each litho unit. Based on statistically determined Pvs, the slopes are classified within High Hazard (Pv >50%), Moderate (Pv 20 -50%) and Low Hazard prone (Pv < 20%) respectively. Higher vulnerability of slopes were recorded in anaclinal slopes of Katarig ali Formation (20%), Morang Forma tion (16.6 6%) and cataclinal slo pes of Kata rigali Formation while the lowest vulnerability was recorded in cataclinal slopes of Morang Formation (2.43%). The high hazard zones are restricted to the river valley along Chamba - Bharmaur road, where the hill slopes are subjected to under cutting by river and greater influence of anthropogenic activities.

4.11 Avinash, K. G., Diwakar, P. G., Joshi, N. V. et al. (2008). "Landslide susceptibility mapping in the downstream region of Sharavathi River Basin, Central Western Ghats". http://wgbis.ces.iisc.ernet.in/energy/paper/BSTC_CES_TVR_205_150108/BSTC_CES_TVR_205_150108.pdf

The aim of paper is to identify landslide susceptibility regions in the Sharavathi river basin downstream using frequency ratio method based on the field investigations. Spatial data layer such as topography, land cover, geology and soil were considered. Factors that influence landslide were extracted from the spatial database. The probabilistic model -frequency ratio is computed based on these factors. Landslide susceptibility indices were computed and grouped into five classes. Validation of LHS, showed an accuracy of 89% as 25 of the 28 regions tallied with the field condition of highly vulnerable landslide regions.

4.12 Awasthi, A. K. and Parkash, S. (2001). "Basin morphometry and landslide potential along Bhagirathi river valley in a part of Uttarkashi district, Garhwal Himalaya, Uttaranchal (India)".

Journal Indian Association of Sedimentologist Vol. 20 No. 1 pp 39-50. http://iasindia.info/abstracts/volume_20_no1_jan-june2001.pdf

The morphometric studies of the drainage basins have been done along the Bhagirathi river valley in a part of Uttarkashi district, Garhwal Himalaya, to identify and establish a mutual relationship between the single most significant morphometric parameter and landslide potential to serve as an instability indicator in the valley using simple statistical techniques like Pearson's product moment correlation coefficient and linear regression analysis. The paper discusses the morphometric attributes of the drainage basin in the study area with special emphasis on their relationship with the landslide potential.

4.13 Babu, G. L. S. and Mukesh, M. D. (2003). "Risk analysis of landslides – A case study". Geotechnical & Geological Engineering Volume 21, Issue 2, pp 113-127. http://link.springer.com/article/10.1023%2FA%3A1023525002893

The effects of uncertainty due to the variability of soil parameters on the risk of landsliding in the Himalayan region are investigated using a random field model combined with slope stability analyses. Effects of spatial variability both in horizontal and vertical directions, number of test samples, variations in piezometric level and the influence of earthquake on the reliability of a typical slope in a slide area are investigated. The results show that the reliability of slopes in the slide area is significantly affected by the coefficients of variation of soil parameters, spatial variations of soil parameters, number of test samples and piezometric variations. The results also show that the assumption of isotropic variations to assess slope reliability isconservative. The results of the study are useful in providing guidelines and pointing to remedial measures in the form of sub-surface drainage to improve slope reliability in the area.

4.14 Badal, R., Sharma, V. M., Venkatachalam, K. (1995). "Landslide blockade on the river Satluj and its removal by underwater blasting". Journal of Rock Mechanics and Tunneling Tech. Vol 1 No 2, pp. 135-146. http:/www.isrmtt.comabstract_download.php?abs=8

Blockade of rivers by landslides have been causing a lot of suffering to the human beings from times immemorial. The damage is further aggravated if the blockade is in the vicinity of a River valley project. The Sanjay Vidyut Pariyojana (Bhabha Project) located in Kinnaur District, Himachal Pradesh is one such examples. It is a run of the river scheme located on the right bank of river Satluj utilizing the water of Bhabha Khad, a tributary of Satluj river. The landslide blockade near the project caused flooding of the power house and interrupted the power generation in the project. Various factors responsible for the landslide and blockade of river have been studied. A strategic program of surface and underwater blasting was adopted to remove the blockade and restart the power generation. The paper presents the above aspects in brief.

4.15 Balaji, P., Pavanaguru, R. and Reddy, D. V. (2010). "A note on the occurrence of landslides in Araku valley and its environs, Visakhapatnam District, Andhra Pradesh, India". International Journal of Earth Sciences and Engineering, Vol. 03, No. 01, February 2010, pp. 13-19. http://cafetinnova.org/wp-content/uploads/2013/04/02030103.pdf

The paper is aimed to identify damage assessment, magnitude of slides and causes of slides with an attempt to suggest some long term corrective and control measures in Araku valley and its environs of Visakhapatnam district of Andhra Pradesh. The slides occurred in a rugged hilly terrain which is a part of Eastern Ghats Mobile Belt. The slides are predominantly debris slides of varying dimensions and occurred in khondalitic country having slopes of the order of 30°. The causes of the slope failure include toe erosion, debris accumulation that resulted in blockade, overtopping and changes in the stream courses.

4.16 Balasubramani, K. and Kumaraswamy, K. (2013). "Application of geospatial technology and information value technique in landslide hazard zonation mapping: A case study of Giri Valley, Himachal Pradesh". Disaster Advances Vol. 6 (1) January 2013. http://www.researchgate.net/profile/Balasubramani_K/publication/234062937_Application_of_Geospatial_Technology_and_Information_Value_Technique_in_Landslide_Hazard_Zonation_Mapping_A_Case_Study_of_Giri_Valley_Himachal_Pradeshfile9c9605159a404b2661.pdf?ev=pub_ext_doc_dl& origin=publication_detail&inViewer=true

This paper evaluates application potential of geospatial technology and information value technique (quantitative) in landslide hazard zonation. To evaluate the application potential and result, a part of Giri valley of Himachal Pradesh, India has been chosen as the study area. The major parameters considered in the landslide zonation include lithology, lineament, slope, streams, vegetation, land use/land cover and road. The layers are generated from satellite images coupled with collateral data. ll these layers are processed through information value technique to find out different landslide hazard zones. Further, the final hazard zonation map is compared with the actual landslide map for validation.

4.17 Bali, R., Bhattacharya, A. R. and Singh, T. N. (2009). "Active tectonics in the Outer Himalaya: Dating a landslide event in the Kumaun sector". Earth Science India, Vol.2 (IV), October, 2009, pp. 276 – 288. http://www.earthscienceindia.info/pdfupload/tech_pdf-1295.pdf

The present study incorporates an additional example of a major landslide event, the Amiyan landslide, associated with the MBT that passes through the toe of this landslide. The Amiyan landslide is one of the biggest debris slides in the Central Himalayan region. Two prominent fault scarps running almost transverse to the MBT have developed during the last 15 years. The slide has been increasing in size at regular intervals from an earlier 0.02 sq km in 1968 to 0.05 sq km till 1992. The results of this work have significant bearing on the seismotectonic, environmental, ground stability and the related aspects in the Himalayan domain.

4.18 Bartarya, S. K. and Valdiya, K. S. (1989). "Landslides and erosion in the catchment of the Gaula River, Kumaun Lesser Himalaya, India". Mountain Research and Development Vol. 9, No. 4 (Nov., 1989), pp. 405-419. http://www.jstor.org/stable/3673588

The paper present landslide and erosion problem in the catchment of the Gaula river, Kumaun lesser Himalaya. More than 550 active landslides in the catchment of the Gaula River, each more than 25 m3, were investigated. The slope failures are related to angle of hillslope, structural conditions of the bedrock, extent and type of vegetation, and also to road construction. The structure, particularly faulting and shearing, greatly influences the stability of the hillslopes. The intensity of storms, the amount of rainfall, and the duration of the storm period affect the occurrence of landslides.

4.19 Bartarya, S. K. (1993). "Hydrochemistry and rock weathering in a sub-tropical Lesser Himalayan river basin in Kumaun, India". Journal of Hydrology Volume 146, 1 June 1993, Pages 149–174. http://www.sciencedirect.com/science/article/pii/002216949390274D

Major ion chemistry of the water of the Gaula catchment — a medium-sized Lesser Himalayan basin in Kumaun, was measured in 1983 and 1984. The results show the influence of rock weathering on the concentration of major constituents in the ground water and surface water. In comparison with the Indian peninsular rivers, the low concentrations of the major constituents in the water of this Lesser Himalayan catchment indicate rapid infiltration and quick outflow of the rainwater and thus a short residence time for water, during which interaction with the rocks could occur, because of the steep slopes.

4.20 Bartarya, S. K. and Sah, M. P. (1995). "Landslide induced river bed uplift in the Tal valley of Garhwal Himalaya, India". Geomorphology Volume 12, Issue 2, May 1995, Pages 109–121. http://www.sciencedirect.com/science/article/pii/0169555X94000856

A large scale landslide occurred in the Tal valley of Garhwal Himalaya in late January, 1990. Studies revealed that the slide occurred because of complex slope processes consisting of rotation and slump movement attributable to the accumulation of pore water pressure in extremely shattered and pulverized rocks during prolonged surface moistening. The process of movement was triggered by the gravitational force exerted upon the sheared material which dislocated a block at the upper part of the slide along a slip plane which terminated below the river bed. Counter resistance was provided by the rocks below the river bed to subdue the further movement of the slide. This indicates that uplift of the river bed and formation of terraces is also related to the nature of the slide and the volume of slumped material.

4.21 Bartarya, S. K., Virdi, N. S. & Sah, M.P. (1996). "Landslide hazards: Some case studies from the Satluj valley, Himachal Pradesh". Himalayan Geology, Vol.17, 1996, pp.193-20. http://www.himgeology.com/himgeol/volume17/abstract22.htm

The paper presents landslide hazards along the National Highway-22 in Upper

Satluj Valley of Himachal Pradesh. Though, a combination of several factors is responsible for these landslides, however, anthropogenic activity is the single most common cause. Road construction and provision of irrigation canals, without proper feasibility studies, on vulnerable slopes has greatly aggrevated their stability and has promoted landslides. The landslides are also related to water seepage, down cutting and toe erosion by rivers and streams, excavation of slopes for widening of existing roads and construction of new ones.

4.22 Bhandari, R.K. (1988). "A novel low cost drum diaphragm wall for landslide control in the Himalaya". Proceedings: Second International Conference on Case Histories In Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 2.60. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/34475/P%200333-%20A%20Novel%20Low%20Cost%20Drum%20Diaphragm%20Wall%20for%20Landslide%20Control%20in%20the%20Himalaya.pdf?sequence=1

A successful case study of construction of drum diaphragm retaining wall is discussed in the paper. The technique could safely be recommended to provide effective and economical substitute for stone masonry or concrete retaining walls elsewhere in the Himalaya. The material used in the construction of drum diaphragm retaining wall was available as in-situ material from the slope.

4.23 Bhasin, R., Grimstad, E., Larsen J. O. et al. (2002). "Landslide hazards and mitigation measures at Gangtok, Sikkim Himalaya". Engineering Geology Volume 64, Issue 4, Pages 351–368. http://www.sciencedirect.com/science/article/pii/S0013795201000965

Landslides and other mass movements are serious geo-environmental hazards in the Himalayas. This paper describes the investigations carried out on recent landslides in Gangtok, Sikkim, India, with emphasis on the triggering mechanisms that have contributed to the release and creep of natural slopes in the region. It is believed that the intense rainfall in the region not only contributes to rapid erosion and weathering of the rock mass, but also increases the groundwater level that leads to reduction in the stability of natural slopes. A landslide instrumentation programme that includes placement of settlement pillars and piezometers is underway to predict the behavior of landslides in the area.

4.24 Bhattacharya, D., Ghosh, J. K., Boccardo, P. et al. (2013). "Automated geo-spatial system for generalized assessment of socio-economic vulnerability due to landslide in a region". European Journal of Remote Sensing - 2013, 46: 379-399. http://dspace.upce.cz/bitstream/10195/54563/1/2013_EuJRS_46_379_399_Bhattacharya.pdf

It explains a system to assess automatically vulnerability due to landslide on socio-economy of a region by categorizing landslide hazard using spatial as well as temporal causative factors. The expert system has input, understanding, expert & output modules & uses digital spatial data of causative factors of landslide. Input accepts thematic images of contributing factors for landslides, Understanding module interprets to extract relevant information as required by expert module consisting of a Knowledge Base & Inference strategy categorizing region into different susceptibilities of landslide.

4.25 Bilham, R. and Bali, B. S. (2014). "A ninth century earthquake-induced landslide and ûood in the Kashmir Valley, and earthquake damage to Kashmir's medieval temples". Bulletin of Earthquake Engineering Volume 12, Issue 1, pp 79-109. http://link.springer.com/article/10.1007%2Fs10518-013-9504-x

An entry in the Tarikh-i-Hassan records that in 883 AD during the reign of King Avantivarman (855–883) an earthquake in Kashmir triggered a landslide that impounded the River Jhelum and flooded the Kashmir Valley. Kalhana's Rajatarangini provides abundant details about how the ninth century engineer Suyya both cleared the natural dam, drained the valley and instituted numerous irrigation works. We identify the landslide(s) responsible for this medieval flood and from twentieth century discharge statistics of the Jhelum calculate that it would have taken at least 2 years to flood the Kashmir Valley to near Anantnag.

4.26 Bobade, S. S., Kumthekar, M. B. and Deshpande, P. K. et al. "Study and analysis of causative factors of slumping for designing the preventive measures: A case study in South Konkan, India". International Conference on Emerging Technology Trends on Advanced Engineering Research, Proceedings published by International Journal of Computer Applications. http://research.ijcaonline.org/icett/number2/icett1019.pdf

The aim of this study is to interpret the observations for sorting out probable factors, which caused the slumping movement. It also includes few suggestions about preventive / remedial measures from geo- technical and geological points of view.

4.27 Champati ray, P. K., Dimri, S., Lakhera, R. C. et al. (2007). "Fuzzy-based method for landslide hazard assessment in active seismic zone of Himalaya". Landslides May 2007, Volume 4, Issue 2, pp 101-111. http://link.springer.com/article/10.1007/s10346-006-0068-6?no-access=true

An attempt is made to derive information on causative parameters and preparation of landslide-susceptible map using fuzzy data integration in one of the seismically active region of Garhwal Himalaya that was recently devastated by a huge landslide. Spatial data sets such as lithology, rock weathering, geomorphology, lineaments, drainage, land use, anthropogenic factor, soil type and depth, slope gradient, and slope aspect were integrated using fuzzy gamma operator. The final map was reclassified in to five classes such as highly to lowly susceptible classes based on cumulative cutoff. The result shows around 72% of known landslide areas including the large Uttarkashi landslide in the high and very high susceptibility classes comprising of only 37% of the total area.

4.28 Chandel, V. B. S., Brar, K. K. and Chauhan, Y. (2011). "RS & GIS based landslide hazard zonation of mountainous terrains a study from Middle Himalayan Kullu District, Himachal Pradesh, India". International Journal of Geomatics and Geosciences Volume 2, No 1, 2011. http://www.ipublishing.co.in/jggsvol1no12010/voltwo/EIJGGS3011.pdf

This work conducts a landslide hazard zonation in western Himalayan district of Kullu in Himachal Pradesh using remote sensing and GIS. The satellite imageries of LANDSAT ETM+, IRS P6, ASTER along with Survey of India (SOI) topographical sheets formed the basis for deriving baseline information on various parameters like slope, aspect, relative relief, drainage density, geology/lithology and land use/land cover. The weighted parametric approach was applied to determine degree of susceptibility to landslides. The landslide probability values thus obtained were classified into no risk, very low to moderate, high, and very high to severe landslide hazard risk zones. The results show that over 80 per cent area is liable to high severe landslide risk and within this about 32 per cent has very high to severe risk.

4.29 Chatterjee, K. and Choudhury, D. (2012). "Seismic stability analyses of soil slopes using analytical and numerical approaches". ISET Golden Jubilee Symposium Indian Society of Earthquake Technology Department of Earthquake Engineering Building IIT Roorkee Paper No. C005. http://iset.org.in/pdf/proceedings/Theme%20C/C005.pdf

The stability of a model soil slope, comprising of an embankment with two canal bunds at the top, at different stages of construction, i.e. only embankment, embankment with empty canal bunds and embankment with canal bunds filled with water, with different foundation soils in different seismic zones have been analyzed and results have been plotted in the form of variation of factor of safety with horizontal seismic acceleration coefficient (kh). The critical case has been further analyzed under dynamic conditions. Dynamic analyses have been carried out by plotting the response spectrum curve and selecting 2001 Bhuj earthquake motion as the typical ground motion.

4.30 Chaudhary, S., Gupta, V. and Sundriyal, Y. P. (2010). "Surface and sub-surface characterization of Byung landslide in Mandakini valley, Garhwal Himalaya". Himalayan Geology, Vol. 31 (2), 2010, pp. 125-132. https://www.academia.edu/attachments/26680382download_file?st=MTQwMDE1MDU4MSwxNjQuMTAwLjEwNS4xMzcsMTc2OTg1NQ%3D%3D&ct=MTQwMDE1MDYzMCwxNzY5ODU1

The study area is located in the Rudraprayag district of Uttarakhand. Byung landslide was triggered in the Mandakini valley subsequent of cloudburst and is active since then. The landslide zone measures about 80 m in length, 110 m in width and has maximum vertical displacement of 3.10m. The total surface area affected by the landslide is about 0.363 km2. The granulometric analyses indicate that the soil within the subsidence zone contains lesser proportion (~ 20.3%) of fines (silt + clay) than the soil in the environs (~32.2% - 37.8%). The lesser proportion of fines in the subsidence zone may be attributed to their washing away by continuous percolation of water into the hill slope by four drainage channels viz, Khumera, Dhom, Dhom-1 and Syul located within the landslide zone.

4.31 Chauhan, S., Sharma, M., Arora, M. K. et al. (2010). "Landslide susceptibility zonation through ratings derived from artificial neural network". International Journal of Applied Earth Observation and Geoinformation. http://swcdis.nchu.edu.tw/AllDataPos/AdvancePos/7098042026/sdarticle.pdf

Artificial Neural Network (ANN) has been implemented to derive ratings of categories of causative factors, which are then integrated to produce a landslide susceptibility zonation map in an objective manner. The results have been evaluated with an ANN based black box approach for Landslide Susceptibility Zonation (LSZ) proposed earlier by the authors. Seven causative factors, namely, slope, slope aspect, relative relief, lithology, structural features (e.g., thrusts and faults), landuse landcover, and drainage density, were placed in 42 categories for which ratings were determined. The results indicate that LSZ map based on ratings derived from ANN performs exceedingly better than that produced from the earlier ANN based approach. The landslide density analysis clearly showed that susceptibility zones were in close agreement with actual landslide areas in the field.

4.32 Chaulya, S. K., Singh, R. S., Chakraborty, M. K. et al. (2000). "Quantification of stability improvement of a dump through biological reclamation". Geotechnical & Geological Engineering Volume 18, Issue 3, pp 193-207. http://link.springer.com/article/10.1023%2FA%3A1026576711324

An integrated study on biological stabilization of a dump slope has indicated that biological reclamation with grass and tree species should be considered for long term stability of this coal mine dump in India. The grasses have greater soil binding capacity and help to control soil erosion and improve dump stability. Native grasses such as Bamboo (Dendrocalmus strictus) and Kashi (Saccharum spontaneum) are the important constituents of grass species which can stabilise the dump slopes.

4.33 Chopra, B. R. (1977). "Landslides and other mass movements along raods in Sikkim and North Bengal". Bulletin of the International Association of Engineering Geology December 1977, Volume 16, Issue 1, pp 162-166. http://link.springer.com/article/10.1007%2FBF02591471

This paper deals with instability and mass movements of hill slopes encountered along about 600 km of mountain roads constructed in part of North Bengal and Sikkim; the causes of slope failures and the remedial measures adopted, extent of their success and future approach to the problem.

4.34 Chingkhei, R. K., Shiroyleima, A., Singh, L. R., et al. (2013). "Landslide hazard zonation in NH-1A in Kashmir Himalaya, India". International Journal of Geosciences. http://www.scirp.org/journal/PaperDownload.aspx?paperID=41579

The present study has been made to derive and identify the important terrain factors contributing to landslide occurrences in the region and corresponding thematic data layers are generated in GIS domain. These terrain data are collected from the topographic maps, satellite imageries, field visits and available published maps. A GIS database is prepared by digitizing these maps along with tabular data and their corresponding weightage is assigned using Analytic Hierarchy Process (AHP) based criteria ranking method for determining the standardized scores of criteria ex- pressing their factor of importance for a given decision problem in terms of thematic parameters, categories and their normalized weights. Statistically integrating weightages from these thematic maps, a specific landslide hazard map was developed on a GIS platform. The resulting landslide hazard zonation map delineates the area into different zones of six classes of landslide hazard zones i.e., severe, very high, high, moderate, low and very low.

4.35 Choubey, V. M., Bartarya, S. K. and Ramola, R. C. (2005). "Radon variations in an active landslide zone along the Pindar River, in Chamoli District, Garhwal Lesser Himalaya, India". Environmental Geology April 2005, Volume 47, Issue 6, pp 745-750. http://link.springer.com/article/10.1007/s00254-004-1196-8?no-access=true

Radon measurements were made in the soil and spring/seepage water in and around an active landslide located along the Pindar river in the Chamoli District of Uttaranchal in Garhwal Lesser Himalaya, to understand the application of radon in geological disasters.

4.36 Choudhury, D. (2006). "Methods for evaluation and mitigation of earthquake-induced landslides". First India Disaster Management Congress, November 29-30, 2006.

The various aspects of static and seismic slope stability analyses have been discussed including the different classical and recent methods devised for these analyses. Among the techniques to evaluate the seismic slope stability, Newmark's sliding block method has been the source of plenty of research work in this field which has led to several improved slope stability analyses procedures under seismic conditions.

4.37 Choudhury, D., Basu, S. and Bray, J. D. (2007). "Behaviour of slopes under static and seismic conditions by limit equilibrium method". Embankments, Dams, and Slopes: pp. 1-10 American Society of Civil Engineers.

The sliding soil mass of a generalized earth slope is divided into a number of vertical slices considering the interfacial forces between two consecutive slices, and using the limit equilibrium analysis for these slices under the influence of static forces along with the pseudo-static seismic forces to obtain the dynamic factor of safety of the slopes. The effects of variation of different parameters like slope angle, soil friction angle and seismic acceleration coefficients both in the horizontal and vertical directions on the dynamic factor of safety (DFS) are presented in the paper.

4.38 Choudhury, D. and Modi, D. (2008). "Displacement-based stability analysis of slopes under seismic conditions". Geotechnical Earthquake Engineering and Soil Dynamics IV: pp. 1-10. http://ascelibrary.org/doi/abs/10.1061/40975(318)189

The most simplified planer failure surface is assumed for the seismic stability analysis of soil slopes and the behaviors of this simple failure surface over the existing complex surfaces are studied. A model reinforced soil slope is divided into a number of finite horizontal slices for the seismic analysis using a limit equilibrium method (LEM) with pseudo-static approach. The variations of factor of safety with respect to horizontal seismic acceleration coefficient under different soil and seismic conditions are shown. It is concluded that the stability of slope decreases with increase in both the horizontal and vertical seismic acceleration coefficients. Also, the displacement of slope for different soil and seismic conditions and time of cycle of earthquake loading are evaluated. As expected, the displacement of the slope is found to increase significantly with increase in the seismic accelerations.

4.39 Das, I., Stein, A., Kerle, N. et al. (2011). "Probabilistic landslide hazard assessment using homogeneous susceptible units (HSU) along a National Highway corridor in the Northern Himalayas, India". Springer Landslides Volume 8, Issue 3, pp 293-308. http://download.springer.com/static/pdf/652/art%253A10.1007%252Fs10346-011-0257-9.pdf?auth66=1401873478_712cb70efba611ab04df7b899a3dbd58&ext=.pdf

The method presented in this study evaluates the landslide hazard on the basis of homogenous susceptible units (HSU). HSU are derived from a landslide susceptibility map that is a combination of landslide occurrences and geo-environmental factors, using an automated segmentation procedure. The study demonstrates that HSU can replace the commonly used terrain mapping units for combining three probabilities for landslide hazard assessment. A quantitative estimate of landslide hazard is obtained as a joint probability of landslide size, of landslide temporal occurrence for each HSU for different time periods and for different sizes.

4.40 Das, I., Oberai, K. and Roy, P. S. (2012). "Database organization in a web-enabled free and open-source software (Foss) environment for spatio-temporal landslide modeling". Remote Sensing and Spatial Information Sciences, Volume I-4, 2012 XXII ISPRS Congress. http://www.isprs-ann-photogramm-remote-sens-spatial-inf-sci.net/I-4/293/2012/isprsannals-I-4-293-2012.pdf

The aim of this research is to present a comprehensive database for generating landslide hazard scenario with the help of available historic records of landslides and geo-environmental factors and make them available over the Web using geospatial Free & Open Source Software (FOSS). FOSS reduces the cost of the project drastically as proprietary software's are very costly. Landslide data generated for the period 1982 to 2009 were compiled along the national highway road corridor in Indian Himalayas.

4.41 Das, I., Stein, A., Kerle, N. et al. (2012). "Landslide susceptibility mapping along road corridors in the Indian Himalayas using Bayesian logistic regression models". Elsevier Geomorphology Volume 179, 15 December 2012, Pages 116–125. http://dx.doi.org/10.1016/j.geomorph.2012.08.004

This study presents Bayesian logistic regression (BLR) for landslide susceptibility assessment along road corridors. The methodology is tested in a landslide-prone area in the Bhagirathi river valley in the Indian Himalayas. Parameter estimates from BLR are compared with those obtained from ordinary logistic regression. By means of iterative Markov Chain Monte Carlo simulation, BLR provides a rich set of results on parameter estimation. We assessed model performance by the receiver operator characteristics curve analysis, and validated the model using 50% of the landslide cells kept apart for testing and validation. The study concludes that BLR performs better in posterior parameter estimation in general and the uncertainty estimation in particular.

4.42 Deshpande, P. K., Patil, J.R., Nainwal, D. C. et al. (2009). "Landslide hazard zonation mapping in Gopeshwar, Pipalkoti and Nandprayag areas of Uttarakhand". Indian Geotechnical Conference, 16-19 December, Guntur, Andhra Pradesh. http://gndec.ac.in/~igs/ldh/conf/2009/articles/T15_04.pdf

Remote Sensing data and the GIS layers mainly DEM, slope maps, and flow accumulation maps were used to create the Landslide Hazard Zonation Map in small areas around Gopeshwar, Pipalkoti and Nandprayag in Uttarakhand state. Slope, lithology, water and road excavation are the main causes of landslide in this region. The ILWIS operations carried out for landslide hazard zonation mapping especially the comparative study of slope maps, flow direction and flow accumulation maps, high resolution RS data etc., have been found to be accurate after generating the predictive point layer. It was concluded that the excavation for road itself is the main cause to initiate a landslide in soft, structurally disturbed and high relief areas of Uttarakhand.

4.43 Dutta, P. J. and Sarma, S. (2013). "Landslide susceptibility zoning of the Kala-Pahar Hill, Guwahati, Assam State, (India), using a GIS-based heuristic technique". International Journal of Remote Sensing & Geoscience. http://ijrsg.com/Files/5a4141da-475d-4705-8147-3c2282dd3ca5_IJRSG_05_08.pdf

The current work encompasses spatial analysis of landslide susceptibility of the Kalapahar hill using remote sensing data along with field data for interpreting various terrain parame-ters such as lithology, slope, relief, land use/land cover and distance-to-road. These parameters were classified, ranked and weighted according to their assumed or expected impor-tance in causing mass movements. A "heuristic technique" or "subjective rating analysis" has been applied for the dis-tribution of ranks and weights. The advantage of this tech-nique is that a landslide inventory is not needed because the weights are assigned based on the field knowledge. Moreo-ver, the use of GIS for the weight assignments and overlays makes this technique fast and easy to use.

4.44 Gaikwad, S., Chandak, P. G., Kumthekar, M. B., et al. (2009). "Pictorial informative support to landslide hazard management maps of Uttarakhand, India". Journal of Mechanical & Civil Engineering (IOSR-JMCE) ISSN: 2278-1684PP: 51-59. http://www.iosrjournals.org/iosr-jmce/papers/sicete(civil)-volume3/35.pdf

Garhwal Himalaya is a disaster prone part of the state of Uttarakhand especially known for huge landslides and torrential floods. Many efforts were made so far for landslide hazard zonation mapping along with mitigation plans. NRSC has published landslide zonation maps along with landslide management maps for the state of Uttarakhand and Himachal. But supportive geotechnical data for the same has not been made available. Therefore, in present paper the mitigative recommendations put by National Remote sensing centre (NRSC), Hyderabad is being explained with pictorial examples. This work may be useful for a construction manager handling the vulnerable sites in Garhwal Himalaya.

4.45 Ganapathy, G. P., Mahendran, K. and Sekar, S. K (2010). "Need and urgency of landslide risk planning for Nilgiri District, Tamil Nadu State, India". International Journal of Geomatics and Geosciences Volume 1, No 1, 2010. http://ipublishing.co.in/jggsvol1no12010/EIJGGS1003.pdf

In the recent times casualties and damage due to landslides have increased in the Nilgiri Hills. More than 110 landslides were reported within five days from 10 to 15 November, 2009, and taken away about 80 human lives, also the vast damage reported on houses, roads and railway lines. This taught the lesson for the need and urgency of landslide planning in NIgiris among the scientific community and planners. One of the most difficult problems concerning landslide hazards in place like Nilgiris is dealing with existing urban areas where buildings are constructed on or close to a landslide. The ideal approach in this situation is to avoid further development in high-risk landslide prone areas, limit existing use rights to rebuild, and limit the use of buildings. The most realistic approach is to avoid further development and use of buildings (building type) is consistent with the level of risk posed and the district plan maps clearly show landslide hazard zones.

4.46 Ganapathy, G. P. and Hada, C. L. (2012). "Landslide hazard mitigation in the Nilgiris District, India – environmental and societal issues". International Journal of Environmental Science and Development, Vol. 3, No. 5, October 2012. http://www.ijesd.org/papers/274-CD0088.pdf

In this paper, feasibility of cost effective technology for slope stabilization, environmental and societal issues need to be addressed for the Nilgiris district were studied and recommendation were given to over come these issues. The present study can be useful information to the environmental scientists, planners and policy makers in landslide hazard mitigation practices in the Nilgiri district.

4.47 Ghosh, J. K. and Bhattacharya, D. (2008). "Landslide Hazard Automated Zonation (LHAZ) System". 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG). http://www.civil.iitb.ac.in/~dns/IACMAG08/pdfs/G07.pdf

An automated system has been developed to determine the intensity and extent of landslide hazard in a given region. The system is based on the automated understanding of thematic maps of landslide contributing factors such as soil, lithology, topography, geology etc. The system makes use of the knowledge base available in IS code 14496: 1998. Finally, using an inference scheme, it categorizes the region as different zones of landslide hazard and provides an output map depicting low, medium and high hazard zones.

4.48 Ghosh, A., Sarkar, S., Kanungo, D. P. et al. (2009). "Slope instability and risk assessment of an unstable slope at Agrakhal, Uttarakhand". Indian Geotechnical Conference, 16-19 December, Guntur, Andhra Pradesh. http://gndec.ac.in/~igs/ldh/conf/2009/articles/T14_02.pdf

The details of site investigation and slope stability analysis and risk assessment have been discussed in the paper. For the slope instability and risk assessment, geological and geotechnical investigation were performed. Geological investigation shows that the area is houses by highly weathered phyllite. For the geotechnical investigation soil samples were collected and tested. It was found that the slope in dry condition is stable but in reality during rainy season the slope gets saturated and as expected the factor of safety gets reduced. But even then this situation does not lead to a catastrophic failure. However when subjected to seismicity the dry slope undergoes displacement of the order of 3–4 cm. When seismicity and saturation of the slope gets coupled catastrophic failure takes place. Slope being situated in the hilly state of Uttarakhand such a combination of forces can not be ruled out.

4.49 Ghosh, C. and Parkash, S. (2010). "Cloudburst induced debris flows on vulnerable establishment in Leh". Indian Landslides Vol. 3 NO. 2.

Ladakh is a highland desert, strongly guarded by Peer Panjal, the Himalaya and the Stok and Zanskar ranges, which do not allow any moist air to reach the Indus valley. Normally, cloudburst like phenomenon occurs over tropical river basins in the hills, where vegetation and river channels provide much needed water content and increase relative humidity. Ladak is an exception for such climatic conditions because of unavailability of widespread water bodies, thick vegetation and clod climate. The reason lies in the type of landscape and the soil in the mountains of ladakh. This paper discuss the cloudburst induced debris flows in Leh.

4.50 Ghosh, J. K. and Bhattacharya, D. (2010). "Knowledge-based landslide susceptibility zonation system". Journal of Computing in Civil Engineering, Vol. 24, No. 4, July 1, 2010

In this paper, a knowledge-based landslide susceptibility zonation (LSZ) system has been proposed. The system consists of input, understanding, expert, and output modules. The input module accepts thematic images of contributing factors for landslides. The understanding module interprets input images to extract relevant information as required by the expert module. The expert module consists of knowledge base and inference strategy to categorize a region into different landslide intensities. Finally the output module provides a LSZ map. It is a pixel-based system and provides output having the scale same as that of the input maps.

4.51 Gomathi, R., Mohan, V R. and Backiaraj, S. (2013). "Landslide susceptibility zonation in Kavithole and Kukalthurai halla watershed in northern part of Nilgiris district". International Journal of Basic and Life Sciences Volume No. 1 (2013), Issue No. 6 (December). http://www.ijmds.com/admin2/adminsettings/upload/6241Landslide.pdf

The present study is a need based research to investigate the landslides and examine their cause and distribution and to classify the region into five zones with different landslide susceptibilities. Two probabilistic method viz., frequency ratio and Weights of Evidence method were used and these maps were validated adopting suitable methods. Among the various causative factors used, aspect, drainage density, distance to drainage, geomorphology, land use and soil have greater influence on landslide susceptibility. Slope though is the main cause of landslides decreases the validation as the frequency ratios do not show progressive variation and areas with very low and high and very high slopes have a lesser probability of landslides with values less than 1. Based on the influencing causative factors it is clear that the type of soil, the geomorphic setup and drainage density which alters the percolation of rainwater as well as the undermining by streams are the main causes of the slope instability.

4.52 Gupta, R. P. and Joshi, B. C. (1990). "Landslide hazard zoning using the GIS approach—A case study from the Ramganga catchment, Himalayas". Engineering Geology Volume 28, Issues 1–2, Pages 119–131. http://www.sciencedirect.com/science/article/pii/0013795290900372

This paper deals with the development of a technique for risk assessment of landslide hazards using the Geographic Information System (GIS) approach. The method has been applied to the Ramganga catchment, lying in the Lower Himalayas, and the investigations are based on multi-data sets. The landslide activity is related to a number of parameters, viz., lithology, land-use, and distance from major tectonic-shear zone and azimuth direction. Based on the data for 522 landslides in four selected sub-basins, an index value, called "landslide nominal risk factor" (LNRF) is defined and developed for each of the important factors. Different weights have been assigned to the terrain depending upon the LNRF and integrated in an ordinal scale, to help locate areas of high, moderate and low landslide risk.

4.53 Gupta, P. and Anbalagan, R. (1995). "Landslide hazard zonation mapping of Tehri-Pratapnagar area of Garhwal Himalaya". Journal of Rock Mechanics and Tunneling Tech. Vol 1 No 1, pp. 41-58. http://www.isrmtt.com/abstract_download.php?abs=5

The mountainous terrains such as Himalaya are characterized by steep slopes, high relative relief, weathered, fractured and folded rocks in addition to unfavorable hydrogeological conditions. The planning, design and execution of development schemes in these terrains should take into account the existing instabilities of the area. Moreover the unstable zones facing environmental degradation have to be identified and studied in detail for evolving suitable mitigation measures. For that purpose a quantitative approach based on the numerical rating called landslide hazard evaluation factor (LHEF) rating scheme has been used for preparing the LHZ map of Tehri-Pratapnagar area.

4.54 Gupta, P., Jain, N., Anbalagan, R. (2000). "Landslide hazard evaluation and geostatistical studies in Garhwal Himalaya, India". Journal of Rock Mechanics and Tunneling Tech. Vol 6 No 1, pp. 41-59. http://www.isrmtt.com/abstract_download.php?abs=27

Landslide Hazard Zonation (LHZ) mapping provides basic information about the status of stability of hill slopes in six different categories. In order to prepare LHZ maps, six basic inherent causative factors have been considered. In addition, relative order of influence of six causative factors has also been established for each hazard zone as well as for whole area of study by using Friedman Test and later verified by Page's Test. The study brings out the percent distribution of sub-categories of each causative factor in different hazard zone, relative behavior of causative factors and their order in which they influence the stability of the area. The result obtained from the analysis will help to identify the important causative factor(s) responsible for instability and will also help to workout suitable remedial measures before implementation of any development scheme in the region.

4.55 Gupta, V., Virdi, N. S. & Parkash, S. (2001). Morphometric assessment of active landslides in the Higher Himalayan Crystallines, Satluj valley, Himachal Pradesh (India). Himalayan Geology, 22 (2), pp 99-107. http://www.himgeology.com/himgeol/vol_22(2)/abstract9.htm

Morphometric assessment of five major and active landslides (mainly translational type) in the Satluj river valley of Indian Himalaya has been done. Various morphometric parameters like classification index, dilation index, tenuity index, flowage index, displacement index etc. have been determined as per the technique suggested by Crozier (1973), for morphometric analysis of landslips using field data of these landslides and topographic information. It has been observed that the technique holds good in interpreting slope stability and the potential process group but there is a need to set the limits of the morphometric indices for various processes of slope movement and the degree of instability that are appropriately defined to suit for the Himalayan terrain. The variations in the limits are also expected due to changes in the nature of slope mass, topography, geology and climate of the terrain.

4.56 Gupta, R. P. and Saxena, M. (2004). "GIS-Based Rockfall Modelling". Himalayan Geology, Vol. 25 (1), pp. 51-57. http://www.himgeology.com/himgeol/vol_25(1)/abstract4.htm

In this study, an area in the Asiganga valley a tributary of the Bhagirathi river, has been taken for rockfall modelling and hazard zonation. Field investigations show numerous sites of rockfalls in the valley. The topographic map (Survey of India, 1:50,000) has been used for generating a digital elevation model (DEM). The rockfall modelling has been carried out starting with the assumption that the rockfall may initiate from slopes steeper than 600; therefore all slopes steeper than 600 were extracted from the DEM to give the rockfall source map. Rockfall velocities and run-out distances have been calculated from three input maps: viz., height difference, rockfall source and coefficient of friction maps. It is found that there is a good correspondence between the source map and the run-out distance map. Scope of further refinement of the method by incorporating geological parameters like structure, orientation of discontinuities, etc. at each location is discussed. It is hoped that the study would stimulate research in this direction for disaster mitigation.

4.57 Gupta, V. (2005). "Application of lichenometry to slided materials in the Higher Himalayan landslide zone". Current Science, VOL. 89, NO. 6, 25 September 2005. http://www.iisc.ernet.in/currsci/sep252005/1032.pdf

The lichen-based study involving the measurement of percent cover of lichens on slided materials in the Pawari landslide zone located in the Higher Himalaya is described. This has been correlated with the indicators showing movement of deposit and activity of the slide. This study can be used as an indirect method to assess the differential movement of slope within the slide mass.

4.58 Gupta, V. (2005). "The relationship between tectonic stresses, joint patterns and landslides in the higher Indian Himalaya". Journal of Nepal Geological Society, 2005, Vol. 31, pp. 51–58. http://www.nepjol.info/index.php/JNGS/article/download/260/258

Tectonic stresses play a major role in the evolution of the present day landscape in the higher Himalayas. One of the principal geological manifestations of these stresses is the spatial orientation of joints and fractures. In this study these planar features and the stresses were correlated with landslides. It is observed that the direction of failure planes of landslides is concentrated either towards minimum stress axis s_3 or along the intermediate stress axis s_2 but never along the maximum stress axis s_1.

4.59 Gupta, V. and Sah, M. P. (2007). "Spatial variability of mass movements in the Satluj Valley, Himachal Pradesh during 1990 - 2006". Journal of Mountain Science Volume 5, Issue 1, pp 38-51. http://link.springer.com/article/10.1007%2Fs11629-008-0038-7

This paper documents the natural as well as anthropogenic changes in Satluj Valley, which have resulted in increased spatial coverage of landslide during 1990-2006. During the last two decades, the area witnessed substantial increase in athropogenic pressure, mainly due to the exploitation of hydropower potential, changing landuse pattern and population growth. In addition, a shift of the climatic patterns in the form of larger area falling under the influence of rains was observed.

4.60 Gupta, V. and Ahmed I. (2007). "Geotechnical Characteristics of Surabhi Resort Landslide in Mussoorie, Garhwal Himalaya, India". Himalayan Geology, Vol. 28 (2), pp.21-32. http://www.himgeology.com/himgeol/vol_28(2)/abstract3.htm

The Surabhi Resort landslide located on the Mussoorie – Kempty link road was triggered during the rains of August 1998 and is active since then. Both natural and human induced factors are responsible for the occurrence of the landslide; however, the main triggering factor was the incessant rainfall during the months of July – August 1998 along with the seepage from the upslope region. Surabhi Resort landslide is a typical debris slide and is causing serious threat to the lives and property in the region. Shear-strength characteristics of the soil in the landslide zone indicate their resistances against sliding, however, the geotechnical characteristics of the rock mass around the landslide zone is of poor class in terms of its slope stability. The present study lays the foundations for further work to link landslide activity to rainfall intensity so that the stochastic relationship between the two may be established.

4.61 Gupta, V. and Sah, M. P. (2008). "Impact of the Trans-Himalayan Landslide Lake Outburst Flood (LLOF) in the Satluj catchment, Himachal Pradesh, India". Natural Hazards Volume 45, Issue 3, pp 379-390. http://link.springer.com/article/10.1007%2Fs11069-007-9174-6

Landslide Lake Outburst Floods (LLOFs) are common in the Himalayan river basins. These are caused by breaching of lakes created by landslides. The active and palaeo-landslide mapping along the Satluj and Spiti Rivers indicate that these rivers were blocked and breached at many places during the Quaternary period. In the present article, we document LLOFs during 2000 and 2005 caused by the breaching of landslide lakes created in the Trans-Himalayan region along the Satluj River and Paree Chu (stream), respectively, both in the Tibetan region of China and its impact on the channel and infrastructure in the Kinnaur district of Himachal Pradesh, India. It has been observed that the loss of life and property due to these LLOFs is directly related to the disposition of the Quaternary materials and the different morphological zones observed in the area.

4.62 Gupta, R. P., Kanungo, D. P., Arora, M. K. et al. (2008). "Approaches for comparative evaluation of raster GIS-based landslide susceptibility zonation maps". International Journal of Applied Earth Observation and Geoinformation Volume 10, Issue 3, September 2008, Pages 330–341. http://www.sciencedirect.com/science/article/pii/S0303243408000123

Landslide susceptibility zonation (LSZ) raster maps of the same area derived from various procedures are spatially compared. The evaluation has been done through three approaches, viz., landslide density analysis, error matrix analysis and difference image analysis. Based on the landslide density values, it is inferred that the combined neural and fuzzy procedure for LSZ mapping appears to be significantly better than other procedures. The error matrix analysis highlights the significant difference between the conventional subjective weight assignment procedure and the objective combined neural and fuzzy procedure. Finally, the significant influence of a causative factor has been revealed by difference image analysis. The use of these spatial evaluation approaches in tandem may be highly beneficial to quantitatively assess the landslide susceptibility zonation or any other such maps.

4.63 Gupta, M., Ghose, M. K. and Sharma, L. P. (2009). "Application of remote sensing & GIS for landslides hazard and assessment of their probabilistic occurrence - A case study of NH31A between Rangpo and Singtam". Journal of Geomatics Vol 3 No.1 April 2009.http://www.researchgate.net/publication/232281764_

Application_of_Remote_sensing__GIS_for_landslides_hazard_and_assessment_of_their_probabilistic_occurrence__A_case_study_of_NH31A_between_Rangpo_and_Singtam/file/9fcfd50811252bea6e.pdf.

In this paper an attempt has been made to assess the landslide hazard using a deterministic method. The study area has been chosen from Rangpo and Singtam along NH 31 A. The identified conditioning factors include soil, geology, forest, and drainage, and triggering factors such as slope and aspects are taken as input to fit into an aggregation model for assessment of landslide hazard. These probabilistic maps are compared with landslide maps generated from Google Earth from recent data (2007) for the accuracy of prediction. The generated hazard maps agree with the observed landslide occurrences. Thus the proposed methodology can be used in landslide hazard zonation prediction.

4.64 Gurugnanam, B. (2013). "GIS data base generation on landslides by tracing the historical landslide locations in Nilgiri District, South India". International Journal of Remote Sensing & Geoscience (IJRSG) Volume 2, Issue 6, Nov. 2013. http://ijrsg.com/Files/fe6e6f08-9b91-4912-ab57-65094cf653dd_IJRSG_10_3.pdf

Generating GIS database for landslide locations is attempted in the present paper. Literature surveys were conducted to take the information on landslides. The existing landslide locations were collected from the Geological Survey of India Miscellaneous publications and other literature survey. This information was collected in the form of latitude and longitude data source. This data were given as input in GIS. To understand the event in year wise information is spatially given to understand the landslide distribution in the study area. Major landslides were recorded in the year 2009 with a human death loss of around 50 numbers in the study area. So far around 900 landslides were reported. But the number of slides present is not identified so far. Many scar landslides are also reported in this paper.

4.65 Haigh, M. J., Rawat, J. S., Bartarya, S. K. et al. (1993). "Environmental influences on landslide activity: Almora Bypass, Kumaun Lesser Himalaya". Natural Hazards Volume 8, Issue 2, pp 153-170. http://link.springer.com/article/10.1007%2FBF00605439

Landslide morphometric variables correlate with other landslide variables and with few external factors. The system exhibits independence (autopoiesis) from its environment. Additionally, landslides dominated by rock-mechanical processes tend to produce lower angle outfalls from higher, north-facing, roadcuts than those dominated by soil-mechanical processes which are associated with greater depths of below-soil regolith. However, the outfall volumes produced by the landslides of different type are similar. These findings are generated from statistical (correlation/T-test/stepwise discriminant) analyses of data produced by a field survey of average environmental conditions, and the morphometry and environmental contexts of 88 landslides, on 7.6 km of the Almora Bypass.

4.66 Haigh, M. J., Rawat, J. S., Rawat, M. S., et al (1995). "Interactions between forest and landslide activity along new highways in the Kumaun Himalaya". Forest Ecology and Management Volume 78, Issues 1–3, October 1995, Pages 173–189. http://dx.doi.org/10.1016/0378-1127(95)03584-5

Forest cover and landslide activity were surveyed along two hill roads crossing steep hillsides in the Kumaun Himalaya. Statistical correlation of forest cover and landslide attributes recorded for each 200 m reach of roadbed demonstrate that, in the suburban case study, forest cover correlates positively with landslide activity—because forest survives mainly on sites which are too steep and unstable for development. However, in reserved forest, negative correlations link forest cover and landslide activity. Correlation of the ratio between forest cover down slope and upslope of the road with environmental and landslide activity attributes produces little that is significant from the combined or Almora data sets.

4.67 Islam, M. A., Chattoraj, S. L and Champati Ray, P. K. (2014). "Ukhimath Landslide 2012 at Uttarakhand, India: Causes and Consequences". International Journal of Geomatics and Geosciences Volume 4, No 3, 2014. http://www.ipublishing.co.in/jggsarticles/volfour/EIJGGS4048.pdf

The study is focused on Ukhimath landslide induced on 14th September of 2012. The primary aim is to find out possible causes and it's after math, mainly the assessment of damaged areas with the help of detail field observation and subsequent remote sensing techniques by comparing very high resolution

Geoeye-1 and the Cartosat-1 imagery of prior to and after the event with special emphasis on building, road and agricultural land.

4.68 Jade, S. and Sarkar, S. (1993). "Statistical models for slope instability classification". Engineering Geology Volume 36, Issues 1–2, Pages 91–98. http://www.sciencedirect.com/science/article/pii/0013795293900214

Statistical models for reliable hazard assessment of landslides in a given area are presented. The models are based on information theory and regression analysis. A FORTRAN 77 program for computer-aided assessment of the landslide hazard has been developed. A case study of landslide hazard assessment of a 66 km2 area in parts of the Alkananda valley, the Gharwal Himalaya is presented. The factors considered in the analysis are angle and height of the slope, rock type and geological structures such as faults and thrusts. The results obtained are illustrated in the form of landslide hazard maps.

4.69 Jaiswal, P., Westen, C. J. V. and Jetten, V. (2011) "Quantitative estimation of landslide risk from rapid debris slides on natural slopes in the Nilgiri Hills, India". Natural Hazards and Earth System Sciences Sci., 11, 1723–1743, 2011. http://www.nat-hazards-earth-syst-sci.net/11/1723/2011/nhess-11-1723-2011.pdf

A quantitative procedure for estimating landslide risk to life and property is presented and applied in a mountainous area in the Nilgiri hills of southern India. Risk is estimated for elements at risk located in both initiation zones and run-out paths of potential landslides. Loss of life is expressed as individual risk and as societal risk using F-N curves, whereas the direct loss of properties is expressed in monetary terms.

4.70 Kanungo, D. P., Sarkar, S. and Mehrotra, G. S. (1995). "Statistical analysis and tectonic interpretation of the remotely sensed lineament fabric data associated with the North Almora Thrust, Garhwal Himalaya, India". Journal of the Indian Society of Remote Sensing December 1995, Volume 23, Issue 4, pp 201-210. http://link.springer.com/article/10.1007/BF03024501

A geostatistical analysis of the remotely-sensed lineament fabric data associated with the North Almora Thrust of Garhwal Himalaya has been carried out. The analysis of data provided 18 major orientations of the lineament density girdles. Further statistical treatment of these derived lineaments using the method of analysts of directional data indicates that the lineaments can be classified into genetic groups. The result indicates that the North Almora Thrust and Kaliasaur Fault are not genetically related and occurred in separate phases of tectonic activities. The results also show that the Alaknanda River is flowing through a tectonically-controlled valley. The study suggests the suitability of statistical methods in lineament-fabric-data analysis for tectonic interpretations.

4.71 Kanungo, D. P., Arora, M. K., Sarkar, S. et al. (2006). "A comparative study of conventional, ANN black box, fuzzy and combined neural and fuzzy weighting procedures for landslide susceptibility zonation in Darjeeling Himalayas". Engineering Geology Volume 85, Issues 3–4, Pages 347–366. http://www.sciencedirect.com/science/article/pii/S001379520600113X

In this paper, apart from conventional weighting system, objective weight assignment procedures based on techniques such as artificial neural network (ANN), fuzzy set theory and combined neural and fuzzy set theory have been assessed for preparation of LSZ maps in a part of the Darjeeling Himalayas.

4.72 Kanungo, D. P. and Sarkar, S. (2003). "Landslides and Terrain Parameters in Darjeeling Himalaya". Himalayan Geology, Vol. 24 (2), pp. 55-62. http://www.himgeology.com/himgeol/vol_24(2)/abstract4.htm

Landslides are the result of interaction among several terrain parameters. Therefore, it is always necessary to study different terrain parameters, which contribute to slope instability in a hilly terrain in order to understand the landslide phenomena. The present paper deals with preparation of few important terrain parameter maps of Darjeeling Himalaya and the spatial distribution of their different classes. Few landslides identified on satellite imagery with limited field checks, are studied to determine their frequency distribution with the terrain parameters. The paper describes the utility of remote sensing and GIS for generation of these thematic layers and an integrated approach to evaluate layer-wise influence on landslide occurrence.

4.73 Kanungo, D. P., Arora, M. K., Gupta, R. P., et al. (2008), "Landslide risk assessment using concepts of danger pixels and fuzzy set theory in Darjeeling Himalayas". Landslides November 2008, Volume 5, Issue 4, pp 407-416. http://link.springer.com/article/10.1007%2Fs10346-008-0134-3

The concept of danger pixels and fuzzy set theory are used for landslide risk assessment of Darjeeling Himalayas, India. The LRA map generated through the concept of danger pixels depicts that 1,015 pixels of habitation and 921 pixels of road section are under risk due to landslides whereas map derived from fuzzy set theory based approach shows that a part of habitat area (2,496 pixels) is under very high risk due to landslides. Also, another part of habitat area and a portion of road network (7,204 pixels) are under high risk due to landslides. Thus, LRA map based on the concept of danger pixels gives the pixels under different resource categories at risk due to landslides whereas the LRA map based on the concept of fuzzy set theory further refines this result by defining the degree of severity of risk to these categories by putting these into high and low risk zones.

4.74 Kanungo, D. P., Arora, M. K. and Sarkar, S. et al. (2009). "Landslide susceptibility zonation (LSZ) mapping - A review". Journal of South Asia Disaster Studies Vol. 2 No. 1. http://saarc-sdmc.nic.in/pdf/Publications/Journal/journal%202009/5-journal.pdf

This article reviews advances in mapping landslide susceptibility zoning and discusses the applicability of a variety of approaches to assess landslide hazards. The review on LSZ mapping suggests that broadly there are two groups of approaches: qualitative and quantitative approaches for LSZ mapping. The qualitative approaches, such as distribution analysis, geomorphic analysis, map combination methods, etc., were very popular at late 1970s among engineering geologists and geomorphologists. The quantitative approaches became popular in the last decades depending on the advancements in the developments of remote sensing and GIS technologies. Advantages or disadvantages of different LSZ mapping approaches have been commonly discussed by the experts in the field of landslide studies in the literature. The qualitative approaches rely on expert knowledge or experience which dictates the selection, the weighting and the combination function of the factors and therefore, can be considered as conventional or subjective. The quantitative models involve the use of mathematics and statistics to express the relationships between the existing landslide distribution and the categories of factors.

4.75 Kanungo, D. P., Sarkar, S., and Sharma, S. (2011). "Combining neural network with fuzzy, certainty factor and likelihood ratio concepts for spatial prediction of landslides". Natural Hazards December 2011, Volume 59, Issue 3, pp 1491-1512. http://link.springer.com/article/10.1007%2Fs11069-011-9847-z

To locate the landslide susceptible zones in Darjeeling Himalaya authors has used techniques such as combined neural and certainty factor concept along with combined neural and likelihood ratio techniques. It is observed from the present study that the LSZ map produced using combined neural and fuzzy approach appears to be the most accurate one as in this case only 2.3% of the total area is found to be categorized as very high susceptibility zone and contains 30.1% of the existing landslide area. This approach can serve as one of the key objective approaches for spatial prediction of landslide hazards in hilly terrain.

4.76 Kimothi, S., Kumar, K. and Mathur S. (2010). "Rock mass and slope mass characterization of Kaliasaur landslide area (Uttarakhand) on National Highway-58 and correlation of results with deformation". Himalayan Geology, Vol. 31 (2), pp. 133-143. http://www.himgeology.com/himgeol/abstracts_30(2)/abstract6.htm

The study area, located on Kilometer-147 at National Highway-58 in Kaliasaur, Uttarakhand, a part of the Lesser Himalaya, was chosen for the rock mass and slope mass characterization. The area was divided into 197 grids of equal size along the National Highway for the slope stability analysis based on rock mass and slope mass characterization. Structural mapping was carried out for data on rock types, their attitude and quality condition i.e. weathering conditions. The type of failure was assessed on the basis of stereographic analysis of discontinuities. The results make it evident that rock mass quality is significantly affected by the weathering and alteration of the rock mass, as the rock mass falling in weak range of rock mass characterization is also invariably associated with the weathered zones.

4.77 Kishore, P., Lakshumanan, C., Viveganandan, S., et al (2012). "Evaluation of limit equilibrium method for landslide susceptibility analysis (LSA) – a case study on Nilgiris district". Int. Journal of Advances in Remote Sensing and GIS, Vol. 1, No. 2, 2012. http://www.jrsgis.com/articlefiles/vol1issue22012/JRSGIS12021.pdf

Limit equilibrium method is used for slope strability estimation. The conventional limit equilibrium method is used to analyze the stability of slope. In the present study, Bishop's simplified slope stability model was adopted to estimate Factor of Safety for the identification of risk. It is observed that when resultant factor of safety is lesser than 1 under wet and dry condition, those locations are seems to be unstable and very higher risk. This also shows that the slope is easily failure under small rainfall and will reaches higher property loss and also it was very evident that model has better reliability in predicting slope instabilities in this area.

4.78 Kothyari, G. C., Pant, P. D. and Luirei, K. (2012). "Landslides and neotectonic activities in the Main Boundary Thrust (MBT) zone: Southeastern Kumaun, Uttarakhand". Journal of the Geological Society of India July 2012, Volume 80, Issue 1, pp 101-110. http://link.springer.com/article/10.1007/s12594-012-0123-y

Landslides are taking place primarily due to high angle slopes, formation of structural wedges along the free steep slopes, sheared nature of the rocks due to proximity to the MBT and neotectonic activities along the MBT and other transverse faults. Wedge failure is a common type of landslides in rock slopes characterized by multiple joints and acts as sliding planes for the failed blocks. Field observations and wedge failure analysis indicates most of the landslides taking place in MBT zone of Kumaun Sub-Himalaya are joint controlled. Safety Factor analysis suggests MBT zone of Kumaun Sub-Himalayan region is prone to landslides and related mass movements. This zone is also neotectonically active as indicated by various geomorphic signatures such as structurally controlled drainage pattern, offsetting of fan by MBT and formation of number of small lakes.

4.79 Kumar, K. and Panigrahi, R. K. (1998). "Instrumentation, Monitoring and Analysis of A Landslide - A Case Study". Proceedings: Fourth International Conference on Case Histories

in Geotechnical Engineering, St. Louis, Missouri, March 9-12, 1998. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/33420/P%200535%20Instrumentation,%20monitoring%20and%20analysis%20of%20a%20landslide%20-%20a%20case%20study.pdf?sequence=2

Geological and geotechnical investigations followed by instrumentation and monitoring of this typical landslide was carried out to notice the nature, magnitude, rate and direction of movement on its surface and subsurface part from 1992 to 1995. Remedial measures recommended on the basis of such studies arc also described.

4.80 **Kumar, A. and Sanoujam, M. (2007). "Landslide studies along the national highway (NH 39) in Manipur". Natural Hazards Volume 40, Issue 3, pp 603-614.** http://link.springer.com/article/10.1007%2Fs11069-006-9024-y

The present study investigates the factors associated with the occurrence of landslides along with the National Highway (NH 39) connecting Assam-Manipur (India) to Myanmar. Kinematics and slope stability analyses were used to gain an understanding of the causes of slope failure despite the terrain comprising material with a high safety factor. The study area falls within a high seismic zone along the regional Churachandpur-Mao Thrust (CMT) situated west of the Indo-Myanmar subduction zone. Based on these studies of seismicity, slip rates, creeping, among others, it was inferred that CMT is a creeping regional fault running parallel to the subduction zone boundary creeping segment of CMT and that the CMT requires further monitoring to assess the landslide hazard in the region.

4.81 **Kumar, K., Prasad, P. S., Goyal, N. (2007). "Study of Rockfall at Amritanjan Bridge site on Mumbai – Pune Expressway – A Case Study", Journal of Rock Mechanics and Tunneling Tech. Vol. 13, No.2, pp. 129 -139.** http://www.isrmtt.com/abstract_download.php?abs=126

Country's first Expressway Mumbai-Pune, which passes through the mountainous and rugged Deccan Trap province, suffers from major rockfall problems along this important transportation corridor. During investigation the team identified 17 sensitive locations, which were prone to rockfall/landslides. Investigations of all the identified areas have been carried out from various aspects which were thought crucial to slope stability such as geological, geomorphological and geotechnical. The extensive field and laboratory investigations were carried out to understand the most possible causes and the possible mechanism of the rockfalls. On the basis of these investigations, appropriate short term and long-term remedial measures were suggested for specific locations. This paper intends to present in brief about the field investigations, probable causes and remedial measures recommended to control the rockfall at one of the trouble location, Amritanjan Bridge site, on Mumbai – Pune expressway.

4.82 Kumar, K. V., Lakhera, R. C., Martha, T. R. et al. (2008). "Analysis of the 2003 Varunawat Landslide, Uttarkashi, India using Earth Observation data". Environmental Geology August 2008, Volume 55, Issue 4, pp 789-799. http://link.springer.com/article/10.1007%2Fs00254-007-1032-z

Varunawat Parbat overlooking Uttarkashi town witnessed a series of landslides on 23 September 2003 and the debris slides and rock falls continued for 2 weeks. Though there was no loss of lives due to timely evacuation, heavy losses to the property were reported. High-resolution stereoscopic earth observation data were acquired after the incidence to study the landslide in detail with emphasis on the cause of the landslide and mode of failure. Areas along the road and below the Varunawat foothill region are mapped for landslide risk. It was found that the foothill region of the Varunawat Parbat was highly disturbed by man-made activities and houses are dangerously located below steep slopes. The potential zones for landslides along with the existing active and old landslides are mapped. These areas are critical and their treatment with priority is required in order to minimise further landslide occurrences.

4.83 Kumar, S. V. and Bhagavanulu, D. V. S. (2008). "Effect of deforestation on landslides in Nilgiris District – A case study". Jornal Indian Soc. Remote Sens. 36:105-108. http://www.indiaenvironmentportal.org.in/files/Effect%20of%20deforestation%20on%20landslides%20in%20Nilgiris%20District.pdf

The paper discuss that how the changing forest cover in Nilgiris District is affecting landslide hazards. A Drastic reduction in forest cover and human interventions in the form of unplanned tea estates has resulted in the loss of natural ecosystem of Nilgiris which is causing massive and frequent landslides.

4.84 Kumar, K., Prasad, P. S., Mathur, S. et al. (2010). "Rockfall and subsidence on Mumbai-Pune expressway". International Journal of Geoengineering Case Histories ©, Vol. 2, Issue 1, p. 24. http://casehistories.geoengineer.org/volume/volume2/issue1/IJGCH_2_1_2.pdf

Mumbai-Pune, India's first expressway, which crosses the mountainous and rugged Deccan Trap Province, suffered from a large amount of rockfall and major landslides in 2003 and 2004. A significant number of accidents and fatalities have occurred on the expressway as a result of such events. On the basis of frequency and magnitude of the recorded incidences of rockfall, seventeen critical areas of the road have been deemed in need of investigations and mitigation. This paper presents the field investigations, probable causes, stability analysis and remedial measures for controlling the subsidence and rock fall on Mumbai-Pune Expressway.

4.85 Kumar, K., Devrani, R. and Mathur, S. (2010). "Landslide Hazard Potential Analysis Using GIS, Patalganga Valley, Garhwal, Western Himalayan Region of India". European Journal of Scientific Research ISSN 1450-216X Vol.45 No.3 (2010), pp.346-366. http://www.scribd.com/doc/45254120/Landslide-Hazard-Potential-Analysis-Using-Gis-Patalganga#

The project Landslide Hazard Potential (LHP) analysis of the Patalganga basin was carried out to prepare a Landslide Susceptibility Potential Map (LSPM) for guiding future development within the basin. To do such analysis and prepare LSPM a variety of thematic information maps pertaining to the different factors were generated in 1:12500 scale using latest satellite data and extensive field investigations. All the maps with their analysis and outputs are prepared in GIS platform. In this paper a stepwise approach applied for landslide hazard potential analysis is described with a final output of Landslide Susceptibility Potential Map of the area which will be helpful in guiding the development of the valley in future.

4.86 Kumar, K., Prasad, P. S., Kathait, A., et al. (2011). "Landslide hazard management on mountainous highways – A critical need". 12th Esri India User Conference 2011. http://esriindia.com/Events/UC2011_files/DM_UCP0053.pdf

Indian highways in mountainous terrain are uninterruptedly suffered due to frequent Landslides of various kinds. It is generally noticed that, the landslides trigger due to unprecedented rainfall of short duration, prolong rainfall of normal intensity and cloud bursting and also during earthquakes. Once such landslides hazards experienced, they become the treasury for repeated recurrence, making the highways unsafe to the commuters. Authors highlight the need for the effective disaster management scheme which could become the part of the developmental activities and result in minimizing the frequency of the hazards and risk associated with them.

4.87 Kumar, K., Devrani, R., Kathait, A, et al. (2012). "Micro-hazard evaluation and validation of landslide in a part of North Western Garhwal Lesser Himalaya, India". International Journal of Geomatics and Geosciences Volume 2, No 3, 2012. http://www.ipublishing.co.in/jggsvol1no12010/voltwo/EIJGGS3075.pdf

The Micro Landslide Hazard Zonation mapping was carried out in a part of North Western Garhwal Lesser Himalaya. Certain factors were selected as per their role in inducing landslides. A base map on 1:500 scale was prepared using high precision Total Station and GPS that was further divided into equal sized grids measuring 45m X 45m. The parameters such as lithology, structures, slope gradients, landuse and landcover and groundwater condition have been quantified and statistically analyzed for evaluating the landslide hazard potential of each of the grid. The Micro LHZ map developed indicates three levels of hazard, low, moderate and high (II, III, & IV) in the region. Further the results were compared with results of geomechanical classification of the area.

4.88 Kumar, K., Kathait, A., Negi, I. S., et al. (2013). "ArcGIS based landslide hazard management on highways". 14th Esri India User Conference 2013, ESRI India. http://www.esriindia.com/Events/UC2013_files/Proceedings_files/Papers/UCP079.pdf

The safety of highways as well as the public commuting on these life lines is always under threat from variety of landslides, especially in mountainous regions and hence the need for an advanced and interactive Landslide Hazard Management system (LHMS). The Geographical Information System (GIS) with its advanced application/tools is being used comprehensively for identification of potential landslide areas and to frame out proper LHMS. In this paper we have discussed the role of GIS in landslide hazard management.

4.89 Kundu, S., Sharma, D. C., Saha A. K. et al (2011). "GIS-based statistical landslide susceptibility zonation: A case study in Ganeshganga Watershed, the Himalayas". 12th Esri India User Conference 2011. http://esriindia.com/Events/UC2011_files/DM_UCP008.pdf

In the present study, an attempt has been made to generate LSZ map of the study area using bivariate statistical modified Information Value (InfoVal) method in a small watershed in the Himalayas. The various causal factors responsible for landslide occurrence e.g., slope, aspect, relative relief, lithology, structure (confirmed thrusts, faults), lineaments, land use and land cover, distance to drainage, drainage density and anthropogenic factors like distance to road that are associated with landslide activity, have been considered and the corresponding thematic layers have been generated using remote sensing and GIS techniques. The accuracy of the LSZ map has been evaluated using frequency ratio and success rate methods and indicates more than 85% of landslide prediction accuracy.

4.90 Lakhera, R. C. and Champatiray, P. K. (1996). "Satellite Census of Landslide prone arras in Himalaya. Himalayan Geology, Vol.17, pp.209-216. http://www.himgeology.com/himgeol/volume17/abstract23.htm

In high mountainous terrain, landslide and other slope failure processes are the most common natural calamity occurring under varied natural conditions prevailing there. This phenomenon is more pronounced in high relief areas of Himalaya, which constitutes a very fragile and delicate ecosystem, and the events of landslides and other slope failure processes are more frequent both in space and time. The magnitude of damage caused every year by these sudden and unexpected earth movements in the Himalayan terrain is enormously high. This has resulted in adversely affecting the socioeconomic conditions and natural environment of the region.

4.91 Lal, A. K., Sharma, B. and Mundepi, A. K. (2002). "Earthquake-induced landsliding in Rudraprayag and Chamoli districts and implications for Mass-Movement Intensity and seismic hazard assessment: A summary of a recent study in Garhwal Himalaya". Himalayan Geology, Vol. 23 (1&2), pp. 95-103. http://www.himgeology.com/himgeol/vol_23/abstract11.htm

Recently a study has been conducted on landsliding and ground damage caused by 29th March 1999, Chamoli earthquake in Garhwal Himalaya. The main aims were to determine a) Relationships between landslide distribution and earthquake magnitude, epicenter, faulting, geology and landform, b) improved environmental response criteria and ground classes for assigning mass movement intensities and c) seismic hazard assessment in Rudraprayag and Chamoli districts. The relationships emerged from the study are revised environmental response criteria (landsliding and subsidence) for Rudraprayag and Chamoli districts indicate provisional ground type classes of varying landslide susceptibilities for assigning mass movement intensities in the habitated area.

4.92 Lallianthanga, R. K. and Laltanpuia, Z. D. (2013). "Landslide hazard zonation of Lunglei town, Mizoram, India using high resolution satellite data". International Journal of Advanced Remote Sensing and GIS 2013, Volume 2, Issue 1, pp. 148-159. http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-111/pdf

To study the landslide prone areas of Lunglei town various thematic layers, namely, lithology, geological structures, slope morphometry, geomorphology and land use/land cover were prepared using Satellite Remote Sensing and Geographic Information System (GIS) techniques. The various parameters were classified, ranked and weighted according to their assumed or expected importance in inducing slope instability based on apriori knowledge of the experts. A heuristic method has been applied for the assignment of ranks and weights. Finally, landslide hazard zonation map is prepared showing five hazard classes ranging from very low hazard to very high hazard. The landslide hazard zonation map prepared in the present study will be useful for carrying out mitigation programmes as well as for planning and implementation of future developmental schemes within the town.

4.93 Lallianthanga, R. K. and Lalbiakmawia, F. (2013). "Landslide hazard zonation of Aizawl District, Mizoram, India using remote sensing and GIS techniques". International Journal of Remote Sensing & Geoscience (IJRSG) Volume 2, Issue 4. http://ijrsg.com/Files/7a7152e5-494e-438c-b685-f32a8fe272a5_IJRSG_07_04.pdf

The present study was taken up to investigate the Landslide Hazard Zonation (LHZ) of Aizawl district, Mizoram that consists of four urban settlements and ninety seven rural villages. Using Remote Sensing and Geographic Information System (GIS) techniques, thematic layers like slope morphometry, geological structures like faults and lineaments, lithology, relative relief and land use / land cover were generated. The weightage rating system was used for different classes of thematic layers which are based on relative importance of various causative factors. The classes were assigned corresponding rating value as A landslide hazard zonation map having five different zones ranging from very low hazard zone to very high hazard zone was prepared with an objective to create reliable database for pre-disaster management and for planning developmental activities in the district.

4.94 Lallianthanga, R. K., Laltanpuia, Z. D. and Sailo, R. L. (2013). "Landslide hazard zonation of Lawngtlai town, Mizoram, India using high resolution satellite data". International Journal of Engineering and Science Vol.3, Issue 6 (August 2013), PP 36-46. http://www.researchinventy.com/papers/v3i6/G036036046.pdf

The present study encompasses the spatial analysis of landslide prone areas in Lawngtlai town using high resolution satellite data along with field data in a GIS environment. The analysis includes various terrain parameters like, lithology, geological structures, slope morphometry, geomorphology and land use/land cover for deriving landslide hazard zones in the town. The various parameters were classified, ranked and weighted according to their assumed or expected importance in inducing slope instability based on apriority knowledge of the experts. A heuristic method has been applied for the assignment of ranks and weights. Landslide hazard zonation map is prepared showing five hazard classes ranging from very low hazard to very high hazard. The study indicates that a majority of the town area falls under Moderate hazard zones, which further signifies that slope stability is still a major concern when taking up developmental activities.

4.95 Lallianthanga, R. K. and Lalbiakmawia, F. (2013). "Micro-level landslide hazard zonation of Saitual town, Mizoram, India using remote sensing and GIS techniques". International Journal of Engineering Sciences & Research Technology. http://ijrsg.com/Files/7a7152e5-494e-438c-b685-f32a8fe272a5_IJRSG_07_04.pdf

Landslide hazard zonation (LHZ) of Saitual town, Aizawl disrict was carried out using Remote Sensing and Geographic Information System (GIS) techniques. Five thematic layers viz., slope morphometry, geological structures like faults and lineaments, lithology, relative relief and land use / land cover were first generated. The thematic layers were ranked and weightage rating system was used for the different classes within these causative factors based on their relative importance in causing landslide. The present study proved that the physical factors like land use/ land cover, lithology, slope, geological structure and relative relief are directly linked with landslide hazard. The landslide hazard map prepared through the present study can be utilized for identifying the critical areas for implementing suitable mitigation measures as well as for selecting sites further expansion of the town.

4.96 Lallianthanga, R. K., Lalbiakmawia, F. and Lalramchuana, F. (2013). "Landslide hazard zonation of Mamit Town, Mizoram, India using remote sensing and GIS techniques". International Journal of Geology, Earth and Environmental Sciences 2013 Vol. 3 (1) January-April pp.184-194. http://www.cibtech.org/J%20GEOLOGY%20EARTH%20ENVIRONMENT/PUBLICATIONS/2013/Vol_3_No_1/20-01...R.K.%20Lallianthanga...Landslide...Techniques.pdf

To investigate the Landslide Hazard Zonation (LHZ) of Mamit town, high resolution satellite data is used. Using Remote Sensing and Geographic Information System (GIS) techniques, thematic layers like slope morphometry, geological structures like faults and lineaments, lithology, relative relief and land use / land cover were generated. The weightage rating system based on relative importance of various causative factors was used for different classes of thematic layers. Summation of these attribute value were then multiplied by the corresponding weights to yield the different zones of landslide hazard. A landslide hazard zonation map was prepared showing five different zones ranging from very low hazard zone to very high hazard zone which is essential for carrying out quicker and safer mitigation programmes, as well as for future developmental planning.

4.97 Lallianthanga, R. K. and Lalbiakmawia, F. (2014). "Landslide susceptibility zonation of Kolasib District, Mizoram, India using remote sensing and GIS techniques". International Journal of Engineering Sciences & Research Technology. http://www.academia.edu/attachments/3337595 download_file?st=MTQwMTcwMzE1NywxNjQuMTAwLjEwNS4xMzc%3D&ct=MTQwMTcwMzIxMw%3D%3D

The present study investigates the Landslide Susceptibility Zones of Kolasib district using Remote Sensing and Geographic Information System (GIS) techniques. The resulting Landslide Susceptibility Zonation map classified the area into five relative susceptibility classes like very high, high, moderate, low, and very low. The final map generated will, therefore, be used by planners and administrators in selecting suitable areas for developments and for implementing appropriate mitigation measures in the landslide prone areas.

4.98 Marrapu, B. M. and Jakka, R. S. (2014). "Landslide hazard zonation methods: A critical review". International Journal of Civil Engineering Research. Volume 5, Number 3, pp. 215-220. http://www.ripublication.com/ijcer_spl/ijcerv5n3spl_03.pdf

Landslides are the most far-flung natural hazards, causing loss of thousands of lives and billions of dollars annually worldwide. Urbanization particularly in the hilly regions has led to the necessity of in-depth study and research in the field of landslide hazard zonation. Despite many technical papers being dealt in this area of study, there is no particular standard method available for evaluating and predicting the pattern of landslides. This paper deals with the compilation of various landslide hazard assessment methods with adequate contextual information. A critical review is presented on each of these methods, highlighting their limitations and suitability of application.

4.99 Mathew, J., Jha, V. K. and Rawat, G. S. (2007). "Weight of evidence modeling for Landslide hazard zonation mapping in part of Bhagirathi Valley, Uttarakhand". Current Science Vol. 92. No. 5. http://www.currentscience.ac.in/cs/Downloadsarticle_id_092_05_0628_0638_0.pdf

Weight of evidence method has been used to find out the probability of occurrence of landslides for unique combinations of evidential themes and to prepare a landslide hazard zonation map of part of Bhagirathi valley, Uttarakhand, within a GIS environment. Lithology, structure, slope, slope aspect, land use/land cover, drainage and distance to road are the evidential themes considered ion the study. The model has been further validated using receiver operator characteristic curve analysis, which shows an accuracy of 8.6%.

4.100 Mayavan, N. and Sundaram, A. (2012). "Statistical analysis for landslide in relation to landuse in Sirumalai Hill, Dindigul District, Tamil Nadu, India, using GIS technologies". Research Journal of Recent Sciences Vol. 1(12), 36-39. http://www.isca.in/rjrs/archive/v1i12/7.ISCA-RJRS-2012-365.pdf

The paper presents a statistical approach through spatial data analysis in GIS with particular reference to land use pattern in Sirumalai Hill. This study to analysis the primary data with combined the engineering analysis method and ground validation to find the characteristics its spatial distribution in the study area. The present study uses sensitivity co-efficient to assess the effect of each land use category on landslide susceptibility. The analysis shows that the vulnerable category of land use is construction land and road, consisting of settlements and agriculture land and plantation. Hence from the study remote sensing and GIS techniques play a vital role in planning and evaluating disaster analysis.

4.101 Mayavan, N. and Sundaram, A. (2012). "An approach for remote sensing and GIS based landslide hazard zonation mapping in Sirumalai Hill, Tamil Nadu". Elixir Remote Sensing 51 (2012) 10829-10833. http://www.researchgate.net/profile/Maya_Van publication255485383_An_approach_for_remote_sensing_and_GIS_based_landslide_hazard_zonation_mapping_in_Sirumalai_Hill_Tamil_Nadu/file/e0b495201ee33d98b2.pdf

The paper presents an integrated GIS and Remote sensing approach for Landslide Hazard Zonation in part of Sirumalai hill, Tamil Nadu. Satellite data, topographic maps, field data and other information maps are used to the study were prepared in GIS environment. Numerical rating scheme for the factors was developed for the spatial analysis in GIS environment to arrive at landslide Hazard Zonation map of the area. Landslide Hazard Index (LHI) value is calculated and landslide hazard zonation is decide by the LHI histogram. The resulting of the landslide Hazard Index Frequency Mapping is classified in five classes: very high, high, moderate, low, very low. Field data on landslide bodies are used to evaluate and validate the LHZ Map.

4.102 Mazari, R. K., Bartarya, S. K., Bagati, T. N. et al. (1996). "Phenomenal river bed uplift in the Gaj Rao, Dehradun a case of slump induced movement in the Middle Siwalik sediments". Himalayan Geology, Vol.17, pp.171-181. http://www.himgeology.com/himgeol/volume17/abstract20.htm

Over the past few years a new trend of geomorphic processes has surfaced in the Himalaya where riverbed uplift has become associated with landsliding. The development of this kind was first noticed in the Lesser Himalayan Tal valley in the east of Dehra Dun in January 1991, but now a repeat has occurred in the Outer Himalayan Gaj Rao in the neighboring Siwalik Range. Analysis of the field data suggests that the Gaj Rao bed uplift is the outcome of a slump on the right hill slope in the Middle Siwalik sequence whereupon the reddish brown mudstone concealed under the stream gravel got jacked up in a trajectory manner under the impact of the rotational movement. The open space in the valley provided ideal situation for compensation of load adjustment along the master slip plane. Hazard wise the new geomorphic phenomena at Gaj Rao is of no serious concern since no loss of life or property has been reported.

4.103 Mehrotra, G. S. and Bhandari, R. K. (1989). "A geological appraisal of slope instability and proposed remedial measures at Kaliasaur Slide on National Highway, Garhwal Himalaya".

Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, SL Louis, Mo., Paper No. 2.40. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/34461P%2024%20A%20geological%20Appraisal%20of%20Slope%20Instability%20and %20Proposed%20Remedial%20Measures%20at%20Kaliasaur%20Slide%20on%20National%20Highway,%20Garwal%20Himalaya.pdf?sequence=1

The authors have highlighted the geological, geomorphological and morphometric parameters to diagnose the factors responsible for instability of slope and the magnitude of the problems involved. A scheme of remedial measures which include modification of existing drainage pattern, timber piling for stitching of debris cover on to the slope, construction of retaining walls and putting back the vegetation on the slope are recommended for control of the landslide.

4.104 Mehrotra, G. S., Dharmaraju, R. and Parkash, S. (1993). "Landslide zonation and geo-environmental appraisal of a part of Garhwal Himalayas, India". Seventh International Conference and Field Workshop on Landslide.

A zoning criteria for the preparation of landslide hazard zonation map of the hilly terrain has been developed and tested in a catchment area of 1066 sq. km. in Tehri-Uttarkashi region of Garhwal Himalaya. The landslide activity has been related with various geo-environmental factors. A numerical weightage designated as Landslide Susceptibility Value (LSV) has been assigned to various geo-environmental factor maps and LSI for each category has been calculated. Based on the range of LSI values obtained, the terrain has been divided into areas of very high, high, moderate, low and very low instability.

4.105 Mehrotra, G. S., Sarkar, S. and Kanungo, D. P. (1994). "A geological appraisal of Landslide Hazards in East Sikkim Himalaya". Journal of Himalayan Geology Vo.5 (1), pp.35-43. http://www.himgeology.com/himgeol/journal5(1)/abstract4.htm

Landslides and slope failures are common phenomenon in Sikkim Himalaya causing much damage to the road network system particularly during monsoon period. The major causes for such a high frequency of landslides in the area are heavy rainfall and immature topography of the terrain. The paper deals with an analysis of existing landslides along the major roads of east Sikkim describing the location, size, mode of failures, causative factors and other details of each landslide. A relationship of frequency of landslides and types of failures with various litho-units of the terrain has been established.

4.106 Mehrotra, G. S., Dharmaraju, R. and Prakash, S. (1994). "Morphometric appraisal of slope instability of Chilla ladnslide, Garhwal Himalaya". Journal of the Geological Society of India Issue: 2, Vol 44 pp 203 – 211.

A major landslide occurred in January 1990 on the left bank of Tal river, near Chilla in Hardwar district which raised a part of the river bed by 6-8 m. The paper highlights the geological, geomorphological and morphometric parameters to identify die factors responsible for instability of slope. A detailed morphometric assessment of the slide area has also been carried out with a view to prepare a zonation map of slide area in terms of instability. The study has been found very useful to understand the mechanism of the slide area and also to suggest suitable recommendations for control measures at proper locations in the slide area.

4.107 Mehrotra, G.S. J., Sarkar, S. J., Kanungo, D.P. , et al. (1995). "Slope stability assessment using slope mass rating technique". The 35th U.S. Symposium on Rock Mechanics (USRMS). https://www.onepetro.org/conference-paper/ARMA-95-0091

The study pertains to determine the degree of stability in rock slopes using Slope Mass Rating (SMR) technique developed by Romana (1985). The technique has been applied to different rock slopes in the Alaknanda valley of Garhwal Himalaya, India. The idea behind the study is to assess the slope instability in the region. The result of the study has shown very low value of SMR where major slope failures have already occurred and higher values for slopes which seem to be more stable. From the study it can be inferred that SMR technique is an easy method for slope stability assessment which gives a more realistic view of the slope condition as the study is based on actual field observations.

4.108 Mehrotra, G. S., Parkash, S. and Dharmaraju, R. (1996). "Geomorphometric assessment of hill slope instability of Matli landslide in Uttarkashi district, Garhwal Himalaya (India)". Landslides -International Symposium pp 309-314.

Slope failures in hilly terrains are always huge losse3 of life and property as well as environmental degradation. Geomorphometric assessment of hilly terrains provides a detailed perspective of the landscape and the geometry of slope. The paper highlights the implication of geomorphometric techniques to identify the factors responsible for causing instability of slope in Garhwal Himalaya. Based on morphomertric assessment the slide area has been delineated in terms if instability zones which has been found useful for prediction of slope failures.

4.109 Mehrotra, G. S., Pandey, Y. Dharmaraju, R. et al. (1996). "Instrumentation and monitoring of Matli landslide area in Garhwal Himalaya - A case study". Proceedings of International Confernce on Disaster and Mitigation, Madras.

This study focuses attention on the application of simple instruments used for monitoring surface movement of Matli landslide area near Uttarkashi, Garhwal Himalaya. The data obtained have produced direct evidences of surface movements based on which the slide area has been delineated into zones e.g., exorbitant, moderate and low movement zones. On the basis of such assessment of slide area prediction of probable failure can be made.

4.110 Mehrotra, V. K. (1996). "Failure envelopes for jointed rocks in lesser Himalayas". Journal of Rock Mechanics and Tunneling Tech. Vol 2 No 1, pp. 59-74. http://www.isrmtt.com/abstract_download.php?abs=11

This paper discusses the shear strength envelopes developed for various rock mass ratings, degree of saturation and rock types tested in the lesser Himalayas. The recommended failure criteria are based on the results of extensive field tests, judgment and own experience of the author. It has been realized that for highly jointed rock masses shear strength will not be governed by the strength of the rock material. The effect of saturation on the shear strength of poor rocks has been found to be significant. The results of the study have been presented in the form of failure envelops which may be used for estimating the angle of internal friction (j) and shear strength developed at a given normal stress.

4.111 Mehta, B. S., Parti, R. and Sharma, R. K. (2010). "Landslide hazard analysis and zonation on National Highway -21 from Panasra to Manali, H.P, India". International Journal of Earth Sciences and Engineering, Vol. 03, No. 03, June 2010, pp. 376-381. http://cafetinnova.org/wp-content/uploads/2013/04/02030507.pdf

An attempt has been made to identify, evaluate and prepare a landslide hazard zonation map for Panarsa to Manali stretch on National Highway - 21 in the state of Himachal Pradesh taking in to account the lithology, slope morphometry, relative relief, structure, lineament, land-use, drainage and rainfall distribution of the area using the deterministic approaches along with the Bureau of Indian Standards (1998) guidelines.

4.112 Mittal, S. K., Singh, M., Kapur, P. et al (2008), "Design and development of instrumentation network for landslide monitoring and issue an early warning". Journal of Scientific and Industrial Research Vol 67, pp 361-365. http://csioir.csio.res.in/209/1/JSIR%2067(5)%20(2008)%20361-365.pdf

CSIO, Chandigarh has designed and developed an instrument network around standard geo-technical and geo-physical sensors and advanced associated electronics. Network was installed in 2006 for instrumental monitoring of the site at Mansa Devi near Haridwar. The paper highlights design approach for network and explains technical details of different sub modules. Network performance in terms of functional reliability, data generation capability and failure rate in the field has been evaluated and necessary design modifications have been incorporated.

4.113 Mittal, S. K., Singh, M., Sardana, H. K. et al. (2009). "Realization and installation of landslides instrumentation network at Mansa Devi (Haridwar)". Indian Landslides Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf

Landslides and other associated mechanism of erosion have to be accepted as part of the natural process. It has been observed that in rainy season and sometimes even otherwise, part of earth gives away down steep slopes causing landslides and which in turn adversely affects a variety of resources. Therefore to mitigate the losses of property and human lives, continuous monitoring of active landslides and their early prediction with the help of instrumentation network is very much essential. CSIO, Chandigarh has installed an Instrument network at Mansa Devi (Haridwar) landslide for the first time in our country. The complete system is operational round the clock and data is being collected and analyzed regularly. In this paper description of complete instrumentation network has been explained.

4.114 Mittal, S. K., Dhingra, S. and Sardana, H. K. (2011). "Analysis of data using neuro-fuzzy approach recorded by instrumentation network installed at Mansa Devi (Haridwar) landslide site". Journal of Scientific and Industrial Research Vol 70, pp 25-31. http://nopr.niscair.res.in/bitstream/123456789/10773/1/JSIR%2070(1)%2025-31.pdf

This paper presents a case study of landslide monitoring and early warning of Mansa Devi (Haridwar), located at Haridwar by pass road. Data recorded by instrumentation network installed at Mansa Devi (Haridwar) landslide site by five sensors (Rain gauge, Inclinometer, Tiltmeter, Crack meter, Earth pressure cell) was analyzed and a relationship between rainfall intensity surface parameter and landslide occurrence drawn with neuro-fuzzy approach for prediction of landslide3 and concept of early warning system is also described. Mansa Devi site is found rain prone and developed model demonstrates a fairly accurate prediction.

4.115 Mondal, S. and Maiti, R. (2013). "Integrating the analytical hierarchy process (AHP) and the frequency ratio (FR) model in landslide susceptibility mapping of Shiv-khola Watershed, Darjeeling Himalaya". International Journal of Disaster Risk Science 2013 Vol 4 Issue (4) 200-2012. http://211.103.157.130/Jwk_ijdrs//EN/Y2013/V4/I4/200

To prepare a landslide susceptibility map of Shivkhola watershed, one of the landslide prone parts of Darjeeling Himalaya, remote sensing and GIS tools were used to integrate 10 landslide triggering parameters: lithology, slope angle, slope aspect, slope curvature, drainage density, upslope contributing area (UCA), lineament, settlement density, road contributing area (RCA), and land use and land cover (LULC). The Analytical Hierarchy Process (AHP) was applied to derive factor weights using MATLAB with reasonable consistency ratio (CR). The frequency ratio (FR) model was used to derive class frequency ratio or class weights that indicate the relative importance of individual classes for each factor. The weighted linear combination (WLC) method was used to determine the landslide susceptibility index value (LSIV) on a GIS platform, by incorporating both factor weights and class weights. The Shiv-khola watershed is classified into five landslide susceptibility zones.

4.116 Mukhopadhyay, B. P., Roy, S., Chaudhuri, S., et al. (2012). "Inûuence of geological parameters on landslide vulnerability zonation of Darjeeling Town, in Eastern Himalayas". Asian Journal of Environment and Disaster Management Vol. 4, No. 2 (2012) 27–46. https://www.academia.edu/attachments/33443489/download_file?st=MTQwMDY1Njg4MiwxNjQuMTAwLjEwNS4xMzcsMTc2OTg1NQ%3D%3D&ct=MTQwMDY1NjkzMywxNzY5ODU1

The study confers generation of a landslide vulnerability zonation map of Darjeeling municipal town based on the geological ûeld study. Investigation was carried out mainly on geological and related aspects; those are having a direct inûuence on slope failure. Studied parameters of the investigation include mainly the lithology, over all structure and orientation of the rock strata, soil type, surface-slope and vegetations. Sum total weighted values of all the investigated geological and related parameters were estimated for individual location and vulnerability of the locations towards landslide was scaled against that calculated weighted values.

4.117 Muthukumar, M. (2013). "GIS based geosystem response modeling for landslide vulnerability mapping parts of Nilgiris, South India". Disaster Advances Vol. 6 (7) July 2013. http://www.indiawaterportal.org/sites/indiawaterportal.org/files/nilgiria_v_maps.pdf

Various methods are being adopted for Landslide Vulnerability Mapping (LVM) resulting into differing types of outputs. So a new method was attempted for Nilgiri Mountains, Western Ghats, and South India by assigning weightages to various geosystem parameters viz: Lithology, Lineament / fracture density, geomorphology, Slope, Land use / Land cover and their sub classes or sub variables, on the basis of their responses to landslides and integrated such weighted five geosystems to arrive finally at a landslide vulnerability map.

4.118 Nagarajan, R. and Khire, M. V. (1998). "Debris slides of Varandh Ghat, west coast of India". Bulletin of Engineering Geology and the Environment Volume 57, Issue 1, pp 59-63. http://link.springer.com/article/10.1007%2Fs100640050021

On 28 June 1994 when 240 mm of rainfall occurred, a huge debris slide took place at Parmachi village in the Varandh Ghat of the Konkan district on the west coast of India. The debris slide resulted in extensive damage to property and killed 20 people in addition to numerous animals. The slide is considered to have occurred due to the development of hydrostatic pressure at the base of colluvial material, such that slope failure took place at the rock/soil interface. In view of the significance of such slides to settlements and highways, it is proposed that a warning system is developed based on a rainfall threshold of 170 mm in a 24-hour period.

4.119 Nagarajan, R., Roy, A., Kumar, R. V. et al. (2000). "Landslide hazard susceptibility mapping based on terrain and climatic factors for tropical monsoon regions". Bulletin of Engineering Geology and the Environment Volume 58, Issue 4, pp 275-287. http://link.springer.com/article/10.1007%2Fs100649900032

Deep weathering, residual material (colluvium) and random rainfall intensity are mainly responsible for landslides in tropical monsoon regions. These parameters are often not taken into consideration in a landslide susceptibility assessment. Sustainable resources development in this region requires information on the spatial distribution of areas susceptible to landslides. This study highlights various aspects of the landslides that take place on the west coast of India and a methodology developed for landslide susceptibility mapping.

4.120 Nagarajan, R. (2002), "Rapid assessment procedure to demarcate areas susceptible to earthquake-induced ground failures for environment management – a case study from parts of northeast India". Bulletin of Engineering Geology and the Environment May 2002, Volume 61, Issue 2, pp 99-119. http://link.springer.com/article/10.1007/s100640100125

Ground failures, such as landslide and the liquefaction of soil induced by earthquake and/or rainfall, not only pose a threat to human settlements but also degrade the environment. In order to be as prepared as possible, prior knowledge of the spatial distribution of areas vulnerable to these natural hazards and the critical locations for different degrees of risk is required. Information on the land cover, surface drainage, morphology, surface material, rock type, geological structure, lineament, rainfall and earthquake was used in developing a procedure to evaluate regions of potential ground failure. A case study from northeast India is presented to illustrate its value.

4.121 Nainwal, H. C. and Prasad, C. (2001). "Micro-zonation of slope instability using SMR approach – a case study from Garhwal Himalaya, India". Himalayan Geology Vol.22 (2), pp.135-146. http://www.himgeology.com/himgeol/vol_22(2)/abstract13.htm

The Kaliasaur landslide area has steeper slopes over moderate to highly weathered quartzites. On the other hand, Rudraprayag landslide area has moderate to steep slopes over low to highly weathered phyllites, slates, metavolcanics and quartzites. The bed rocks of Kaliasaur landslides has generally poor to fair RMR, whereas those of Rudraprayag slide area have very poor to poor RMR. The rocks of Kaliasaur area generally have dominant planar and minor wedge failures, whereas in case of Rudraprayag landslide, wedge and planar failures are almost equal. On the basis of Rock Mass and Slope Mass Ratings, relatively various stable and unstable zones of both landslides were identified.

4.122 Naithani, A. K., Bhatt, A. K. and Sundriyal Y. P. (2007). "Landslide hazard zonation mapping: A case study for the Hydropower Project in a part of Garhwal Himalaya, Uttaranchal, India". Himalayan Geology, Vol. 28 (1), pp.63-73. http://www.himgeology.com/himgeol/vol_28(1)/abstract5.htm

Landslide hazard zonation mapping of Loharinag-Pala area, where a hydropower scheme of 600 MW is proposed on Bhagirathi River was carried out. In the present study statistical analysis of various geo-environmental factors such as the lithology, slope, structure, relative relief, landuse and hydro-geological conditions were used. For preparing the landslide hazard zonation map a quantitative approach called landslide hazard evaluation factors (LHEF) rating has been used. Remote sensing data were also used for data base creation. The study indicates that structures, steeper angle of hill slopes and rainfall plays major role in triggering landslides in this part of the Himalaya. The study further suggests that in the geotechnical investigation of hydropower, landslide hazard evaluation factor (LHEF) rating scheme can provide rapid hazard.

4.123 Naithani, A. K. and Rawat G. S. (2009). "Investigations of Bunga landslide and its mitigation - a case study from Pinder valley, Garhwal Himalaya, Uttarakhand". Indian Landslides Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf

The Geological and geomorphological studies of the Bunga landslide was carried out, in order to understand the causative factors and the mechanism of sliding. The sliding process was monitored from May 2002 to May 2004 with the help of measuring pedestals, in order to identify the unstable areas, were analyzed. The sampling followed grid patterns to analyze for the clay mineralogy and the major oxides of the debris material of slide zone. The presence of montmorillonite, which causes slope failures is recorded. The investigation shows that the main causative factors are the heavy precipitation, construction of road supplemented by toe erosion and presence of subsurface seepage. The mechanism of sliding is debris flow in upper part and mudflow in lower part, with rotational sliding. After detailed investigation various remedial measures are being suggested to minimize the damage to the road, settlements and cultivated fields.

4.124 Nalina, P., Meenambal, T. and Sridhar, R. S. (2014). "Slope stability analysis of Kallar-Coonoor hill road stretch of the Nilgiris". Journal of Computer Science. http://thescipub.com/pdf/10.3844/jcssp.2014.1107.1114

The investigation was carried out at 32 locations in the hill road stretch to estimate the factor of safety of the slope determined by Mohr-Coulomb theory based on shear strength parameter calculated from direct shear test which is a conventional procedure for the study. Back Propagation Artificial Neural Network (BP-ANN) Model is used to predict the factor of safety. The input parameters for the (BP-ANN) are chosen as Cohesion, Angle of internal friction, Density and Slope angle and the factor of safety as output. Out of the parameters of 32 locations, the study of BP-ANN is trained with parameters of first 25 locations. Factor of safety was calculated for the remaining 7 locations. The results obtained in BP-ANN method were compared with that of conventional method and observed a good agreement between these two methods.

4.125 Natarajan, T. K., Chandra, D. and Murty, A. V. S. R. (1988). "Control of surficial slides by different erosion control techniques". Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 3.05. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/34480/P%200361%20Control%20of%20Surficial%20Slides%20by%20Different%20Erosion%20Control%20Techniques.pdf?sequence=1

Many natural and embankment slopes fall due to the erosion of the top surficial soil mantle. Denudation of vegetation from soil slopes combined with the further steepening of slopes due to natural and man-made causes such as cuts result in such a type of failure. Essentially, the corrective measures appropriate for stabilizing these slopes comprise erosion control by establishing vegetation on the slope. The methods of vegetative turfing include asphalt mulch, coir/jute netting, geogrids and stone apron techniques. The paper presents the case history giving details of some of the relatively new techniques for erosion control on a hill road in India and evaluates the relative performance and the relative economics of these methods.

4.126 Nautiyal, H. and Bhandari, S. P. (2012). "Ddmap, district disaster management action plan for hill district Uttarkashi, (Uttarakhand)". International Journal of Scientific & Technology Research. http://www.ijstr.org/paper-references.php?ref=IJSTR-0712-5272

Present investigations were carried out on the Disaster Management Action Plan of Uttarkashi district (Garhwal Himalaya). The main central thrust and the main boundary thrust lines are passing through the district. It was main focal point of the earthquake disaster in 1991 (6.4 in Richter scale). The district also faced the heavy flood in 1978, 1997 and 1998, mass land slide in Varunavat hill in 2003, 2007 and 2007, in Bhatwari village in 2011. Thus the possibility of earthquake, flood and land slides are always there. The present paper highlights the planning steps of disaster management plan for hill districts (Uttarkashi).By following the disaster action plan; we can prevent or can minimize the impact of disaster and can save the lives and properties as much we can.

4.127 Negi, R. S., Parmar, M. K., Malik, Z. A. et al. (2012). "Landslide hazard zonation using remote sensing and GIS: A case study of Giri Valley, District Sirmaur Himachal Pradesh". International Journal of Environmental Sciences Vol.1 No.1. 2012. pp. 26-39. http://www.researchgate.net/profile/Zubair_Malik/publication 236033098_Landslide_Hazard_Zonation_using_Remote_Sensing_and_GIS_A_Case_Study_of_Giri_Valley_District_Sirmaur_Himachal_Pradesh/file/50463515ea0370fcd1.pdf

The Himachal part of extra-peninsula that has been compressed about 65% and resulted in the orogenesis to form very steep mountain range. The structural disturbances like folding, faulting and shearing are very common in this region. Slopes, deforestation, heavy precipitation and the road construction itself have found to be the main cause of slope instability. In this work, the effort has been made to make the land slide susceptibility zonation map by using the integrated geoinformatics along with the information value technique. Various generated rasters were given the experience based weightage and analysis was made in the GIS environment to prepare the final landslide susceptibility zonation map.

4.128 Neharika, S. G. & Neelima, S. D. (2013). "Dynamic analysis of landslide in the north Bengal-Sikkim during 18th Sep 2011 earthquake". International Journal of Landslide and Environment Vol 1, No 1. http://web2py.iiit.ac.in/research_centres/publications/downloadinproceedings.pdf.bd7f3382744b1e9e.6a6f75726e616c2070617065722e2e706466.pdf.

This paper discusses the unsteadiness and mass movements of hill slopes along mountain roads in Sikkim region. Detailed evaluation of the slope failures has been studied under dynamic loading .The slope is modeled using Plaxis software and the configuration including geometry and properties of slope was considered for analysis. Numerical analysis was performed for the slope considered using Plaxis 2D. Dynamic and static analyses were carried out using detailed geotechnical properties to estimate displacements and stresses in the slope.

4.129 Nimbalkar, S. S., Choudhury, D. and Mandal, J. N. (2006) "Seismic stability of reinforced soil-wall by pseudo-dynamic method". Geosynthetics International, 2006, 13, No. 3 pp 111-119. http://dspace.library.iitb.ac.in/xmlui/bitstream/handle/10054/47/gi1.pdf?sequence=1

A pseudo-dynamic method is adopted in the analysis, which considers the effect of phase difference in both the shear and primary waves travelling through the backfill due to seismic excitation. Reinforced soil walls with cohesionless backfill material have been considered in the analysis. Results are presented in graphical and tabular form to show the required tensile force and length of geosynthetic reinforcement to maintain the stability of the reinforced soil wall under seismic conditions. The effects of variation of parameters such as soil friction angle and horizontal and vertical seismic accelerations on the stability of the reinforced soil wall have been studied.

4.130 Nithya, S. E. and Prasanna, P. R. (2010). "An integrated approach with GIS and remote sensing technique for landslide hazard zonation". International Journal of Geomatics and Geoscience Volume 1, No. 1, 2010. http://ipublishing.co.in/jggsvol1no12010/EIJGGS1007.pdf

This paper deals with an integrated approach of remote sensing and geographical information systems for landslide hazard zonation. The landslide distributions are mapped by extraction of features from the satellite images. In order to analyze landslide susceptibility efficiently, the existing maps are digitized and processed with the help of integration of terrain information by GIS. Six categories of controlling factors for landslides i.e. aspect of slope, geology, land use, drainage, lineament and runoff are defined. The data obtained is integrated to form landslide hazard zonation map. An effort is made to generate a landslide susceptible map from satellite imagery, DEM (Digital Elevation Model) and maps. Finally, a map divided into four susceptibility zones is produced using the weight value of all controlling factors using the method of multi objective decision making process and then each susceptibility zone is evaluated by comparing with the distribution of each controlling factor class.

4.131 Onagh, M., Kumra, V. K. and Rai, P. K. (2012). "Landslide susceptibility mapping in a part of Uttarkashi district (India) by multiple linear regression method". International Journal of Geology, Earth and Environmental Sciences 2012 Vol. 2 (2) May-August, pp.102-120. http://www.cibtech.org J%20GEOLOGY%20EARTH%20ENVIRONMENT/PUBLICATIONS/ 2012/Vol%202%20No%202/11-038%20Ounagh... Application...Uttarkashi.pdf

The parameters of slope, aspect, lithology, land cover, rainfall, distance from fault, distance from river, and distance from road were used as variables in the Multiple Linear Regression analysis. ILWIS 3.31 Academic, Arc GIS 9.3, Global Mapper 13.0 and Excel softwares have been used for zonation, and statistical analyses respectively. Finally, an overlay analysis was carried out by evaluating the layers obtained according to their accepted coefficient in final model. The result was validated using the Area Under Curve (AUC) method and temporal data of landslide occurrences. The validation results showed satisfactory agreement between the susceptibility map and the existing data on landslide locations. As a result, the success rate of the model (76.2%) shows high prediction accuracy. The study area has been classified into five classes of relative landslide susceptibility, namely, Low, Moderate, High, and Very High.

4.132 Pachauri, A. K. and Pant, M. (1992). "Landslide hazard mapping based on geological attributes". Engineering Geology Volume 32, Issues 1–2, Pages 81–100. http://www.sciencedirect.com/science/ article/pii/001379529290020Y

A landslide susceptibility zoning technique is proposed and has been tested in a catchment area of 317 km2 along the Aglar River, a tributary of the River Yamuna in the Himalayas. The Aglar catchment is characterised by varied rock types, mostly sedimentary, an active fault, landslides, moderate to intense seismic activity and moderate human influence. Very little is known about this terrain except for one previous study. This study focusses on the relationship between the terrain parameters and landslide hazard mapping. A landslide susceptibility map is presented which can serve as first generation map on which subsequent detailed information can be incorporated. It is the first map of this kind from the Himalayas based on quantitative evaluation of geomorphological and geological parameters on a classified terrain database map.

4.133 Pachauri, A. K. Gupta, P. V. and Chander, R. (1998). "Landslide zoning in a part of the Garhwal Himalayas". Environmental Geology Volume 36, Issue 3-4, pp 325-334. http://link.springer.com/article/10.1007%2Fs002540050348

This work is aimed at providing another example of landslide susceptibility mapping based on geological and geomorphological attributes. The data collected from aerial photographs, topographic sheets and the image suggests that there is a correlation between the distribution of landslides and some of the geological and geomorphological factors, for example, the distance from an active fault, relative relief and slope. Parameters like factor of safety, altitude, relief, slope and the distance from the fault lineament have been included in the study. A rating system has been applied to the factors for arriving at a quantitative estimate of landslide susceptibility for each physiographic unit

4.134 Pal, S., Kaynia, A. M., Bhasin, R., et al. (2011). "Distinct element stability analysis of Surbhee resort landslide in Garhwal Himalayas, India". Disaster & Development. Journal of NIDM, Vol. 5, No.1 & 2 April & November. http://www.eqrisk.info/pdf/paper_NIDM_Shilpa_2009_02.pdf

Numerical studies have been carried out in 2-D to predict the behavior of the jointed rock slope in the Surbhee Resort landslide in Mussoorie, Garhwal Himalayas, India. Study has been carried out in two stages. In first stage, total slide has been modeled in 2-D. The total volume of the rock mass that becomes unstable is 11.58 million m3. Slope is stable otherwise under static and dynamic loading cases. In second stage, only the zone of detachment has been modeled in 2-D. Study under static and dynamic environment indicates that most of the total displacement observed in the model of the slide is due to the zone of detachment. The numerical results indicate the effect of degradation of discontinuities and dynamic environment based on the amplification of the input loading results in the instability of the top layer of the slide. Both sliding and rotation contributes to the failure of the blocks.

4.135 Pande, A., Joshi, R. C. and Jalal, D. S. (2002). "Selected landslide types in the Central Himalaya: Their relation to geological structure and anthropogenic activities". Environmentalist Volume 22, Issue 3, pp 269-287. http://link.springer.com/article/10.1023%2FA%3A1016536013793

The paper describes landslide types in the Central Himalaya and their relationship to geological structure and anthropogenic activities. Bedding and joint plane dip slopes, high joint and joint set frequencies, low vegetation cover, high monsoonal rainfall, thin soil cover and anthropogenic activities were found to be the main causative factors of the landslides. Anthropogenic activities include local path, canal and road construction, mining and quarrying, overgrazing, deforestation and unscientific agricultural practices, such as tilling steeper slopes without contour benches and without provision of drainage ditches, and overcropping without giving rest to the overtaxed soils.

4.136 Pande, R. K. and Uniyal, A. (2007). "The fury of nature in Uttaranchal: Uttarkashi Landslide of the Year 2003". Disaster Prevention and Management: An International Journal Vol. 16 No. 4, pp 562-575. http://www.emeraldinsight.com/journals.htm?articleid=1626592

The study aims to highlight fundamental causes and effects of disasters in the northern district of Uttarkashi, which lies in the fragile mountains of Himalaya. Disasters such as the 1991 Uttarkashi Earthquake, the flash floods of the Bhagirathi river and the devastation caused by the Gyansu landslide are discussed. The Himalayan state of Uttaranchal has been witnessing the fury of nature for a long time. The Himalayan orogenic belt is tectonically active and subject to modifications by natural processes. Adding further to the fragility of this belt are the anthropogenic activities like the unplanned cutting of slope for construction activity, blasting of highly jointed rock mass for road construction and unplanned disposal of the slope cut debris material. The study is based on the data/information collected during the monsoon season from 15 June to 15 September 2003. The period is short for developing any hypothesis but sufficient care has been taken to consider vital factors. The study highlights fundamental causes and effects of the landslide and suggests steps to overcome them.

4.137 Pande, R. K. (2008). "Nainital: A landslide town of Uttarakhand (India)". Disaster Prevention and Management, Vol. 17 Iss: 4, pp.478 – 487. http://www.emeraldinsight.com/journals.htm?articleid=1742498

The paper gives a full description: Bending of rock beds, their disjointing, and disruption and drag-folding are characteristic features of a creeping mass. Tilted trees and poles are indicative of creep movement as seen on a number of hillslopes in and around Nainital town. It was found that, to meet the requirement, construction activities are in full pace, which have given rise to the new landslide problems or have aggravated the existing slope instability problems. The paper describes proposes systematic studies which are required to deal with every aspect of the outstanding problems of slope instability.

4.138 Pandey, A. C., Nathawat, M. S. and Singh, G. (2006). "Evaluating geo-aspects implications on landsliding in Himalayan terrain in a part of Aizwal District, Mizoram state using remote sensing and GIS". The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 34, Part XXX. http://www.isprs.org/proceedings/XXXVI/part4/WG-VIII-2-13.pdf

The paper demonstrates the use of remote sensing and GIS in evaluating geo-aspects implications on land sliding in Himalayan terrain. Remote sensing is an important and effective aiding tool in geological- geomorphological mapping in the Himalayan region where major parts of the terrain are inaccessible. Remotely sensed images provide a wealth of information, which permit evaluation of regional geological structures, broad lithological discrimination and spatial distribution of landforms. Landslide frequency and landslide density was evaluated in relation to various geoenvironmental parameters to visualize relative susceptibility of different terrain parameters to landslide occurrence. The maximum landslide frequency within a range of 50m distance from the road corroborates the fact that construction of roads is one of the prominent anthropogenic activities leading to an increase in the occurrence of landslides.

4.139 Pandey, A., Dabral, P. P., Chowdary, V. M. et al. (2008). "Landslide hazard zonation using remote sensing and GIS: a case study of Dikrong river basin, Arunachal Pradesh, India". Environmental Geology June 2008, Volume 54, Issue 7, pp 1517-1529. http://link.springer.com/article/10.1007/s00254-007-0933-1?no-access=true

In the present study, Landslide Hazard Zonation (LHZ) of Dikrong river basin of Arunachal Pradesh was carried out using Remote Sensing and Geographic Information System (GIS). Various thematic layers namely slope, photo-lineament buffer, thrust buffer, relative relief map, geology and land use / land cover map were generated using remote sensing data and GIS. The weighting-rating system based on the relative importance of various causative factors as derived from remotely sensed data and other thematic maps were used for the LHZ.

4.140 Pandey, R. J. (2013). "Landslide and risk assessment in Uttarakhand with special reference to Malpa". International Journal Of Innovative Research & Development Vol 2, Issue 3 pp. 197-205. http://www.ijird.com/index.php/ijird/article/download/35273/28469

A Malpa landslide occurred on 18th August during 00:30 to 03:00 AM. This devastated landslide took lives of more than two hundred persons along with sixty Kailash Mansarovar pilgrims. The whole Malpa village lost its very existence due to this landslide tragedy. The sixty members of the Kailash Mansarovar pilgrims lost their lives. In the economic loss the camp and residences of KMVN, the material and the minimum permitted amount of 500 dollars for payment to Chinese agency of the pilgrims was destroyed in the debris. The local residents of that area, who lost their lives, were mostly young and the earning members of their family. That is well known that the natural disasters cannot be avoided but all possible attempts to mitigate its affects should be made timely. The lesson learnt from Malpa landslide stresses upon the utilization of these experiences in future to mitigate the landslides.

4.141 Panigrahi, R. K. and Rout, M. (2012). "Rock engineering investigation and remediation for unstable hill rock slope: A new approach". Geotechnical and Geophysical Site Characterization 4 Edited by Paul W. Mayne CRC Press 2012 Pages 1213–1219. http://www.crcnetbase.com/doi/abs/10.1201/b13251-157

The outcome of field and investigation of unstable and prone to failure rock block are presented in this paper. Rock engineering investigation of unstable rock slope area are described based on different method such as Rock Mass Rating (RMR), Slope Mass Rating (SMR), Rock Mass Quality (Q) and Rock Defect study by determining the Block volume (Vb), volumetric joint count (Jv) etc. The paper mainly deals with rock slope characterization based on rock engineering investigation of establish the mechanism of failure and followed by remediation of rock slope.

4.142 Panigrahi, R. K. (2013). "Rock dynamic and fracture studies for hill rock slope". Proceedings of Indian Geotechnical Conference December 22-24, 2013, Roorkee. http://www.igs.org.in/igc2013/igc_2013_roorkee_proceedings/full_length_paper/9%20TH%20PDF/9%20Th-10.pdf

National and state highways aligned through unstable rock slope stretches in mountainous terrain are highly prone to failure and require a set of suitable remedial measures to stabilize them. The present paper deals with different types of geological and geotechnical investigations for rock slopes, Shear Strength of Rock Mass, rock dynamic studies, and fracture mechanics of rock along with other studies which help to evolve a set of cost optimized remedial measures for stabilization of rock slopes.

4.143 Panikkar, S.V., Subramanyan, V. (1996). "A geomorphic evaluation of landslides around Dehradun and Mussoorie, Uttar Pradesh, India". Geomorphology, Vol. 15, pp 169-181. http://www.sciencedirect.com/science/article/pii/0169555X9500121K

Various geomorphological parameters have been assessed, in conjunction with the geological and anthropogenic aspects, to evaluate the occurrence of the different types of landslides in the area. Seventy-five landslides were identified by remote sensing. These were studied in the context of geological aspects such as lithology, proximity to active faults and lineament density, geomorphological aspects such as landform, slope, lateral erosion by streams, drainage texture, spring sapping, elevation difference between adjacent valleys, altitude and relief and anthropogenic factors including landuse/land cover and distances from roads. The important causes were found to be lithology, proximity to the active faults (Main Boundary Thrust and Sairku fault), slope angle and aspect, lateral erosion by stream undercutting and deforestation due to human interference. The triggering factors include rainfall and seismicity. The preventive measures to be adopted to stabilise the slopes have also been described.

4.144 Pardeshi, S. D., Autade, S. E. and Pardeshi, S. S. (2013). "Landslide hazard assessment: recent trends and techniques". Springer Plus a SpringerOpen Journal. http://www.springerplus.com/content/2/1/523

It is a review of literature published in recent years on landslide hazard mapping. Landslides are influenced by several preparatory and triggering factors which vary significantly from region to region. It is therefore difficult to determine weights for given parameter. The assignment weights based on relative importance of landslide causative factors is determined by several LHZ methods differently. Heuristic and semi quantitative techniques involve subjectivity in assigning of weights therefore validity of these maps cannot be assessed. Quantitative methods on the other hand, provide objective methods for determining weights for a given parameter based on their relationships with landslide occurrence. Multi-criteria decision approach provides tools to determine weights based on pair wise comparison.

4.145 Pareta, K. and Pareta, U. (2012). "Landslide modeling and susceptibility mapping of Giri River watershed, Himachal Pradesh (India)". International Journal of Science and Technology Volume 1 No. 2, February, 2012. https://www.academia.edu/attachments/30866402download_file?st=MTQwMTE2ODc4NywxNjQuMTAwLjEwNS4xMzcsMTc2OTg1NQ%3D%3D&ct=MTQwMTE2ODgzOCwxNzY5ODU1

Giri river watershed of Yamuna basin was selected for the model implementation. Important terrain factors, contributing to landslide occurrences in the region, were identified and corresponding thematic data layers were generated. These data layers represent the soil, land use, geological, topographical, and hydrological conditions of the terrain. A numerical rating scheme for the factors was developed for spatial data analysis in a GIS. The resulting landslide susceptibility map delineates the area into different zones of four relative susceptibility classes: very high, high, moderate, and low. The very high susceptibility class has located in the Rawana, Jabyana, Gusan, Chandesh and Parar villages. The susceptibility map was corroborated by correlating the landslide frequencies of different classes. This has shown a close agreement with the existing field variability condition.

4.146 Pareta, K., Kumar, J. and Pareta, U. (2012). "Landslide hazard zonation using quantitative methods in GIS". International Journal of Geospatial Engineering and Technology Vol. 1, No. 1, 2012, pp. 1-9. https://www.academia.edu/attachments/30866409/download_file?st=MTQwMDEzODg4NSwxNjQuMTAwLjEwNS4xMzcsMTc2OTg1NQ%3D%3D&ct=MTQwMDEzODkzMywxNzY5ODU1

It is an attempt towards development of a landslide model by using multi-criteria decision analysis in GIS and remote sensing techniques for landslide hazard zonation. Giri river watershed of Yamuna basin was selected for the model implementation. WorldView-02-MS and ResourceSAT-2 LISS- 4-Mx satellite imageries, SoI topographical maps, and field data were used as inputs to the study. These data layers represent the soil, land use, geological, topographical, and hydrological conditions of the terrain. A numerical rating scheme for the factors was developed for spatial data analysis in a GIS. The resulting landslide hazard zonation map delineates the area into different zones of four relative HZ-classes: very high, high, moderate, and low.

4.147 Pareek, N., Sharma, M. L. and Arora, M. K. (2010). "Impact of seismic factors on landslide susceptibility zonation: a case study in part of Indian Himalayas". Landslides Volume 7, Issue 2, pp 191-201. http://link.springer.com/article/10.1007/s10346-009-0192-1

Landslides are one of the most widespread natural hazards in high mountain terrains such as the Himalayas, which are one of the youngest tectonically and seismically active mountain ranges in the world. The crustal movements along the longitudinal thrusts and transverse faults give rise to earthquakes and in turn initiate landslides in the region. In fact, in addition to various static factors causing landslides, earthquakes are one of the major causes of landslides. It is thus imperative to incorporate seismic factor also while carrying out landslide susceptibility zonation map preparation in a seismically active areas like Garhwal Himalayas. In this paper, a study on the effect of earthquakes on landslide susceptibility zonation has been demonstrated by taking Chamoli earthquake as an example.

4.148 Pareek, N., Pal, S., Sharma, M. L. et al. (2013). "Study of effect of seismic displacements on landslide susceptibility zonation (LSZ) in Garhwal Himalayan region of India using GIS and remote sensing techniques". Journal Computers & Geosciences Volume 61, December, 2013 Pages 50-63. http://dl.acm.org/citation.cfm?id=2538070

An attempt has been made to estimate the seismic displacements using Differential Synthetic Aperture Radar Interferometry (DIn SAR). European Remote Sensing Satellite-1/2 (ERS-1/ 2) SAR images have been used for preparing differential interferogram. Geometric and temporal decorrelation in SAR images is very high in the study area, which limits the use of DInSAR for displacement estimation. Theoretical displacement has been estimated using fault displacement modeling parameters for Chamoli earthquake.

4.149 Parkash, S. and Awasthi, A. K. (2001). "Slope movement through time at Matli Site, Uttarkashi District, Garhwal Himalaya, India". Himalayan Geology Vol.22 (2), pp.109-120.

Geoscientific studies on landslides often call for instrumentation and monitoring of the potentially unstable and failed slopes in order to understand the time dependent behavior for risk estimation and for planning appropriate corrective measures. Besides forecasting the long term behavior of slopes, the studies also help in evaluating the efficacy of existing control measures and the need for possible additional measures. The study provides feedback from observational data on slope movement through time at one of the problematic sites in Bhagirathi valley of Garhwal Himalaya in India.

4.150 Parkash, S., Sah, M. P. and Virdi, N. S. (2001). "Causes and control of Karsingsa Landslide, Arunachal Pradesh". Structure and

Tectonics of the Indian Plate, Bull. I. G. A., Chandigarh, Vol. 34 (1&2), 171-180.

Erosion and landsliding near Karsingsa nala have caused instability/ failure of slopes. The paper discusses the causes of failure and suggests appropriate remedial measures at proper locations which includes seepage control, removal of all obstructions to the flow of water and maintenance of existing drains, provision of artificial drains of appropriate material and size, protection of river bank with wire crated stone walls and spurs, construction of retaining structures on uphill and downhill sides and vegetative turfing of cut slopes.

4.151 Parkash, S. and Awasthi, A. K. (2002). "Geotechnical investigation and stability analysis of slopes at Malti site in Garhwal Himalaya". Journal of Rock Mechanics & Tunnelling Technology Vol 8 No. 1. http://www.isrmtt.com/paper_view.php?e_id=17&vol_id=9

The paper deals with the geotechnical investigations of slope mass, comprising rocks and overburden soils, which failed along the state highway (SH-53) near village Matli in the Uttarkashi district of Garhwal Himalaya, India. The site was taken up for detailed investigations which included topographical, geological, geomorphological, morphometric, geotechnical, instrumentation and monitoring studies. The present paper aims to discuss the results of geotechnical investigations of the slope materials viz. point load and uniaxial compressive strength of the various rocks exposed at the affected site, grain size analysis including hydrometer analysis, bulk density, water content, liquid and plastic limits, cohesive strength and friction angle of the overlying soil mass in the failed area.

4.152 Parkash, S., Sah, M. P. and Virdi, N. S. (2002). "Inventory of slope failure along National Highway -52A between Bhanderdewa and Itanagar, Arunachal Pradesh". Natural Hazard and their Mitigation, Bulletin of the Indian Geologist Associtation Vol 35 pp 49-60.

The paper presents an inventory of slope failure and the data include their location, geology, geomorphology, hydrology, landuse and anthropogenic activity between Bhanderdewa and Itanagar. In all, 17 zones of slope failures have been observed over a road length of about 29 km. Frequently of slope failure is 0.59 per kilometer or on slide after every 1.7 km of the road length. Slope failures were mainly debris slides, debris falls or debris flows of varying magnitudes that have occurred generally during the rainy periods. Appropriate measures have been proposed to mitigate slope failures.

4.153 Parkash, S., Awasthi, A. K. and Virdi, N. S. (2003). "Stability assessment of rock slopes using modified SMR technique and kinematic analysis along SH-53 between Dunda and Uttarkashi, Uttaranchal". Journal of the Geological Society of India Vol. 61 pp. 595-60.

SMR technique is a field based study which involves collection of data on rock types, their strength, quality, condition of discontinuities, spacing of discontinuities, orientation of discontinuities, ground water conditions and method of slope excavation etc. Eight sites, selected on the basis of good exposures of the rock outcrops and the slopes that have been blasted or mechanically disturbed during road construction or at some later stage, were studied and analyzed for their potential degree of stability using SMR approach. The kinematic method also helped in identifying the potentially unfavorable planes that could be involved in the movement.

4.154 Parkash, S. and Awasthi, A. K. (2002). "Matli landslide, Garhwal Himalaya - A case study". Proceedings of the ISEG Colloquium on Role of Engineering Geology in National Development.

The Matli landslide, near Uttarkashi city is one of problematic sites where the road used t be get blocked from several hours to days due to landsliding. Detailed topographical, geological, geomorphological, morphometric, geotechnical, instrumentation and monitoring studies were undertaken to understand the nature and behavior of slopes and the processes acting on them. The paper presents the history of landslides and discusses the results of the investigations. Based on the studies, remedial measures were suggested to prevent/control the slope movements.

4.155 Parkash, S. (2005). "A case study on Matli landslide, Garhwal Himalaya, India". International Conference on Landslide Risk Management, Vancouver, Canada.

The paper presents an integrated comprehensive study of a problematic failed slope in the Lesser Himalayan zone of Garhwal region in India. The study included recurrence history of the site, topographical studies, geology and geomorphology of the site, morphometric assessment, geotechnical analysis, instrumentation and monitoring of slope movements. The paper discusses the outcomes of this attempt.

4.156 Parkash, S. (2011). "Historical records of socio-economically significant landslides in India". Journal of South Asia Disaster Studies Vol. 4 No. 2.

Landslides are widespread, frequent and sudden hazards that strike human lives, livestock, livelihood, living places and environment in an adverse manner leading to colossal losses and damages directly or indirectly in a cumulative way. This paper is an attempt to compile the information related to the incidents and impacts of landslides in terms of their location, time of occurrence and losses/damaged caused to the humans, habitations and highways. The list of landslide incidences comprises 371 socio-economically significant vents with respect to the above said point of view.

4.157 Parkash, S. (2012). "Ethics in disaster management". Annals of Geophysics Vol 55 No 3. http://www.annalsofgeophysics.eu/index.php/annals/article/view/5633/6034

This article mentions some cases of rumors about natural disasters, and particularly earthquakes, and the response of society, media and government. It emphasizes the role of geoscientists as the ethical responsibility to inform the public about the actual situations and the geohazards, to avoid panic caused by rumors from non-specialists or hyperactive pseudo experts. This article indicates the recent rumors about a lake outburst, flash floods, and volcanic activities after a moderate earthquake (M 6.9, September 18, 2011) in the Sikkim State of India, and considers the actions taken by the geoscientific community to correctly inform people about the real situation.

4.158 Parkash, S. (2012). "An overview of the national guidelines for management of landslides with particular reference to infrastructure projects". Journal of Water and Energy International Vol. 69 Iss. 3 pp 29-37. http://www.indianjournals.com/ijor.aspx?target=ijor:wei&volume=69&issue=3&article=006

The paper focuses mainly on the soft infrastructure, with particular emphasis on landslide risk reduction related to development, maintenance and management of hard infrastructure in hilly terrains. It is well known fact that unplanned and unscientific developments have aggravated the incidences and impacts of disasters/landslides on the society as well as environment in hills, resulting in huge losses. According to an economic estimate, India loses about Rs.100 billion annually on an average due to landslides. Besides the economic losses, hundreds of human lives are lost and thousands of people become homeless and/or jobless.

4.159 Parkash, S. (2013). "Education, training and capacity development for mainstreaming landslides risk management". Landslide Science and Practice 2013, pp 257-264. http://link.springer.com/chapter/10.1007%2F978-3-642-31313-4_33

The multifaceted aspects of landslide management, especially risk assessment, prevention, mitigation, preparedness and response require an inter-disciplinary cross-sectoral and multi-level action strategy. But the success of the strategy depends on education, training and capacity building of all stakeholders to make them act in an integrated manner towards a convergent holistic approach for mainstreaming landslides risk reduction and disaster management. The paper discusses about the issues and initiatives proposed or taken in this direction, with particular reference to India.

4.160 Parkash, S. (2013). "Earthquake related landslides in the indian himalaya: experiences from the past and implications for the future". Landslide Science and Practice, pp 327-334. http://link.springer.com/chapter/10.1007/978-3-642-31427-8_42

Most parts of the Indian Himalaya fall in seismic zone V and IV, indicating a high degree of susceptibility to earthquakes. Although numerous studies on earthquake risk assessment have been done by different researchers yet very few of these studies and reports have focused on landslides related to earthquakes. It has been observed globally that many casualties during an earthquake in a hilly terrain are attributed to the incidences of landslides triggered by the earthquake and the response actions are also hurdled by the rockfalls/ landslides along the highways. An attempt has been made to differentiate freshly triggered and reactivated co-seismic landslides in earthquake affected areas as well as post-seismic landslides.

4.161 Parkash, S. (2013). "Capacity development for landslides risk reduction in India". Landslides: Global Risk Preparedness pp 369-383. http://link.springer.com/chapter/10.1007/978-3-642-22087-6_26

Disaster management, public safety and sustainable development initiatives in areas with hilly terrain have identified capacity development for landslides risk reduction as one of the essential components of the planning, policy and decision making process at different levels in all sectors. The present chapter discusses the terms and concepts related to capacity, capacity development, levels and process of capacity development, initiatives for landslides risk reduction through capacity development at global, regional, national and local levels by the different stakeholders in capacity development like UN organizations, regional and international organizations / networks, government and non-government bodies.

4.162 Parkash, S. (2013). "Methodology used for community based multi-hazard risk management in Garhwal Himalaya, Uttarakhand state, India". Forms of Community Participation in Disaster Risk Management Practices.

In the past, many communities in Uttarakhand suffered from major earthquakes, landslides, debris flows, flash floods, forest fires, hailstorms and lightning etc. During the last one decade, the interventions made by the governmental and non-governmental organizations through various disaster risk reduction projects as well as some pilot programmes undertaken under the leadership of local community-based organizations have built the communities capacity to prepare themselves against such disasters. The community based disaster risk management, the process of operation, the outcome and its sustenance are discussed.

4.163 Parvaiz, I., Champatiray, P. K., Bhat, F. A. et al. (2012). "Earthquake-induced landslide dam in the Kashmir Himalayas". International Journal of Remote Sensing Volume 33, Issue 2. http://www.tandfonline.com/doi/abs/10.1080/01431161.2010.512948#.U5ANUHKSwqM

The Kashmir earthquake of 2005 triggered numerous landslides in inaccessible areas of the western Himalayas, which could be mapped using satellite remote sensing. The largest recorded seismicity-induced landslide dammed a river, which resulted in the formation of a stream in the toe region and created two reservoirs that pose an enormous threat in the event of a landslide dam breach. Using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data sets corresponding to the pre- and post-earthquake period and derived digital elevation models, landslide-induced lakes were monitored. The aerial extent, depth profile and volume of both the reservoirs were determined. This study has demonstrated the utility of ASTER data in providing valuable information that is critical for hazard mitigation in case of a landslide dam breach.

4.164 Patwary, M. A. A., Champati Ray, P. K. and Parvaiz, I. (2009). "IRS-LISS-III and PAN data analysis for landslide susceptibility mapping using heuristic approach in active tectonic region of Himalaya". Journal of the Indian Society of Remote Sensing Volume 37, Issue 3, pp 493-509. http://link.springer.com/article/10.1007/s12524-009-0036-4

The paper state that using remotely sensed data and Geographic Information System (GIS), geological and terrain factors can be integrated for preparation of factor maps and demarcation of areas susceptible to landslides. Moderate to high resolution data products available from Indian Remote Sensing satellites have been utilized for deriving geological and terrain factor maps, which were integrated using knowledge driven heuristic approach in Integrated Land and Water Information System (ILWIS) GIS. The resultant map shows division of the area into landslide susceptibility classes ranked in terms of hazard potential in one of the structurally disturbed zones in western Himalaya around Rishikesh.

4.165 Paul, S. K., Bartarya, S. K., Rautela, P. et al. (2000). "Catastrophic mass movement of 1998 monsoons at Malpa in Kali Valley, Kumaun Himalaya (India)". Geomorphology Volume 35, Issues 3–4, November 2000, Pages 169–180. http://www.sciencedirect.com/science/article/pii/S0169555X00000325

The paper documented a catastrophic landslide, initiated on 18 August 1998 near Malpa Village in Kali Valley of Higher Kumaun Himalaya and killed 221 persons. The landslide was a complex rock fall–debris flow. The mass movement generated around one million cubic metres of debris and partially blocked the Kali River, Malpa Gad (a tributary of Kali) being blocked completely. The slide clearly demonstrates the distressed state of the rock mass in the Himalayan region due to the ongoing northward drift of the Indian plate.

4.166 Peshwa, V. V. and Kale, V. S. (1988). "Role of remote sensing in the detection of potential sites for landslides/rockfall in the Deccan Trap lava of Western India". Environmental Geotechnics and Problematic Soils and Rocks. https://www.academia.edu/attachments/31692808/download_file?st=MTQwMDY2MTgzOCwxNjQuMTAwLjEwNS4xMzcsMTc2OTg1NQ%3D%3D&ct=MTQwMDY2MTg5MSwxNzY5ODU1

The paper state that the investigations using remotely sensed data on two scales (i.e. low scale for regional studies and high scale for local identifications), could provide considerable information regarding the failure susceptibility of the escarpment faces in the Western Ghats.

4.167 Pradhan, B., Singh, R. P. and Buchroithner, M. F. (2006). "Estimation of stress and its use in evaluation of landslide prone regions using remote sensing data". Elsevier Advances in Space Research Volume 37, Issue 4, 2006, Pages 698–709. http://www.researchgate.net/profile/Biswajeet_Pradhan/publication/222169973_Estimation_of_stress_and_its_use_in_evaluation_of_landslide_prone_regions_using_remote_sensing_data/file/e0b4952d40933bbc59.pdf

Terrain information such as land cover, geology, lineament, faults, mega faults, geomorphology and drainage has been derived from the satellite imageries, and the existing thematic information has been updated to enable the quantification of landslide causative parameters. Spatial and temporal multi-layered information have been used for landslides hazard susceptibility analysis. The qualitative hazard analysis has been carried out using the map overlying techniques in GIS environment along the central part of Himalayan region. It has been observed that the high potential zones have been found to have very high lineament density, moderate to low drainage density and high slope areas of the terrain. On the basis of the geological and morphological analysis, it is further suggested that the combined impacts of the crushed nature of bed rock (due to the neo-tectonic activities), heavy rainfall and lack of vegetation cover cause persistent recurrence of landslides along this region.

4.168 Pramada, V. (2007). "Numerical and statistical modeling for stabilization of landslides". An International journal of Applied Mathematics and Computation, Science Direct, Vol. 186, pp. 1083-1093.http://www.sciencedirect.com/science/article/pii/S0096300306010344

In this paper an attempt has been made to find the maximum quantity of discharge of water flowing into the trench drain by two methods (i) through comprehensive diagram and (ii) through mathematical models. A comprehensive diagram for quantity of discharge of water flowing into the trench drain has been plotted from finite element solution for different anisotropic soil media, from which maximum quantity of discharge of water flowing into the drain corresponding to optimum spacing can be identified. In the second method mathematical models have been developed with the help of the numerical data on the maximum quantity of water flowing into the trench drain, the geometrical details such as depth, width, spacing of the trench drain and different types of soil conditions. The comprehensive diagram and the mathematical models will be of great use for developing guidelines for designing the trench drainage system within the anisotropic soil media for stabilizing landslides.

4.169 Raj, R. and Parkash, S. (2011). "A preliminary investigation of important landslides in Goa - A case study". Disaster & Development Vol. 5, No. 1 & 2, April & November.

The paper presents observations of some of landslides in Goa, India, and includes site-specific information on location, geology, causes and impact of landslides, field characteristics, various mitigation measures undertaken by concerned departments, and the efficacy of remedial measures. The survey indicates that there is an urgent need to study these landslides in a holistic manner to avoid future landslide risks to the people, properties, infrastructures and other developmental activities in the region.

4.170 Raj, T. N., Mohan, V. R., Backiaraj, S. et al. (2011). "Landslide hazard zonation using the relative effect method in South Eastern Part of Nilgiris, Tamilnadu, India". International Journal of Engineering Science and Technology (IJEST) Vol. 3 No. 4 April 2011. http://www.ijest.info/docs/IJEST11-03-04-249.pdf

The landslide hazard and the effect of landslide-related factors at South Eastern part of Nilgiri District, Tamilnadu using the Relative Effect Method (REM) model, Geographic Information System (GIS) and remote sensing data have been evaluated. The authors suggest the Relative Effect Method (REM), which is statistical method using GIS software for landslide hazard zonation. This method determines the relative effect (RE) of each unit, such as surface geology, slope morphometry, climatic conditions, land use and land cover by calculating the ratio of the unit portion in coverage and landslide.

4.171 Ramakrishnan, S. S., Kumar, V. S., Sadiq, Z., et al. (2002). "Landslide disaster management and planning-A GIS based approach". Indian Cartographer. http://incaindia.org/INCA-PDF/vol22/32.pdf

In this study, a methodology has been developed to identify landslide prone areas using Photogrammetry with 3D GIS. A small area in the Kothagiri taluk of the Nilgiris district has been selected for this study. Orthophoto map was generated by ORTHOCOMP from aerial photograph on 1: 8,000 scale. The advantage of the high-resolution data helps in deriving 2 m contour, which is ideal to get the elevation and slope values of the terrain.

4.172 Ramakrishnan, D., Ghose, M. K., Chandran, R. V., et al. (2005). "Probabilistic techniques, GIS and remote sensing in landslide

hazard mitigation: A case study from Sikkim Himalayas, India". Geocarto International, Vol. 20, No. 4, December 2005. http://www.researchgate.net/profile/Ramakrishnan_D/publication/233035767_Probabilistic_Techniques_GIS_and_Remote_Sensing_in_Landslide_Hazard_Mitigation_A_Case_Study_from_Sikkim_Himalayas_India/file/9c960526237cf7cfe6.pdf

This paper evaluates the landslide hazard zones using information theory (I) and regression analysis (R) in GIS environment. In all, 14 variables are identified as conditioning and triggering factors and accordingly probabilistic prediction maps are prepared individually by both the methods. The results thus generated are compared and classified into three slope instability zones viz. low, medium and high on the basis of histogram distribution. Further, these probabilistic prediction maps are compared with the actual landslide map generated from recent satellite data (January 2002) for the accuracy of prediction. The generated hazard maps agree with the observed landslide incidences. Thus, the proposed methodology can be utilized effectively in landslide hazard zonation studies.

4.173 Ramana, Y. V. and Gogte, B. S. (1982). "Quantitative studies of weathering in saprolitized charnockites associated with a landslip zone at the porthimund dam, India". Engineering Geology Volume 19, Issue 1, Pages 29–46. http://www.sciencedirect.com/science/article/pii/0013795282900047

Studies on saprolitized charnockites associated with a landslip observed in the Blue Mountains in close proximity of the Porthimund Dam (11°22′E 76°342 303 N), Nilgiris District, Tamilnadu State, South India, are reported. Such studies should prove valuable in the mapping of weatherability zones and the assessment and determination of foundation conditions.

4.174 Ramana, Y. V. and Gogte, B. S. (1990). "Catastrophic landslip activity in two hard rock terrains of peninsular India". Environmental Geology and Water Sciences Volume 15, Issue 3, pp 199-205. http://link.springer.com/article/10.1007%2FBF01706411

This paper presents the case histories of two catastrophic landslips in hard rock terrains with varied climatic and geological environments. The first slip is associated with a power project in very close proximity (200 m) of the Porthimund Dam (11°222 N, 76°342 302 2 E), in a charnockitic terrain in the Nilgiri hills (Tamil Nadu), and the second is associated with a railroad structure (19°522 52 2 N, 78°172 202 2 E), in Adilabad district (Andhra Pradesh), in a basaltic terrain.

4.175 Ramani, S. E., Pitchaimani, K. and Gnanamanickam, V.R. (2011). "GIS based landslide susceptibility mapping of Tevankarai Ar sub-watershed, Kodaikkanal, India using binary logistic regression analysis". Journal of Mountain Science Volume 8, Issue 4, pp 505-517. http://link.springer.com/article/10.1007%2Fs11629-011-2157-9

An attempt is made to map the landslide susceptibility in Tevankarai Ar sub-watershed, Kodaikkanal, India using binary logistic regression analysis. Geographic Information System is used to prepare the database of the predictor variables and landslide inventory map, which is used to build the spatial model of landslide susceptibility. The model describes the relationship between the dependent variable (presence and absence of landslide) and the independent variables selected for study (predictor variables) by the best fitting function. A forward stepwise logistic regression model using maximum likelihood estimation is used in the regression analysis.

4.176 Ramesh, M. V. (2009). "Real-time wireless sensor network for landslide detection". Third International Conference on Sensor Technologies and Applications IEEE Computer Society. http://www.researchgate.net/profile/Maneesha_Vinodini_Ramesh/publication/221933039_Real Time_Wireless_Sensor_Network_for_Landslide_Detection/file/50463528ffdd01a5a8.pdf

This paper discusses the development of a wireless sensor network(WSN) to detect landslides, which includes the design, development and implementation of a WSN for real time monitoring, the development of the algorithms needed that will enable efficient data collection and data aggregation, and the network requirements of the deployed landslide detection system. The actual deployment of the test bed is in the Idukki district of the Southern state of Kerala, India, a region known for its heavy rainfall, steep slopes, and frequent landslides.

4.177 Rao, P. J., Babu, G. L. S, Kumar, K. et al. (1997). "Investigation, instrumentation and monitoring of landslide at Powari, Kinnaur District (H.P.) - A case study". Journal of the Indian Roads Congress, Volume: 58, Issue Number: 2. http://trid.trb.org/view.aspx?id=539505

This paper reports the investigation, instrumentation, monitoring, and mathematical analysis of slope movements and landslides. It details geological considerations and geotechnical aspects, such as magnitude, rate, and direction of slope movement, and stability analysis of slopes. It emphasizes the importance of instrumented monitoring of slope movements in areas of India liable to landslides.

4.178 Rath, S., Sahoo, B. P. S., Pandey, S. K. et al. (2013). "Multi-parameter decision support with data transmission over GSM/GPRS network: a case study of landslide monitoring". National Conference on Modeling Design Solutions for Technology Development & Decision Support (MODSOLVE), CSIR-NISCAIR, May 2013. http://arxiv.org/ftp/arxiv/papers/1312/1312.4179.pdf

This paper briefly addresses earth observation and areas of critical importance to people and society. A case study has also been carried out for disaster like Landslide in the North Eastern region of India. Application software has been developed for the said study for online data acquisition and analysis with pre-disaster early warning system. The system monitors the changing geotechnical condition of this region using various geo-technical sensors like Rain gauge, In-place Inclinometer, Tilt-meter, Piezo-meter and Crack meter. This paper also touches upon the aspects of data transmission over Global System for Mobile Communication (GSM) / General Packet Radio Service (GPRS) to a remote data center.

4.179 Rautela, P. and Thakur, V. C. (1999). "Landslide hazard zonation in Kaliganga and Madhyamaheshwar valleys of Garhwal Himalaya: A GIS based approach". Himalafan Geology. Vo\. 20(2), 1999, pp. 31-44. http://dmmc.uk.gov.in/files/Documents/LANDSLIDEHAZARD.pdf

Landslide hazard zonation (LHZ) and risk assessment studies have been carried out in Kaliganga and Madhyamaheshwar valleys under Geographical Information System (GIS) environment employing statistical index method. Geology, structure, landuse, old slides, slope, shape of the slope, slope aspect, and drainage are the different parameters affecting mass movement and have been considered for LHZ exercise. For risk assessment population (1991 census) bas been considered the sole criteria as most infrastructures in the region are interwoven around population centers. This exercise bas brought out areas and population groups that are particularly vulnerable to landslides.

4.180 Rautela, P. and Lakhera, R. C. (2000). "Landslide risk analysis between Giri and Tons Rivers in Himachal Himalaya (India)". International Journal of Applied Earth Observation and Geoinformation Volume 2, Issues 3–4, Pages 153–160. http://www.sciencedirect.com/science/article/pii/S0303243400850096

The area around Sataun in the Sirmur district of Himachal Pradesh, India (falling between the rivers Giri and Tons; both tributaries of the Yamuna River) was studied for landslide vulnerability on behalf of the inhabitants. The study was made using extensive remote sensing data (satellite and airborne). It is well supported by field evidence, demographic and infrastructural details and aided by Geographic Information System (GIS) based techniques. Field observations testify that slope, aspect, geology, tectonic planes, drainage, and land use all influence landslides in the region. These parameters were taken into consideration using the statistical approach of landslide hazard zonation.

4.181 Rautela, P. and Paul, S. K. (2001). "August, 1998 landslide tragedies of central Himalayas (India): Learning from experience". International Journal of Environmental Studies Vol. 58, pp. 343-355. http://dmmc.uk.gov.in/files/Documents/CENTRAL%20HIMALAYAS.pdf

During the monsoons of 1998 Central Himalaya was struck hard by landslides. Major incidences took place in Kali, Kaliganga and Madhyamaheshwar river valleys and the death toll in these crossed three hundred. Fieldwork undertaken in these valleys has brought forth interrelationship between various geomorphic parameters and the landslides. At the same time, it was observed that under compulsions of increasing population and fragmenting social set-up, traditional resource management strategy is often bypassed aggravating the problem. Based on these experiences and laboratory based GIS and remote sensing analysis of the parameters affecting landslides an anthropocentric approach for mitigating disasters in the region is proposed.

4.182 Ravindran, A. A. and Prabhu, H. M. A. K. (2012). "Prediction and control of landslide using W-4 system - 2d electrical resistivity imaging technique in Padukadu, Ooty, Nilgiri District, Tamilnadu, India". ARPN Journal of Earth Sciences VOL. 1, NO. 2. http://www.arpnjournals.com/jes/research_papers/rp_2012/jes_1112_08.pdf

W-4 is the Multi Function Digital DC Resistivity IP/Meter, our latest all-purpose model equipped with the latest technologies. It features multiple functions, high accuracy, fast speed, high reliability and excellent expandability. It can function General resistivity/IP sounding and Multi-Electrode 2D/3D resistivity imaging. The survey was carried out using multi electrodes and W-4 resistivity system with help of Wenner configuration. The study reveals that the investigation area is highly vulnerable to landslide which is evident from the low and high resistivity zone of the study area. The water body with loose sand is identified from low resistivity, highly weathered zone indicate the charnockite and compact charnokite gives high resistivity zone in the study area. The case study focuses in the palaeoslides and with the related upcoming landslides in the study area. The resistivity image obtained from the Res2DINV software is used for the prediction of landslide in Ooty area.

4.183 Rawat, R. K. (2005). "Geotechnical Investigations of Chandmari Landslide located on Gangtok - Nathula road, Sikkim Himalaya, India". Himalayan Geology, Vol. 26 (2), pp. 309-322. http://www.himgeology.com/himgeol/vol_26(2)/abstract1.htm

Chandmari landslide is located at the back of Gangtok town at about 11 km on Nathula road. The local people first noticed the slope movement in the year 1966 when a minor subsidence at road level came into sight which is continuously extending during every monsoon, resulting in loss of property, lives and recurrent disruption of the road network. Keeping in view the severity of the problem, the author adopted a systematic approach to study primarily the causes and mechanism responsible for slope failure and secondly to calculate a factor of safety, based on the actual site conditions and the physico-mechanical properties of the slide material. Lastly, an attempt has been made to suggest some remedial measures based on the present studies, which might be useful to control further slope movement.

4.184 Rawat, M. S., Joshi, V., Rawat, B. S. et al. (2011). "Landslide movement monitoring using GPS technology: A case study of Bakthang Landslide, Gangtok, East Sikkim, India". Journal of Development and Agricultural Economics Vol. 3(5), pp. 194-200. http://www.academicjournals.org/article/article1379504619_Rawat%20et%20al.pdf

To monitor the landslide phenomena, it is imposed to represent the area under investigation by a number of points that are monumented durably. Some stations are used to define a stable reference frame and remaining stations are the monitoring points situated in the deformation area. In this way, the determination of the movement of the control stations is done relatively to the reference ones. Bakthang falls landslide selected for its movements. This paper therefore highlights an investigation of landslide motions to discover possible precursors of mass movement and periodical changing of landslide.

4.185 Rawat, M. S., Rawat, B. S., Joshi, V. et al. (2012). "Statistical analysis of landslide in South District, Sikkim, India: using remote sensing and GIS". IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). http://www.iosrjournals.org/iosr-jestft/papers/vol2-issue3/I0234761.pdf

Landslide Hazard Zonation (LHZ) of South district, Sikkim State was carried out using Remote Sensing and Geographic Information System (GIS). Various thematic layers were generated using remote sensing data and GIS. The weighting rating system based on the relative importance of various causative factors as derived from remotely sensed data and other thematic maps were used for the LHZ. The different classes of thematic layers were assigned the corresponding rating value as attribute information in the GIS and an ''attribute map'' was generated for each data layer. Each class within a thematic layer was assigned an ordinal rating from 0 to 9. Summation of these attribute maps were then multiplied by the corresponding weights to yield the Landslide Hazard Index (LHI) for each cell. Using trial and error method the weight-rating values have been re-adjusted. A LHZ map was prepared showing the five zones, namely ''very low hazard'', ''low hazard'', ''moderate hazard'', ''high hazard'' and ''very high hazard'' by using the ''slicing'' operation.

4.186 Rentala, V. and Neelima Satyam D. (2011). "Numerical modeling of rock slopes in Siwalik Hills near Manali region: A case study". The Electronic Journal of Geotechnical Engineering Vol 16, pp 763-783. http://www.ejge.com/2011/Ppr11.056/Ppr11.056ar.pdf

In this research paper, an endeavor has been made to model an active slope between Longitudes 32°07′N-32°13′N and Latitudes 77°08′E-77°11′E in the Manali area of Himachal Pradesh, India. The slope has been modeled using PLAXIS 2D a Finite Element Method considering both static and dynamic cases. In the present research work, detailed analysis has been carried out by considering different joint sets in three stages for predicting the behavior of the rock slopes for different joint sets considered in the present research work. This research paper provides very useful information in the deformation mechanism of the rock slopes in Siwalik Hills. In first and second cases the slope is stable but in dynamic case the slope is critical since the displacements observed in the model will reflect the settlement. Excavation profiles of the slopes can be optimized and analyses can be carried out for those displacement profiles.

4.187 Ritika, Chatterjee, K. and Choudhury, D. (2011). "Effect of blast load on seismic slope stability using FLAC". Proceedings of Indian Geotechnical Conference December 15-17, 2011, Kochi (Paper No. K-099). http://gndec.ac.in/~igs/ldh/conf/2011/articles/Theme%20-%20K%205.pdf

The numerical models of soil slope have been analyzed under seismic and blast loadings by using the finite difference based geotechnical software FLAC2D. The necessity of counting blast load in seismic slope stability analysis is revealed. It is found that for the case of clays, there is a need for considering blast loading in the seismic analysis, because vertical displacement for blast load is significant. However, in sand it is optional to include blast load, because slope may not be stable in the seismic case itself due to shear fluidization. And if also dense sandy slope becomes gentler, the vertical displacement in seismic case is coming more significant as compared to blast load.

4.188 Roy, T. B. and Saha, S. (2011). "Study on landslide incidents of Paglajhora and adjacent areas –An overview; Kurseong Block, Darjeeling, India". Indian Streams Research Journal Vol - I, ISSUE - IX October 2011: Geography. http://www.isrj.net/Uploaded Data/513.pdf

The Himalayan regions are susceptible to extremely steep and corrugated slope dispositions with frequent instability over the unsaturated and solifluctional plasticized mass of rocks. Most of the studies conducted on the Himalayan regions include the demarcation of sensitive landslide susceptibility areas. The aim and objective of the study is identification of the important causes of land slide, establishment of cause effect relationship of landslides, analysis of relationship of landslide effects and its impact on social lifestyle and sketch building and generalization of important landslide types in the area.

4.189 Sah, M. P., Virdi N. S. & Tarya S. K. (1996). "Slope failure and Damming of River Channels: Some examples from the Satluj Valley, Himachal Pradesh". Himalayan Geology, Vol.17, pp.183-191. http://www.himgeology.com/himgeol/volume17/abstract21.htm

The Satluj valley and its major and minor tributaries have faithfully recorded the past history of damming due to glacial moraines, landslides and rock falls and creation of temporary lakes which were subsequently drained out. These are now reflected by extensive fluvial, glaciofluvial and lacustrinal deposits occurring at various levels along the Spiti, Ropa, Baspa and the Satluj itself. The Satluj river was blocked twice during 1993 due to a major landslide and a rockfall near Jakhri and Nathpa respectively. A partial block also occurred at Palingi in 1988 where Soldan Khad joins the Satluj. These major blockades and many zones of land subsidence along NH – 22 between Bhabanagar and Jakhri call for detailed investigation and preventive measures since the construction of a number of mega run – off – the river hydel schemes are in progress in this section of the Satluj valley.

4.190 Sah, M. P. and Bartarya, S. K. (2002). "The impact of March 29th, 1999 Chamoli earthquake on slope stability and spring discharge in Chamoli and Rudraprayag districts of Garhwal Himalaya". Himalayan Geology, 23 (1&2), pp 121-133. http://www.himgeology.com/himgeol/vol_23/abstract13.htm

An earthquake of 6.8 magnitude on Richter Scale occurred on March 29, 1999 at 00:35 hrs IST and jolted the entire northern India. At several places undermining and subsidence of the road have taken place. Majority of the slides measured less than 5 m in dimension (length and width) and only 9 slides have exceeded 25 m in their physical expansion. A number of ground cracks ranging from 5 m to 3000 m in length are oriented in NW-SE, N-S and E-W direction have adversely affected the slope stability of the region. This has increased the possibility of occurrence of large landslide and subsidence in earthquake affected area in near future.

4.191 Saha, A. K., Gupta, R. P. & Arora, M. K. (2002). "GIS-based landslide hazard zonation in the Bhagirathi (Ganga) Valley, Himalayas". International Journal of Remote Sensing Volume 23, Issue 2. http://www.tandfonline.com/doi/abs/10.1080/01431160010014260#

A part of the Bhagirathi Valley in the Garhwal Himalaya was selected for landslide hazard zonation. The study utilized different types of data including Survey of India topographic maps, geological (lithological and structural) maps, IRS-1B and-1D multispectral and PAN satellite sensor data and field observations. The processing of multi-geodatasets was carried out in a raster GIS environment. The various data layers generated and co-registered were: landuse/landcover, buffer map of thrusts, buffer map of photo-lineaments, lithology, buffer map of drainage, slope angle and relative relief. Data integration was carried out using the ordinal scale (qualitative) relative weighting rating technique to give a Landslide Hazard Index (LHI) value. The breaks in the LHI frequency diagram were used to delineate various landslide hazard zones, namely, very low, low, moderate, high and very high.

4.192 Sah, M. P., Asthana, A. K. L. and Rawat, B. S. (2003). "Cloud burst of August 10, 2002 and related Landslides and Debris flows around

Budha Kedar (Thati Kathur) in Balganga Valley, District Tehri". Himalayan Geology, Vol. 24 (2), pp. 87-101. http://www.himgeology.com/himgeol/vol_24(2)/abstract7.htm

Cloud burst and related flash flood affected 54.10 km2 area of Medh Gad and Dharam Ganga basin by landslides, debris flows and debris slides. These two channels are major tributaries of Balganga draining in the Higher Himalayan region. The lower and middle slopes between below 1600m and 2000m altitudinal zone facing towards south and southwest are mainly affected by landslide and debris flow. The paper deals with the general geology, geomorphology, land use and their response to damages caused due to cloud burst and associated mass movement in the area. The cloud burst and associated mass movement cause death of 28 people, 99 cattle, and complete damage of 38 houses and estimated Rs. 67.5 million losses to public property. More than 1200 people of 17 villages were affected by this event.

4.193 Saha, A. K., Arora, M. K., Gupta, R. P., et al. (2005). "GIS-based route planning in landslide-prone areas". International Journal of Geographical Information Science Vol. 19, No. 10, November 2005.http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.97.4760&rep=rep1&type=pdf

In this study, in a test area in the Himalayas, various thematic layers, viz. landslide distribution, landslide hazard zonation, landuse/landcover, drainage order and lithology are generated and integrated using Remote Sensing–GIS techniques. The integrated data layer in raster form has been called a 'thematic cost map' and provides an estimate of the cost of route development and maintenance. The relative cost assignment is based on experts' knowledge. Route planning is based on neighborhood analysis to find various movement possibilities from a pixel to its immediate neighbors. A number of patterns such as those analogous to movements in chess games have been considered.

4.194 Saha, A. K., Gupta, R. P., Sarkar, I. et al. (2005). "An approach for GIS-based statistical landslide susceptibility zonation—with a case study in the Himalayas". Landslides Volume 2, Issue 1, pp 61-69. http://link.springer.com/article/10.1007/s10346-004-0039-8

In this work, two methods, the Information Value (InfoVal) and the Landslide Nominal Susceptibility Factor (LNSF) methods that are based on bivariate statistical analysis have been applied for LSZ mapping in a part of the Himalayas. Relevant thematic maps representing various factors (e.g., slope, aspect, relative relief, lithology, buffer zones along thrusts, faults and lineaments, drainage density and landcover) that are related to landslide activity, have been generated using remote sensing and GIS techniques. The LSZ derived from the LNSF method, has been compared with that produced from the InfoVal method and the result shows a more realistic LSZ map from the LNSF method which appears to conform to the heterogeneity of the terrain.

4.195 Sajinkumar, K. S., Anbazhagan, S., Pradeepkumar, A. P. et al. (2011). "Weathering and landslide occurrences in parts of Western Ghats, Kerala". Journal Geological Society of India Vol.78, September 2011, pp.249-257. http://www.geosocindia.org/abstracts/2011/sept/sep2k11/jgsi-d-09-000104.pdf

This paper reports on how the weathering in the windward slope of Western Ghats influences the occurrence of landslides and the factors which accelerate the weathering process. Rock and soil samples were collected from the weathering profile of hornblende gniess and granite gneiss. The chemical analysis and the calculated Chemical Index of Alteration (CIA) indicate the significant weathering and its possible influence on landslide occurrences in the study area. Mainly, the CIA value of lateritic soil and forest loam indicated the extent of high chemical weathering in this region. Rainfall is the dominant parameter influencing the chemical weathering process. In addition, deforestation, land use practices and soil erosion are some of the other important factors accelerating the weathering process and landslide occurrences in the region.

4.196 Samadhiya, N. K. (2007). "Constitutive Laws for Jointed Rock Mass". Journal of Rock Mechanics and Tunneling Tech. Vol. 13, No.2, pp. 77 - 92. http://www.isrmtt.com/abstract_download.php?abs=125

The rock masses essentially consist of two constituents: intact rock and discontinuities. The presence of these natural discontinuities such as joints and bedding planes in rock masses can exert a significant influence on the response of rock masses in both surface and underground excavations. The existence of one or several sets of discontinuities in rock mass creates anisotropy in its response to the applied stress field. The discontinuities may be oriented arbitrarily in any direction. Before any of these influences may be evaluated for a given rock engineering project, it is necessary that the discontinuities in the rock mass be properly characterized and their properties established. Three approaches can be followed to account for the effect of joints on rock mass strength and deformability.

4.197 Samui, P. (2008). "Slope stability analysis: a support vector machine approach". Environmental Geology Volume 56, Issue 2, pp 255-267. http://link.springer.com/article/10.1007%2Fs00254-007-1161-4

Artificial Neural Network (ANN) such as back propagation learning algorithm has been successfully used in slope stability problem. However, generalization ability of conventional ANN has some limitations. For this reason, Support Vector Machine (SVM) which is firmly based on the theory of statistical learning has been used in slope stability problem. In this study, SVM predicts the factor of safety that has been modeled as a regression problem and stability status that has been modeled as a classification problem. For factor of safety prediction, SVM model gives better result than previously published result of ANN model. In case of stability status, SVM gives an accuracy of 85.71%.

4.198 Sarkar, S., Kanungo, D. P. and Mehrotra G. S. (1995). "Landslide hazard zonation: A case study in Garhwal Himalaya India". Mountain Research and Development Vol. 15, No. 4, Nov., 1995. http://www.jstor.org/discover/10.2307/3673806?uid=3738256&uid=2&uid=4&sid=21104262223523

This paper describes the methods of landslide hazard zonation that were tested in the Srinagar-Rudraprayag area of the Garhwal Himalaya. The factors of slope angle, lithology, distance from a major geological discontinuity, land use, drainage, relative relief and existing landslides all contribute to slope instability. These are analyzed in relation to landslide frequency and are numerically weighted based on their relative importance.

4.199 Sarkar, S. and Kanungo, D. P. (2002). "Landslides in relation to terrain parameters – A remote sensing and GIS approach". Proc. of 5th Annual Int. Conf.on Map India.

Three terrain parameters drainage, lineament and road have been considered to analyze the slope stability. The paper describes the utility of remote sensing and GIS for generation of the four thematic layers; drainage, lineament, road and landslide and an integrated approach to evaluate layer-wise influence on landslide occurrence in parts of Darjeeling Himalaya.

4.200 Sarkar, S. and Kanungo, D. P. (2004). "An integrated approach for landslide susceptibility mapping using remote sensing and GIS". Photogrammetric Engineering & Remote Sensing Vol. 70, No. 5, May 2004, pp. 617–625. http://info.asprs.org/publications/pers/2004journal/may/2004_may_617-625.pdf

A methodology for landslide susceptibility mapping using an integrated remote sensing and GIS approach is presented. A part of the Darjeeling Himalaya was selected for the model execution. IRS satellite data, topographic maps, field data, and other informative maps were used as inputs to the study. Important terrain factors, contributing to landslide occurrences in the region, were identified and corresponding thematic data layers were generated. These data layers represent the geological, topographical, and hydrological conditions of the terrain. A numerical rating scheme for the factors was developed for spatial data analysis in a GIS. The resulting landslide susceptibility map delineates the area into different zones of four relative susceptibility classes: high, moderate, low, and very low.

4.201 Sarkar, S., Kanungo, D. P. and Chauhan, P. K. S. (2004). "Landslide disaster of 24th September 2003 in Uttarkashi". Current Science, Vol.87, No.2, pp.134-137. http://www.iisc.ernet.in/currsci/jul252004/134a.pdf

A landslide disaster occurred in Uttarkashi on 24 September 2003 which has affected a part of the town. The paper highlights the probable causes of the slide, degree of instability in the Varunavat hill and risk assessment. According to an earlier assessment some instability was persisting in the Varunavat Parvat which triggered the slide after a heavy rainfall. The earlier landslide scars and cracks present prior to the slide contributed to the instability in the hill. The potential zone of risk in the foothill has been assessed and suggestions were made to administrative authorities to minimize loss of life and property.

4.202 Sarkar, S., Kanungo, D. P. and Patra, A. K. (2005). "Landslides in the Alaknanda Valley of Garhwal Himalaya, India". Quarterly Journal of Engineering Geology and Hydrology, Vol. 39, pp. 79-42.http://www.cbri.res.inindex.php?option=com_content&view=article&id=149&Itemid=54

The occurrence of landslides is a recurring problem along the hill roads of Himalaya. Roads are often blocked due to landslides, which sometimes also leads to casualties. Identification of such unstable slopes is an imperative task to save life and property. The paper outlines features of major landslides along a National Highway in the Alaknanda valley of Garhwal Himalaya through photo documentation.

4.203 Sarkar, S., Kanungo, D. P., Patra, A. K. et al (2006). "GIS based landslide susceptibility mapping — A case study in Indian Himalaya". Disaster Mitigation of Debris Flows, Slope Failures and Landslides pp. 617–624. http://www.interpraevent.at/palm-cms/upload_files/Publikationen/Tagungsbeitraege/2006_2_617.pdf

The paper presents GIS based spatial data analysis for landslide susceptibility mapping in parts of Sikkim Himalaya. Six important causative factors for landslides were selected and corresponding thematic data layers were prepared in GIS. The input data were collected from the topographic maps, satellite image, and field data and published maps. Numerical weights for different categories of these factors were determined based on a statistical approach and then integrated in GIS environment to arrive at landslide susceptibility map of the area. The landslide susceptibility map classifies the area into five classes of landslide susceptible zones i.e., very high, high, moderate, low and very low. An attempt was also made to validate the map with the existing landslides of the area.

4.204 Sarkar, K. and Singh, T. N. (2008). "Slope stability study of Himalayan rock – A numerical approach". International Journal

of Earth Sciences and Engineering. http://cafetinnova.org/wp-content/uploads/2013/04/020101-Slope-Stability-Study-of-Himalayan-Rock-A-Numerical-Approach.pdf

In this paper, an attempt has been made to determine the stability of road cut slope in Luhri area, Himachal Pradesh using three dimensional numerical simulation tool Fast Lagrangian Analysis of Continua in 3 Dimensions (FLAC 3D).The representative rock samples were collected from the study area to determine the important geotechnical properties, which were later on used as an input parameter for the numerical simulation. The deformations and the stress distribution along the failure surface have been established for suitable, economical and scientifically proved method to design the existing slope. The stress distribution and overall factor of safety has been determined to assess the condition of the slope and suggest possible remedial measure. The study indicates slope is marginally stable and some protections of it need proper understanding to stabilize it.

4.205 Sarkar, S., Kanungo, D. P., Patra, A. K. et al. (2008). "GIS Based Spatial Data Analysis for Landslide Susceptibility Mapping". Journal of Mountain Science Volume 5, Issue 1, pp 52-62. http://link.springer.com/article/10.1007%2Fs11629-008-0052-9

The paper presents a statistical approach through spatial data analysis in GIS for landslide susceptibility mapping in parts of Sikkim Himalaya. Six important causative factors for landslide occurrences were selected and corresponding thematic data layers were prepared in GIS. Topographic maps, satellite image, field data and published maps constitute the input data for thematic layer preparation. Numerical weights for different categories of these factors were determined based on a statistical approach and the weighted thematic layers were integrated in GIS environment to generate the landslide susceptibility map of the area.

4.206 Sarkar, S. and Anbalagan, R. (2008). "Landslide hazard zonation mapping and comparative analysis of hazard zonation maps". Journal of Mountain Science Volume 5, Issue 3, pp 232-240. http://link.springer.com/article/10.1007%2Fs11629-008-0172-2

Landslide hazard zonation mapping at regional level of a large area provides a broad trend of landslide potential zones. A macro level landslide hazard zonation for a small area may provide a better insight into the landslide hazards. The main objective of the present work was to carry out macro landslide hazard zonation mapping on 1:50,000 scale in an area where regional level zonation mapping was conducted earlier. In the previous work the regional landslide hazard zonation maps of Srinagar-Rudraprayag area of Garhwal Himalaya in the state of Uttarakhand were prepared using subjective and objective approaches. In the present work the landslide hazard zonation mapping at macro level was carried out in a small area using a Landslide Hazard Evaluation Factor rating scheme.

4.207 Sarkar, K. and Singh, T. N. (2010). "Rock slope stability analysis along NH-22 in Luhri Area, Himachal Pradesh- A case study". Indian Geotechnical Conference – 2010, GEOtrendz December 16–18, 2010 IGS Mumbai Chapter & IIT Bombay. http://gndec.ac.in/~igs/ldh/conf/2010/articles/t056.pdf

The present paper demonstrates the slope stability analysis along the road section (NH-22) of Luhri area, Himachal Pradesh which connects border district Kinnaur (near to China border) to rest of India. A detail field study has been carried out to collect the representative rock samples for determination of geotechnical properties of rock. These properties have been used as input parameters for the three dimensional finite difference slope analysis using FLAC-3D code. The present study reveals that the slope is critically stable but any external factors may further reduce the Factor of Safety (FoS) and causes the instability. The presence of random and intense jointing in rockmass and intensive rainfall further accelerated the slope failure.

4.208 Sarkar, S. and Kanungo, D. P. (2010). "Landslide disaster on Berinag–Munsiyari Road, Pithoragarh District, Uttarakhand". Current Science, VOL. 98, NO. 7. http://www.indiaenvironmentportal.org.in/files/Landslide%20disaster%20on%20Berinag%20Munsiyari%20Road.pdf

The landslide disaster on 8 August 2009 near Kuity village in Pithoragarh district of Uttarakhand State buried two villages and took 43 lives. The landslide, triggered by cloud burst resulted in massive debris flow along a stream channel. The site is still in danger as shown by the presence of huge quantity of debris and ground cracks on the slope. Here we present inferences drawn from the field observations. The landslide disaster on 8 August 2009 near Kuity village in Pithoragarh district of Uttarakhand State buried two villages and took 43 lives. The landslide, triggered by cloud burst resulted in massive debris flow along a stream channel. The site is still in danger as shown by the presence of huge quantity of debris and ground cracks on the slope. Here we present inferences drawn from the field observations.

4.209 Sarkar, S., Kanungo, D. P. and Kumar, S. (2012). "Rock mass classification and slope stability assessment of road cut slopes in Garhwal Himalaya". Geotechnical and Geological Engineering August 2012, Volume 30, Issue 4, pp 827-840. http://link.springer.com/article/10.1007%2Fs10706-012-9501-x

There are many rock mass classification schemes which are frequently used for different purposes such as estimation of strength and deformability of rock masses, stability assessment of rock slopes, tunneling and underground mining operations etc. The rock mass classification includes some inputs obtained from intact rock and discontinuity properties which have major influence on assessment of engineering behaviour of rock mass. In the present study, detail measurements were employed on road cuts slope faces in Garhwal Himalayas to collect required data to be used for rock mass classification of Rock Mass Rating (RMR) and Geological Strength Index (GSI). The stability assessment of rock slopes were also done by using Slope Mass Rating. In addition the relation between RMR and GSI were also evaluated using 50 data pairs.

4.210 Sarkar, S., Ghosh, A., Kanungo, D. P., et al. (2013). "Slope stability assessment and monitoring of a vulnerable site on Rishikesh-Uttarkashi Highway, India". Landslide Science and Practice 2013, pp 67-71. http://link.springer.com/chapter/10.1007%2F978-3-642-31445-2_8

Landslides are frequently occurring phenomenon in the Himalayas, in the Northern part of India. There were many landslide disasters in the recent past which have taken lives and caused extensive damage to property and public utility services. It is an imperative task to assess the slope instability and evaluate the risk where lives and property are at danger. A vulnerable slope on Rishikesh-Uttarkashi road having few houses, which are under distress, was studied for slope stability assessment. The slope instability was evident by road subsidence and development of cracks in few houses. A comprehensive geological and geotechnical investigation was carried out along with slope movement monitoring. The paper describes the findings of the study.

4.211 Sarkar, S., Kanungo, D. P., Sharma, S., et al. (2013). "Potential landslide zones along Pipalkoti-Joshimath road, Alaknanda valley". Proceedings of Indian Geotechnical Conference December 22-24, 2013, Roorkee. http://www.igs.org.in/igc2013/igc_2013_roorkee_proceedings/full_length_paper/10%20TH%20PDF/10%20Th-03.pdf

The landslide hazard along Piplakoti-Joshimath highway, which is severely affected by many landslides, was assessed. The landslide hazard along Piplakoti-Joshimath highway, which is severely affected by many landslides, was assessed by delineating a few landslide potential zones. To assess the degree of hazard in these potential zones, landslide intensity was considered as the measure of hazard. An attempt has been made to define landslide intensity based on types of failure, landslide volume and expected landslide velocity. Such studies of hazard assessment are very useful to decide the need of implementing control measures and also to keep watch during heavy rains so that timely warning can be made.

4.212 Sarkar S., Kanungo D. P. and Sharma S. (2013). "Landslide hazard assessment in the upper Alaknanda valley of Indian Himalayas". Geomatics, Natural Hazards and Risk. http://www.tandfonline.com/doi/full/10.1080/19475705.2013.847501#

In the upper reaches of Alaknanda valley of Garhwal Himalaya, there are several landslide potential zones along the Pipalkoti–Badrinath National Highway (NH-58). In the present study, landslide hazard assessment has been carried out in the above said area by delineating a few landslide potential zones. An attempt has been made to define landslide intensity to assess the degree of hazard in these potential zones of landslide. A landslide intensity scale was defined for this part of Garhwal Himalaya. So far the criterion for landslide intensity has not been defined in the Indian context. The approach used can be used in other potential landslide areas of the Himalayas.

4.213 Sarmah, P. C. and Singh, K. D. (2011). Landslide Monitoring and Early Warning – Special Reference to NE Region of India. Science and Culture 77 (11–12) 496-498. http://www.scienceandculture-isna.org/nov-dec-2011/17-02%20Research%20Communication%20-%20Pratap%20Chandra%20Sarmah.pdf

Landslide hazard is a major natural disaster in India. Out of the total landslide occurrences in the country, nearly 20% are found in NE region of India. Conventional method of monitoring landslide is not reliable. A real time monitoring of landslide has been under research stage. Some important technologies under studies are wireless monitoring, GPS system, optical fiber sensing etc. The wireless monitoring of landslide has been undertaken by NEIST, Jorhat. The place selected for this purpose is at Karsingsa in Arunachal Pradesh. To get a proper monitoring method an attempt has been made in that area by using wireless network of sensors. The hardware embedded software for these sensors are used and altogether five different sensors are placed in a network. This system of sensors is then wirelessly connected using RFID technology to a server for monitoring and collection of data for prediction of landslide.

4.214 Sati, S. P. and Sundriyal, Y. P. (2007). "Role of some Tree Species in Slope Instability". Himalayan Geology, Vol. 28 (1), pp.75-78. http://www.himgeology.com/himgeol/vol_28(1)/abstract6.htm

Most of the studies carried out so far on the relationship between the landslides and vegetation have emphasized the positive role of vegetation on slope stability. However, we have recorded that all types of vegetation do not support the slope stability. The present paper unravels the role of some of the tree species occurring in the Garhwal Himalayan forests in slope instability. Various types of slopes and general vegetation growing on them are also discussed.

4.215 Sengupta, A., Gupta, S. and Anbarasu, K. (2010). "Landslides - investigations and mitigation in Eastern Himalayan Region". Journal of the Indian Roads Congress, July-September 2010 Paper

No. 560. http://irc.org.in/ENU/knowledge/archive/Technical%20Papers%20for%20Irc%20Journals/Landslides%20-%20Investigations%20and%20Mitigation%20in%20Eastern%20Himalayan%20Region.pdf

The geological and geotechnical study of the major trouble spots along national highway NH-31A, North Sikkim Highway (NSH) and Singtam-Dikchu road in Sikkim (India), Pagla Jhore landslide zone on Hill Cart road in Darjeeling (West Bengal) and a perennial trouble spot at Sonapur on national highway NH-44 in Meghalaya identified regional geology or rock type, structure of the bedrocks (like, orientation of the rock foliations and faults), excessive rainfall and human interference (like, mining of stones and fines, and diversion of streams) as the main factors triggering the landslides in the region.

4.216 Sharma, S., Anbalagan, R. and Raghuvanshi, T. (1996). "A statistical approach to landslide analysis". Journal of Rock Mechanics and Tunneling Tech. Vol 2 No 2, pp. 99-118. http://www.isrmtt.com/abstract_download.php?abs=13

The approach of Hoek & Bray (1981) to analyse the plane failure analysis is modified to take into account the release joint inclination. Accordingly, the equations to calculate the factor of safety and other parameters have been changed. This modified approach has been subjected to statistical tools and simple equations have been proposed for direct estimation of the factor of safety of plane failure of slopes. These new equations are obtained using the multiple regression analysis. Adequacy of these equations has been tested by applying F Test, Durbin-Watson Test and Heterosedasticity and Homosedasticity Tests.

4.217 Sharma, V. K. (2006). "Zonation of landslide hazard for urban planning- case study of Nainital Town, Kumaon Himalaya, India". IAEG2006 Paper number 191 The Geological Society of London 2006. http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_191.PDF

The paper aims to classify the area around Nainital town in Kumaon Himalaya into zones of relative susceptibility to landslide hazard. The geological parameters used for the study include-slope forming material, structural details, tangent of slope angle, slope direction, spatial distribution of landslides and land use pattern.

Thematic maps viz. slope morphometry, slope forming material and landslide occurrence are prepared and their inter layering derived various parametric inputs. The Micro-zoning of landslide hazard of the town has been attempted evolving a failure probability model that estimates the failure of slopes out of the total number of slopes in a specific domain of geo-factors.

4.218 Sharma, M. and Kumar, R. (2008). "GIS-based landslide hazard zonation: A case study from the Parwanoo Area, Lesser and Outer Himalaya, H. P., India". Bulletin of Engineering Geology and the Environment February 2008, Volume 67, Issue 1, pp 129-137. http://link.springer.com/article/10.1007/s10064-007-0113-2?no-access=true

GIS-based landslide hazard zonation has been carried out for a tectonically active region of the Himalayas, which is under pressure for rapid economic development. Thematic layers of slope, fault, geology, land use, flow accumulation, drainage and roads were prepared based on topographic maps, satellite imagery, published geological maps and ground truth. Five classes of landslide hazard were identified; 24% of the total area falls into the Very high or high hazard zones where 54% of the observed landslides were recorded.

4.219 Sharma, L. P., Patel, N., Ghosh, M. K., et al. (2009). "Geographical information system based landslide probabilistic model with trivariate approach - A case study in Sikkim Himalayas". Eighteenth United Nations Regional Cartographic Conference for Asia and the Pacific Bangkok, 26-29 October 2009. http://unstats.un.org/unsd/geoinfo/RCC/docs/rccap18/IP/18th_UNRCCAP_econf.100_IP19.pdf

The purpose of this study was to categorize the land in the study area with respect to their vulnerability and susceptibility to landslides into different zones, for focused implementation of specific strategies for landslide reduction and loss prevention in the most vulnerable areas. The major parameters causing the landslide were identified based on past research and experts' opinion. The influencing soil parameters were soil depth, stoniness, hydraulic conductivity, soil drainage behavior, soil slope, soil erosion, surface texture and inner texture. Other parameters were lithology, slope, drainage network, and road network and land use pattern. The trigging factors are rainfall and anthropogenic interference like civil construction and deforestation.

4.220 Sharma, A. K., Joshi, V., Parkash, S. et al. (2009). "Land use pattern mapping using remote sensing and GIS in Gangtok area, Sikkim Himalaya, India". Geospatial World. http://www.geospatialworld.net/Paper/Application/ArticleView.aspx?aid=440

This paper discovers the use of satellite images and Geographical Information Systems (GIS) for developing a sampling frame stratify the sample based on the analysis of remotely sensed information. The use of GIS and Remote Sensing can be helpful for time saving and efficient land use mapping. Remote sensing provides the essential data to undertake inventory of land, as well as the temporal information required to monitor sustainable land management practices. The study has been carried out at Gangtok area, East District of Sikkim, the total area of study is 30.25 sq. km.

4.221 Sharma, V., Bhat, G. M., Choudhary, J. B. et al. (2010). "Stability Assessment of rock slopes using RMR, modified SMR Technique and Kinematic analysis around Barrage site of Chutak Hydroelectric Power Project Kargil, J&K, India". Himalayan Geology, Vol. 31 (1), pp. 35-42

The stability of rock slopes and safety of an engineering project is a major concern of the project construction agency. Any kind of slope failure may lead to destruction to the project and socio-economic activities, and loss of property, injuries or sometimes-even deaths of humans and/or livestock, and environmental degradation. Therefore, an assessment of the stability conditions in and around the project impact area is important. The slope mass rating (SMR) technique was employed for slope stability analysis. Six sites were selected around the barrage site for the purpose. Kinematic analysis was also carried out to evaluate these sites for slope and wedge failures and a number of potentially vulnerable sites were identified.

4.222 Sharma, R. and Mehta, B. (2012). "Macro-zonation of landslide susceptibility in Garamaura-Swarghat-Gambhar section of national highway 21, Bilaspur District, Himachal Pradesh (India)'. Natural Hazards; Feb2012, Vol. 60 Issue 2, p671.

The paper discuss the preparation of macro-zonation maps of landslide susceptibility in an area of about 100 sq km on 1:50,000 scale across Garamaura-Swarghat section of National Highway-21. The map has been prepared by superimposing the terrain evaluation maps in a particular zone such as lithological map, structural map, slope morphometry map, relative relief map, land use and land cover map and hydrological condition map using landslide susceptibility evaluation factor rating scheme and calculating the total estimated susceptibility as per the guidelines of IS: 14496 (Part-2)). Numerical weightages are assigned to the prime causative factors of slope instability such as lithology, structure, slope morphometery, relative relief, land use and groundwater conditions as per the scheme approved by Bureau of Indian Standard for the purpose of landslide susceptibility zonation.

4.223 Shukla, D. P. , Dubey, C. S. , Ningreichon, A. S., et al. (2014). "GIS-based morpho-tectonic studies of Alaknanda River Basin: A precursor for hazard zonation". Journal of the International Society for the Prevention and Mitigation of Natural Hazards Volume 71 Number 3. http://www.researchgate.net/profile/Dericks_Shukla/publication/260529092_GISbased_morphotectonic_studies_of_ Alaknanda_river_basin_a_precursor_for_hazard_zonation/file/9c960537b34797669.pdf?ev=pub_ext_doc_dl&origin=publication_detail&inViewer=true

The study presents GIS-based morpho-tectonic studies of Alaknanda River basin. Alaknanda river basin is considered to be tectonically active where damaging earthquakes and landslides have occurred. The whole basin was divided into 8 sub-basins to carry out morphometric analyses, hypsometric integral (HI) analysis and valley floor width to valley height ratio (Vf) factor. The data plotted for earthquakes and landslides occurrences are consistent with morpho-tectonic map and can be used as a precursor for demarcation of natural hazard vulnerable zones.

4.224 Singh, M., Rao, K. S. and Ramamurthy, T. (2002). "Strength and deformational behaviour of a jointed rock mass". Rock Mechanics and Rock Engineering Volume 35, Issue 1, pp 45-64.

An attempt has been made in the present study to develop a link between strength and deformability of jointed block masses with the properties of intact specimens, obtained from simple laboratory tests, taking into account the influence of the properties of the joints. Extensive experimentation has been carried out on large specimens of jointed block masses under uniaxial compression. The model material represents a low strength rock. Various joint configurations were introduced to achieve the most common modes of failure occurring in nature. A coefficient called Joint Factor has been used to account for the weakness brought into the intact rock by jointing. Methods of computing the Joint Factor for various modes of failure of a jointed mass in an unconfined state have been established.

4.225 Singh, M. and Singh, B. (2004). "Critical state concept and a strength criterion for rocks". Proceedings of the ISRM International Symposium 3rd ARMS, Ohnishi & Aoki (eds) © 2004 Millpress, Rotterdam.

The paper proposes that there should a saturation limit for the differential stress at failure, and the rock should reach a critical state at certain confining pressure. The critical state is assumed ato be attained when rock reaches the brittle-ductile transition, which occurs when confining stress equals the uniaxial compressive strength of the intact rock. Finally it is suggested that a strength criterion must account for the effect of the critical state of rocks.

4.226 Singh, T. and Devi, M. (2006). "Landslide Occurrences and Risk Assessment in Itanagar Capital Complex, Arunachal Himalaya". Himalayan Geology, Vol. 27 (2), pp.145-162. http://www.himgeology.com/himgeol/vol_27(2)/abstract5.htm

Itanagar Capital Complex, which came into existence only in 1981, has reached a critical state of human settlement and other developmental activities. A number of lineaments and active faults have made the area more vulnerable to the landslides, which are occurring not only along the roads but also in the urban agglomeration area. Nearly 46 major landslides have been recorded and detailed inventory of these landslides has been prepared. The landslides, which include both old and presently active slides, are located within the unconsolidated Quaternary deposits and poorly cemented Siwalik sediments. Landslides, and other geologic and geomorphic features suggest that the area is tectonically unstable and geodynamically active.

4.227 Singh, M. and Singh, B. (2008). "Laboratory and numerical modelling of a jointed rock mass". The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG) 1-6 October, 2008 Goa, India. http://citeseerx.ist.psu.edu/viewdocdownload?doi=10.1.1.383.9735&rep=rep1&type=pdf

A set of more than fifty physical model tests of jointed rock mass under uniaxial loading conditions have been conducted simulating three joint sets. A methodology has been suggested to estimate strength and tangent modulus of rock masses through a weakness coefficient. The methodology involves mapping of joints in the field and laboratory testing of intact rock specimens to arrive at rock mass properties. It is concluded that the distinct element method can predict realistically the phenomenon of high lateral strain ratio. It is recommended that actual measurement of lateral strains should be made during the field investigations and this should be carefully considered in analysis and design of important rock structures.

4.228 Singh, T. N., Gulati, A., Dontha, L. et al. (2008). "Evaluating cut slope failure by numerical analysis—a case study". Natural Hazards Volume 47, Issue 2, pp 263-279. http://link.springer.com/article/10.1007%2Fs11069-008-9219-5

The present article mainly deals with the analysis of the stability of road cut slopes of Rudraprayag Area, Uttarakhand, India. The area experiences local as well as regional slides every year. Extensive field study was carried out along the road cut slopes. Laboratory experiments were conducted to determine the various Physio-mechanical properties of rock mass. These properties have been used as input parameters for the numerical simulation of slope using FLAC3D (Fast Lagrangian Analysis of Continua) including geological discontinuities. The computed deformations and the stress distribution along the failure surface are compared with the field observations. The study indicates that the overall slope is unstable except at the location E where slope is critically stable. The effects of instability have been thoroughly considered and remedial measures have been recommended.

4.229 Singh, Y., Singh, T., Kaushal, A., et al. (2008). "GIS based landslide inventory of Itanagar-the capital of Arunachal Pradesh". Indian Landslides VOl. 1 No. 2, November, 2008. http://lib.icimod.org/record/13566/files/3836.pdf

The Himalayas are highly susceptible to natural disasters, particularly the landslides, due to the inherent fragility prvaling in this mountainous terrain, which are further enhanced by neotectonic activities. The paper discuss a GIS based Landslide inventory of the Itanagar, integrating all the possible information pertaining to the particular landslide on the map as well as in the spatial database, which may prove useful to identify the areas to landslides, and to formulate suitable mitigation measures to minimize the losses caused by the landslides.

4.230 Singh, V. K., Singh, B., Champati ray, P. K. and Reddy, D. V. (2009). "Geotechnical investigation for landslide study in Garhwal Himalaya". International Journal of Earth Sciences and Engineering, Vol. 02, No. 03, July 2009, pp. 180-184. http://cafetinnova.org/wp-content/uploads/2013/04/02020302.pdf

The study is an attempt has been made to identify different geotechnical parameters for different litho - units to identify its impact on landslides. For displacement analysis the famous Newmark Model has been used which consider landslides as rigid friction-blocks having a known critical acceleration, resting on an inclined plane. The database is organized in ArcGIS platform and preliminary results show simulation of slope response to reference seismic events and its probable effect on slope stability.

4.231 Singh, V. K. and Champati Ray, P. K. (2009). "Interferometry SAR for landslide hazard assessment in Garhwal Himalaya, India". International Journal of Earth Sciences and Engineering Vol. 02, No. 05, October 2009, pp. 389-395. http://cafetinnova.org/wp-content/uploads/2013/04/02020501.pdf

Space borne or ground-based synthetic aperture radar (SAR) interferometry has been shown to be an effective complementary tool for landslide monitoring. The present study illustrates some current and potential uses of satellite Synthetic Aperture Radar Interferometry (InSAR) for landslide assessment in Garhwal Himalaya.

4.232 Singh, T. N. and Sarkar, K. (2009). "Landslides and flooding around Mumbai". Indian Landslides Vol.2 No.1. http://www.indianlandslide.info/images/v2_2.pdf

Slope instability is a major concern in hilly regions, particularly due to heavy rains. Here, an attempt has been made to establish some relation with landslide and flooding all along the Mithi river because of its long course and passing through the area which experience flooding many a times during monsoon. Laboratory experiments were conducted to explore the slake durability index of the basalt. The present study shows that excessive siltation from nearby slope along the Mithi River, unscientific construction activity in low lying areas, improper drainage system, unprecedented rainfall during monsoon and landslide in nearby area are the major causes of Mithi river flooding in Mumbai region.

4.233 Singh, Y. and Bhat G. M. (2010). "Role of Basin Morphometric Parameters in Landslides along the National Highway - 1A between Udhampur and Batote, Jammu and Kashmir, India: A case Study". Himalayan Geology, Vol. 31 (1), pp. 43-50. http://www.himgeology.com/himgeol/abstracts_30 (1)/abstract7.htm

The paper reports occurrence of 22 landslides and slope failures, which are distributed within 59 km in the Udhampur-Batote sector of the National Highway - 1A passing through thrust and slope belts. The data on 11 landslides and 19 basin morphometric parameters have been evaluated for understanding the causative factors behind the failures. The role of various lithological and soil characteristics in conjunction with basin morphometric parameters in triggering slope failures in the study area has been evaluated in this paper.

4.234 Singh, C. D., Behera, K. K. and. Rocky, W. S. (2011). "Landslide susceptibility along NH-39 between Karong and Mao, Senapati District, Manipur". Journal Geological Society of India Vol.78, December 2011, pp.559-570.

Landslide susceptibility zonation has been carried out along NH-39 between Karong and Mao following GSI guideline, a modified form of BIS (1998). The investigation reveals that 57% of the facets belong to low susceptibility zone. It is followed by moderate susceptible zone (33%), high susceptible zone (9%) and very low susceptible zone (1%). All the facets of high susceptible zone are concentrated along the road section of NH-39, especially Maram-Mao sector. The landslide susceptibility zonation map gives an overall picture of the stability condition of the hill slopes so it can be used as a base map for planning any developmental scheme or maintenance of the existing one.

4.235 Singh, C. D. and Singh, J. (2013). "Landslides caused due to ignorance - case studies from Northeast India". Journal Geological Society of India Vol.82, July 2013, pp.91-94. http://link.springer.com/article/10.1007%2Fs12594-013-0123-6

Stable slopes are converted into unstable slopes by the people residing in the area by artificial modification/alterations of the hill slope without basic knowledge of hill slope management. Such cases are very common in the hilly terrain including northeast India and they have caused loss of many lives even though the sizes of such landslide are very small. The present paper describes four examples from different parts of the northeast India where the terraced hill slopes that remained stable for an appreciable length of time have been converted to unstable slopes.

4.236 Srikantia, S. V. and Bhargava, O. N. (1972). "Subsidence sinkhole at Runjh (Himachal Pradesh, India)". Engineering Geology Volume 6, Issue 3, Pages 191–201. http://www.sciencedirect.com/science/article/pii/0013795272900026

The sinkhole at the Runhj village in Himachal Pradesh, India is the first reported occurrence from the Himalayas. It is situated in the Precambrian (?) basic volcanic rocks. The present study has revealed that the subsidence was caused due to the solvent action of subsurface water on salt, occurring on the sub-thrust side of the basic volcanic subnappe with the consequent removal of support affecting the ability of the roof to sustain the lithostatic load. This ultimately resulted in the formation of catastrophic sinkhole of cylindrical type.

4.237 Srivastava, L. S. (1970). "Discussion of stability of rock slopes, a three-dimensional study". Journal of Soil Mechanics & Foundations Div. http://trid.trb.org/view.aspx?id=127396

Since rock slopes are a result of erosion, the stability analysis of various sections of a mountain rock slope should consider the overall stability of the entire surface, as the force pattern and the mechanism of movement in the various parts differ. In the lower parts of the slopes of high mountain ranges, the movement is controlled by the deformation modulus of the rock. Considering the stability of a whole mountain face, two aspects need attention: (1) stability of the near surface material, and (2) stability of the whole mountain range. Methods of evaluating discontinuity planes and surfaces are presented.

4.238 Srivastava, L. S. (1988). "Landslides in rock slopes during January 19, 1975, Kinnaur earthquake in Himachal Pradesh, India". Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 4.14. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/34290/P%200779-%20Landslides%20in%20Rock%20Slopes%20during%20January%2019,%201975,%20Kinnaur%20Earthquake%20in%20Himachai%20Pradesh,%20India.pdf?sequence=1

Ground failures in rugged terrain with more that 10,000ft (3000m) elevation above mean sea level in the epicentral tract of 19 January 197 5 Kinnaur earthquake in Himachal Pradesh, India, indicate that most of the earthquake generated landslides occur in surficial cover. The study indicates the significance and desirability of detailed study of surficial cover on rock slopes in mountainous terrains for evaluation of stability of hill sides during earthquakes. In high altitude frozen ground and rock slopes, seismic stress waves play a significant role in shattering near surface rock mass.

4.239 Srivastava, N. N. and Anbalagan, R. (2007). "Landslide hazard zonation mapping and digital elevation model (DEM) development of a Part of Tehri Dam reservoir area pertaining to Bhilangna Valley". Journal of Rock Mechanics and Tunneling Tech. Vol. 13, No. 2, pp. 109 - 228. http://www.isrmtt.com/abstract_download.php?abs=86

The mountainous terrains such as Himalaya are characterized by steep slopes, high relative relief, weathered, fractured and folded rocks in addition to unfavorable hydrogeological conditions. The planning, design and execution of development schemes in these terrains should take into account the existing instabilities of the area. Moreover the unstable zones facing environmental degradation have to be identified and studied in detail for evolving suitable mitigation measures. For that purpose a quantitative approach based on the numerical rating called landslide hazard evaluation factor (LHEF) rating scheme has been used for preparing the Landslide Hazard Zonation (LHZ) map of a part of Tehri Dam Reservoir Area pertaining to Bhilangna Valley.

4.240 Sujatha, E. R., Rajamanickam, G. V. and Kumaravel, P. (2012). "Landslide susceptibility analysis using probabilistic certainty factor approach: A case study on Tevankarai stream watershed, India". J. Earth Syst. Sci. 121, No. 5, October 2012, pp. 1337–1350. http://www.ias.ac.in/jess/oct2012/1337.pdf

This paper reports the use of a GIS based Probabilistic Certainty Factor method to assess the geo-environmental factors that contribute to landslide susceptibility in Tevankarai Ar sub-watershed, Kodaikkanal. The spatial database of the factors influencing landslides are compiled primarily from topographical maps, aerial photographs and satellite images. They are relief, slope, aspect, curvature, weathering, soil, land use, proximity to road and proximity to drainage. Certainty Factor Approach is used to study the interaction between the factors and the landslide, highlighting the importance of each factor in causing landslide. The results show that slope, aspect, soil and proximity to roads play important role in landslide susceptibility. The landslide susceptibility map is classified into five susceptible classes – low, very low, uncertain, high and very high.

4.241 Sundriyal, Y. P., Tripathi, J. K., Sati, S. P. et al. (2007). "Landslide-dammed lakes in the Alaknanda Basin, Lesser Himalaya: Causes and implications". Research Communications, Current Science, 93(4). http://www.currentscience.ac.in/Downloads/article_id_093_04_0568_0574_0.pdf

Observations on landslide-dammed lake deposits located in the vicinity of the E-W and NW-SE trending, south-dipping North Almora Thrust, in the Alaknanda Basin around Srinagar Garhwal were presented. Preliminary observations suggest that activation of crumpled and unstable phyllite dominated slopes led to temporary damming of second and third order tributaries of the Alaknanda river. Sedimentary styles of the succession indicate deposition under the transient lacustrine environment, with seasonality. Luminescence chronology suggests that the lakes were formed after the Last Glacial Maximum (LGM) and probably continued till the Mid-Holocene. Lake formation is attributed to the reactivation of phyllite-dominated slopes following the reestablishment of the southwest monsoon after the LGM. Presence of contorted laminas is interpreted as episodic events of seismic activity. Finally the lakes disappeared due to large-scale slope reactivation around Mid-Holocene.

4.242 Tiwari, K. C., Ganapathi, S., Mehta, A., et al. (2006). "Landslide hazard zonation of Tawaghat – Jipti route corridor, Pithoragarh, Uttaranchal State: Using GIS and probabilistic technique approach". Disaster Forewarning Diagnostic Methods and Management, edited by Felix Kogan, Shahid Habib, V. S. Hegde, Masashi Matsuoka, Proc. of SPIE Vol. 6412, 64120Q, (2006). http://www.researchgate.net/profile/Ramakrishnan_D/publication/257923541_Remote_SensingGIS_Research_and_Development_Section Probabilistic_Techniques_GIS_and_Remote_Sensing_in_Landslide_Hazard_Mitigation_A_Case_Study_from_Sikkim_Himalayas_India/file/60b7d52636304d7ac0.pdf

The study aims to develop a methodology that could produce a hazard map over a large area with higher degree of accuracy in a GIS environment; incorporating utility of information theory in landslide hazard zonation. In all, 37 variables are identified as conditioning and triggering factors and accordingly probabilistic prediction map is prepared by this method. On the basis of histogram distribution, the polygon elements are classified into five hazard classes viz. very low (Ij <= -0.02), Low (-0.02 < Ij < 0.103) moderate (0.10 <Ij <0.23), high (0.23 < Ij < 0.40) and very high (Ij > 0.40) landslide hazard prone zones. Further, this probabilistic prediction map is compared with the actual landslide map generated from recent satellite data (IRS ID LISS-III+PAN, December 2002) for the accuracy of prediction. The generated hazard maps agree with the observed landslide incidences.

4.243 Umrao, R. K., Singh, R., Ahmad, M., et al. (2011). "Stability analysis of cut slopes using continuous slope mass rating and kinematic analysis in Rudraprayag District, Uttarakhand". Scientific Research

Geomaterials, 2011, 1, 79-87. http://www.scirp.org/journal/PaperDownload.aspx?paperID=8176

The stability analysis based on continuous slope mass rating (CSMR) technique has been carried out on road cut slopes along NH-109 which goes to holy shrine of Kedarnath. CSMR is modification of original slope mass rating (SMR) proposed by Romana which is based on well established rock mass rating (RMR) technique. Kinematic analysis was also carried out to evaluate these sites for types of failure and its potential failure directions. The potentially vul-nerable sites were identified. The results indicate that the CSMR technique may be exploited to assess the stability of rock slopes in the Himalayan territory. the values of CSMR indicate that phyllite and Tilwara quartzite slopes are more vulnerable as compared to Haryali quartzite and Epidio-rite slopes of the region.

4.244 Uniyal, A. and Rautela, P. (2005). "Disaster management strategy for avoiding landslide induced losses to the villages in the vicinity of the Himalayan township of Mussoorie in Uttaranchal (India)". Disaster Prevention and Management: An International Journal Vol. 14, No. 3, 2005; pp.378 – 387. http://dmmc.uk.gov.in/files/Documents/avoiding.pdf

Many villages in the vicinity of the hill township of Mussoorie in the Indian Himalayas are witnessing signs of an impending disaster. These villages are witnessing active wastage that might take a heavy toll of human interest during the monsoon season and therefore the paper proposes examining this subject. A detailed study was undertaken in the area of Mussoorie. It is suggested that a series of prevention and mitigation measures (both structural and non-structural) with the involvement of the local community are required for ruling out the possibility of any mishap in the area. This paper highlights the importance of having disaster management strategies for the region and involving the community with these.

4.245 Uniyal, A. and Prasad, C. (2006). "Disaster management strategy for mass wasting hazard prone Naitwar Bazar and surrounding areas in Upper Tons valley in Uttarkashi district, Uttaranchal (India)". Disaster Prevention and Management: An International

Journal Vol. 15, No. 5, 2006; pp. 821– 837. http://www.emeraldinsight.com/journals.htm?articleid=1576479

Naitwar Bazar in the Upper Tons valley Indian Himalaya (Uttarkashi district of Uttaranchal in India) is showing signs of an impending disaster. This settlement has witnessed active mass wastage during rainy season of 2003 which has caused damage to infrastructure (crucial road link), hospital (i.e. the sole health facility) and residential cum commercial area. This paper highlights the need for hazard prognosis and vulnerability assessment in the remotest settlements of Himalayas in order to timely plan the awareness initiatives, response mechanism and structural and non structural mitigation measures. An attempt has also been made to bring forth importance of incorporating the disaster management component into the local developmental planning.

4.246 Uniyal, A. (2008). "Prognosis and mitigation strategy for major landslide-prone areas: A case study of Varunavat Parvat landslide in Uttarkashi township of Uttarakhand (India)". Disaster Prevention and Management, Vol. 17 Iss: 5, pp.622 – 644.

The paper present discuss on the prognosis and mitigation of one of the major landslide in Uttarakhand i.e. Varunavat landslide, Uttarkashi. The sequence of sliding events of Varunavat Parvat, Uttarkashi, response of masses and administration and causative factors of sliding events has been presented in detail for prognosis and mitigation of large slide zones. The paper also state that, there should be minimum anthropogenic activity in the form of slope cutting for road or building construction in Himalayan habitations such as Uttarkashi.

4.247. Verma, A. K and Mushtaq, R. (2013). "Landslides: An environmental hazard in the Pir-Panjal Himalayan Range in Poonch District of J&K State, India". Indian Journal of Scientific Research 4(1): 143-148, 2013. http://www.ijsr.in/upload/1845553011CHAPTER_26.pdf

An attempt has been made to find out the landslides affected areas in the Mughal road in Poonch district. The possible factors triggering the landslides and need for checking of landslides have also been discussed.

4.248 Verma, D., Kainthola, A., Thareja, R. and Singh, T. N. (2013). "Stability analysis of an open cut slope in Wardha valley coal field". Journal Geological Society of India Vol.81, June 2013, pp.804-812. http://www.geosocindia.com/abstracts/2013/june/pp.804-812.pdf

The 32 m high Wardha valley coal field slope was examined for slope stability analysis using a two dimensional numerical simulation. The bench slope consisted of a low strength sandstones, shales and clay sequence. It was observed that indicate that the slope is critically stable and may lead to failure without warning and needs proper attention. The analysis has also shed light on the varied shear stress generation for the FOS calculation using the simplified Bishop's method and corrected Janbu's method. The shear stress generated in the former method has been higher compared to the latter method. The results of stability analysis state that the slope requires immediate treatment to ensure long term stability, productivity and excavability of the mines.

4.249 Vijith, H. and Madhu, G. (2008). "Estimating potential landslide sites of an upland sub-watershed in Western Ghat's of Kerala (India) through frequency ratio and GIS". Environmental Geology, Volume 55, Issue 7, pp 1397-1405. http://link.springer.com/article/10.1007%2Fs00254-007-1090-2

The purpose of this study is to assess the susceptibility of landslides in parts of Western Ghats, Kerala, India, using a geographical information system (GIS). Landslide inventory of the area was made by detailed field surveys and the analysis of the topographical maps. The landslide triggering factors are considered to be slope angle, slope aspect, slope curvature, slope length, distance from drainage, distance from lineaments, lithology, land use and geomorphology. ArcGIS version 8.3 was used to manipulate and analyze all the collected data. Probabilistic-likelihood ratio was used to create a landslide susceptibility map for the study area. The result was validated using the Area under Curve (AUC) method and temporal data of landslide occurrences.

4.250 Westen, C. J. V., Ghosh, S., Jaiswal, P., Martha, T. R. et al. (2011). "From landslide inventories to landslide risk assessment; an attempt to support methodology development

in India". Proceedings of the Second World Landslide Forum – 3 7 October 2011, Rome. http://changes-itn.eu/Portals/0/Publications/2011%20Van%20Westen%20et%20al%20WLF2.pdf

The paper gives an overview of a recent research project between GSI, the National Remote Sensing Centre (NRSC) and ITC (the Netherlands) on how the existing methods for landslide inventory, susceptibility and hazard assessment in India could be improved, and how these could be used in (semi)quantitative risk assessment. Due to the unavailability of air photos in large parts of India, satellite remote sensing data has become the standard data input for landslide inventory mapping. NRSC has developed an approach using semi automatic image analysis algorithms that combine spectral, shape, texture, morphometric and contextual information derived from high resolution satellite data and DTMs for the preparation of new as well as historical landslide inventories. Also the use of existing information in the form of maintenance records, and other information to generate event based landslide inventories is presented.

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6.23 International Journal of Geoengineering Case Histories

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6.26 International Journal of Advanced Life Sciences

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6.29 Journal of the Geological Society of India

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6.31 Journal of Scientific and Industrial Research

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8. Glossary / Terminology related to Landslides

Acceptable Risk - A risk for which we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Cloud Burst: Clouds are formed when water vapors reach a height where temperature is low. Water vapors condense to form small water droplets. When nucleation of such clouds takes place, water droplets grow in size to form raindrops, depending on the thickness of clouds and low temperature, the rain is light or heavy. In case of cloud bursts, cyclonic winds virtually compress the clouds and forced nucleation amounting to sudden precipitation takes place where all the water from the clouds is poured out. This is called cloud burst.

Sudden rainfall with great velocity is called a cloud burst. It results from the condensation of stratus clouds. It does not last very long. Heavy rains on the other hand are caused by nimbus clouds which are black in color and suspended at a lower height

Controlling (Perpetuating) Factors which dictate the condition of movement as it takes place; i.e. factors which control the form, rate and duration of movement.

Hazard - A condition with the potential for causing an undesirable consequence. Alternatively, the hazard is the probability a particular landslide occurs within a given time and space.

Individual Risk - The risk of fatality and/or injury to any identifiable (named) individual who lives within the zone exposed to the landslide, or who follows a particular pattern of life that might subject him/her to consequence of the landslide.

Landslides are simply defined as down slope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. **Landslide** is the most common and universally accepted collective term for most slope movements of the mass movement type. The term has sometimes been considered unsuitable as the active part of the word denotes sliding.

Mass Movement is outward or downward gravitational movement of earth material without the aid of running water as a transporting agent. It does not deny the importance of water in either its solid or liquid state as a destabilising factor nor does it excludes subsidence and other movements on flat ground.

Mass Wasting is a broader term commonly used in conjunction with the erosion cycle to refer to the mass reduction of the interfluves as opposed to the degradation by streams. In effect it must include the action of all non-linear erosional processes working on the slopes between streams.

Preparatory Factors which dispose the slope to movement; i.e. the factors which make the slope susceptible to movement without actually initiating it and thereby tending to place the slope in a marginally stable state.

Risk - A measure of the probability and severity of an adverse effect to individuals or populations, property or the environment.

Risk Management - The complete process of risk assessment and risk control.

Slope Failure refers to the process of rupture or shearing in materials rather than to a particular ground feature. Terzaghi (1950) advocated this term for slope movements on engineered slopes.

Slope Instability refers to the predisposition of a slope to mass movement. The condition may be recognised by analysis of stress within the slope, by various slope characteristics or by analysis of historical records of slope development.

Slope Movements restricts to mass movements on slopes.

Societal Risk - The risk of multiple injuries or deaths to society whole: one where society would have to carry the burden of a landslide accident causing a number of deaths, injuries, financial, environmental and other losses.

Stability Factors - All forces determining stability are controlled or influenced by identifiable phenomena are referred as Stability factors. When these operate to induce instability, they are called destabilsing or causative factors. e.g. climate, slope strength, vegetation etc. Indeed there are many components of the slope system which can change independently to destablise the slope but the significance of any change is dependent on the aggregated effect of all the components. An examination of the *temporal variability* of factors identifies some as being **passive** (slow or gradually changing) e.g weathering, and **transient or active** (fast changing).

Triggering Factors which initiate movement; i.e those factors which shift the slope from a marginally stable to actively unstable state.

Tolerable Risk - A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

9. Index (Author's Surname, Initials[Page No.])

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National Institute of Disaster Management
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