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Spatial Pattern of Landslide Vulnerability at Block Level in District Mandi of Himachal Pradesh: A GIS Based Approach

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ABSTRACT:

Keeping in view the complex topography and other physico – climatic factors the present analysis, a rating scheme to various parameters responsible for landslide occurrences has been developed. The previous work has been also considered for this rating system. A numerical rank ranging from 0 to 9 scale has been assigned to all the physico – climatic factors. Weight to parameters has been given from 0 to 9 as per their influence and relative importance to slope failure occurrence. The area obtaining higher weight indicates higher probability of landslides. Different parameters has been sub – categorized and assigned weight as per the probability of toward landslide. Each block of the district Mandi has been visited to verify the results of overlay analysis. Though, the study area has witnessed a number of landslides of various dimensions in the past and some of them are clearly identified during field investigation yet they are covered with fresh vegetation.

Keywords: Field verification, Landslide, Overlay analysis, Slope

INTRODUCTION

Mountainous terrain has been generally subjected to slope failure under the influence of various contributing factors (Singh and Sarkar, 2009). Rapid growth of human population and their activities such as deforestation, infrastructure development and expansion in built-up area is increasing the frequency and magnitude of slope failures (Rajbhandari *et al.*, 2002). Landslide hazard zonation is the demarcation of areas on the land surface and ranking of landslide prone areas as per the degree of vulnerability from the landslide or other mass movements on the slopes (Varnes, 1984). In general, landslide hazards cannot be completely prevented but the impact of the hazard can be minimized if the problem is predicted before any type development activity (Nithya and Prasanna, 2010). Therefore in this context, spatial mapping or demarcation of landslide vulnerable areas is essential for land development activities and management decision support in hilly terrain. Landslide susceptibility delineation is also an important issue for urban and rural planning in the various parts of the country. There are various analytical and empirical methods to identify the landslide vulnerable zones in order to generate a useful tool for urban planning and development (Sepulveda *et al.*, 2006). The

susceptibility to slope failure or landslide depends on the physiographical characteristics of the land surface. Landslide is complex phenomenon to study, in which multiple responsible factors needs to be analysed systematically in order to locate the vulnerable areas for landslide (Ramakrishan *et al.*, 2002). Landslide occurrence and geo-physical setting of the area has a defined relationship with each other (Chandel *et al.*, 2011). Successful spatial zonation of the landslide hazard and mapping of landslide prone areas is possible with the collection of relevant spatial layers which accelerate the landslide events. Landslide hazard zonation maps have gained wide acceptance in many countries of the world. These techniques and maps are serving as an effective tool in guiding and controlling the development in hilly areas.

STUDY AREA

The Mandi district comprises the area of present study. District Mandi is centrally located district of Himachal Pradesh. District Mandi is located between 31°13'50" to 32°4' 30 North latitudes, and 76°37'20" to 77°23'15" East longitudes, lying along the left bank of the river Beas in the foothills of Shivalik range (Figure 1). The total geographical area of the district is 3950 square kilometer which makes 7.10% area of the state and ranks 7th in the

state Himachal Pradesh. The district is bounded by Kangra districts on the north-west, Hamirpur & Bilaspur districts in the west, Arki tehsil of Solan district in the south, Shimla district in the south-west and Kullu district in the east. The district was formed

by merging of two princely states - Mandi and Suket on 15th April 1948, when the State of Himachal Pradesh came into existence.

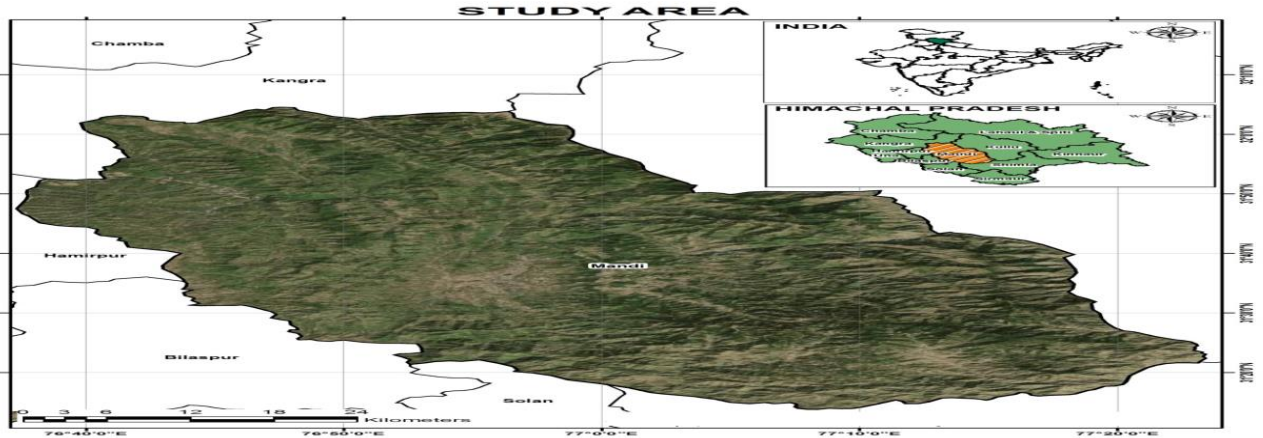


Fig.1 Study area

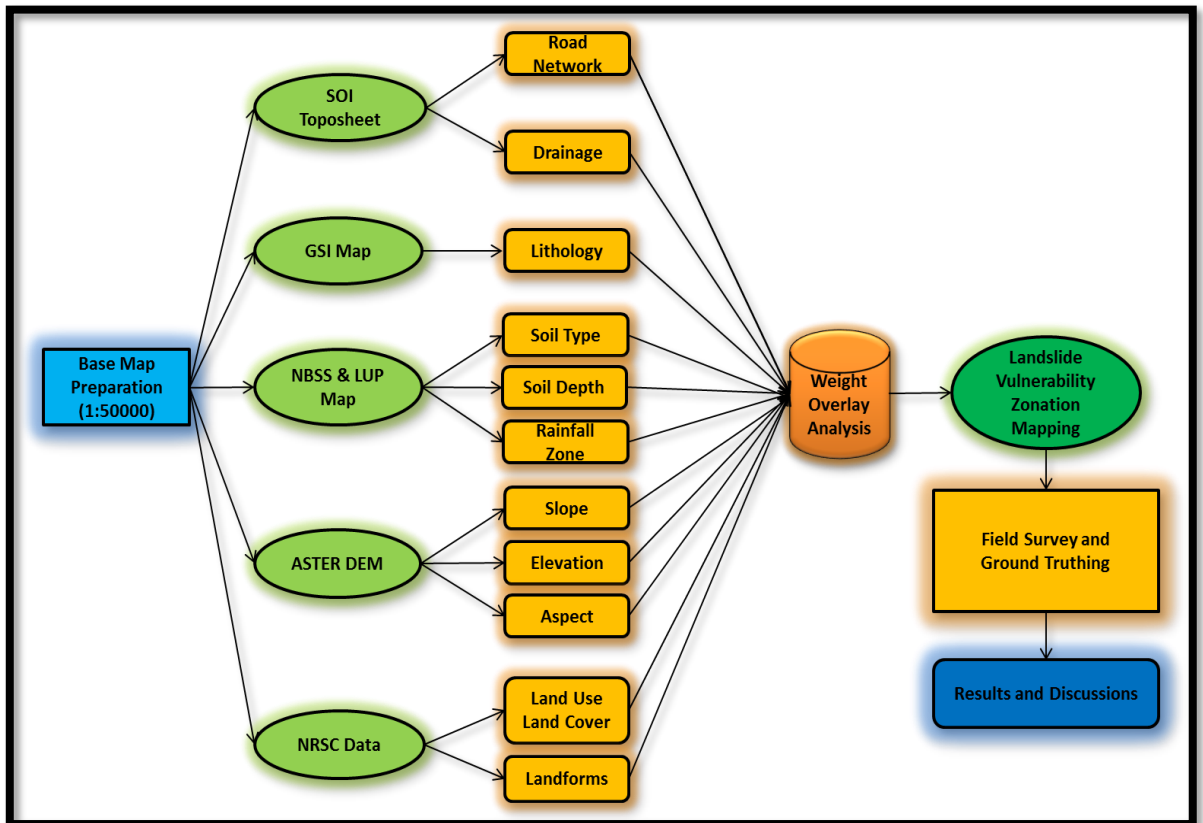


Fig.2 Flowchart

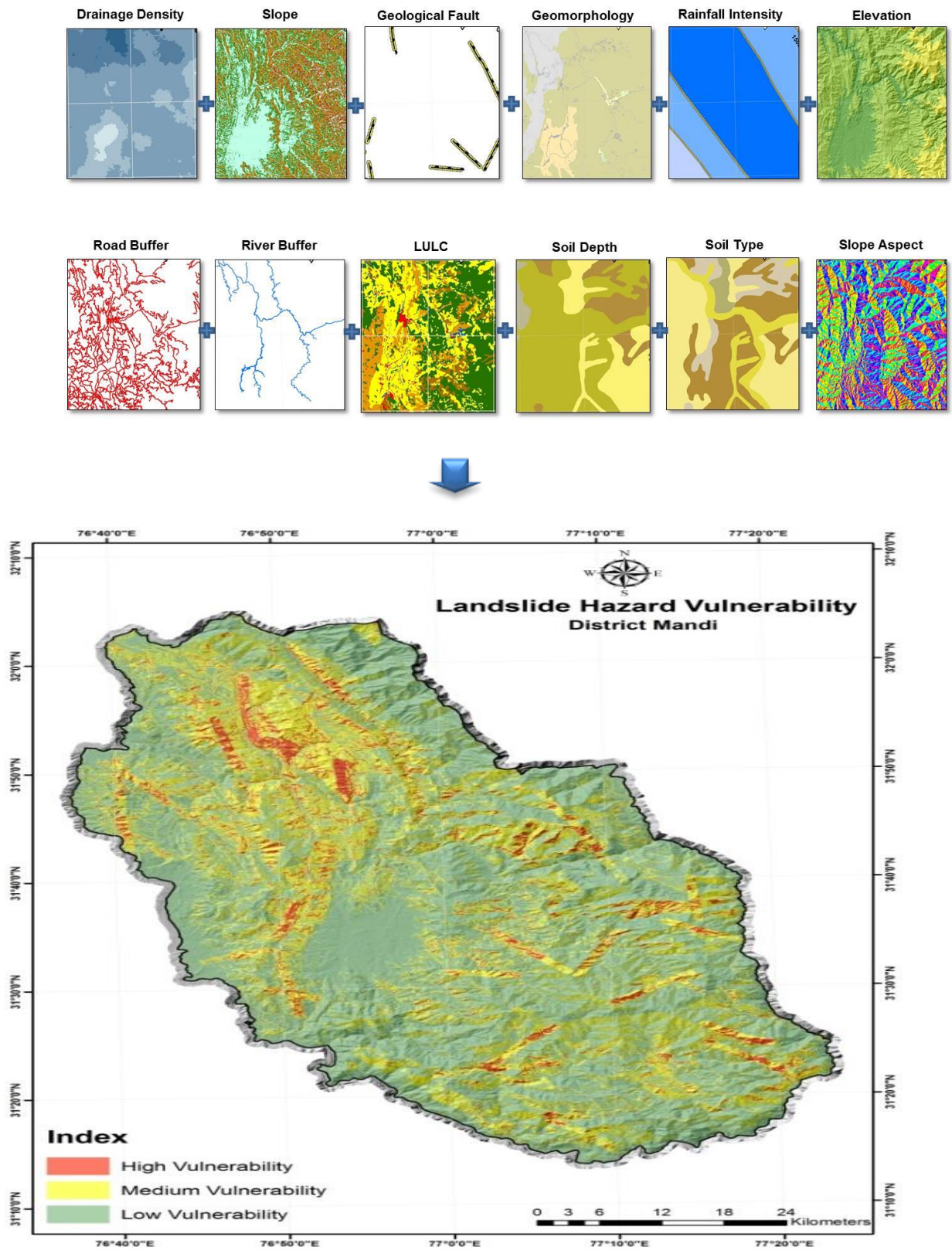


Fig. 3 Overlay analysis of Landslide

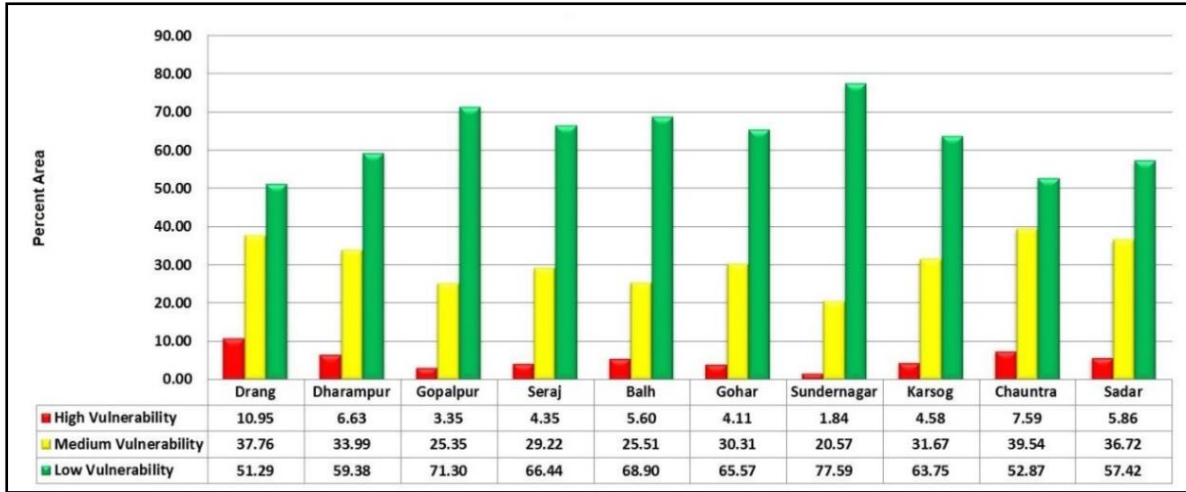
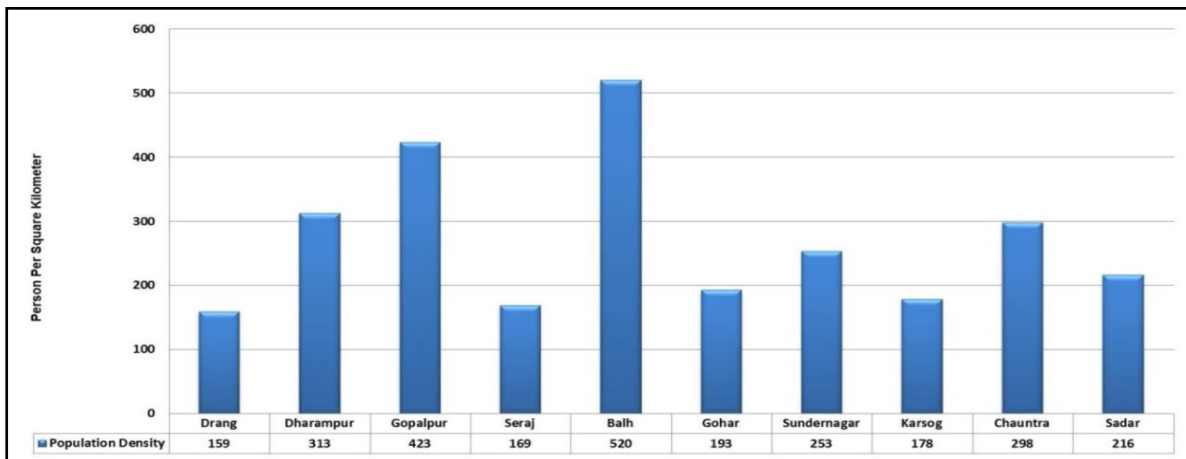
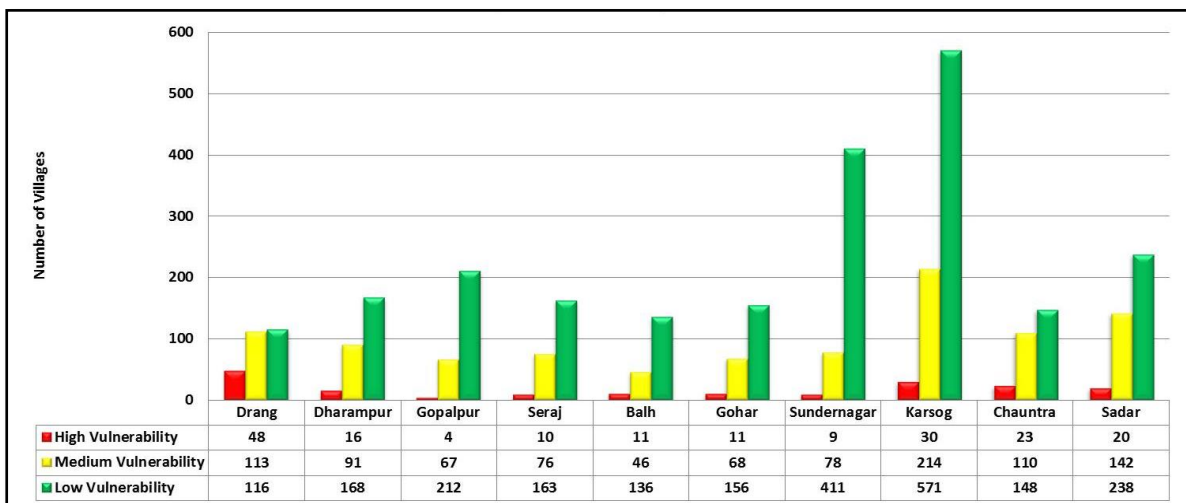


Fig. 5 Source : Calculated From Fig.4



Source: District Statistical Handbook of District Mandi, Himachal Pradesh, Census:2011

Fig.6 Block wise Population Density of District Mandi



Source: Calculated from figure 5.5

Fig.8 Block wise Community Vulnerability to Landslide Hazard in District Mandi

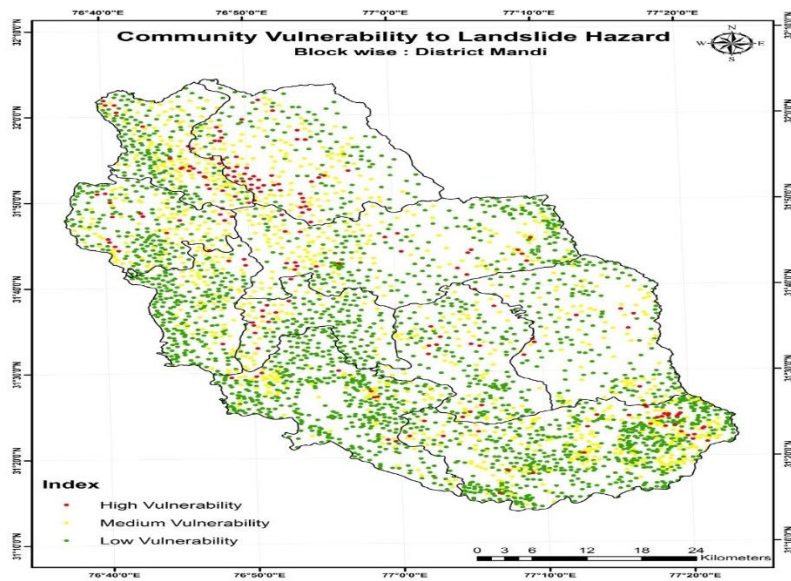


Fig.7 Source: Survey of India Toposheets

Photo Plate 1 - Landslide incidences due to road construction and widening nearby (a) Bhalog village of Karsog Block (b) Chirh village (c) Basahi village (d) Below Chakka village (e) Chimnhu village of Chauntra block and (f) Barjohru village of Gohar block



a



b



c



d



e



f

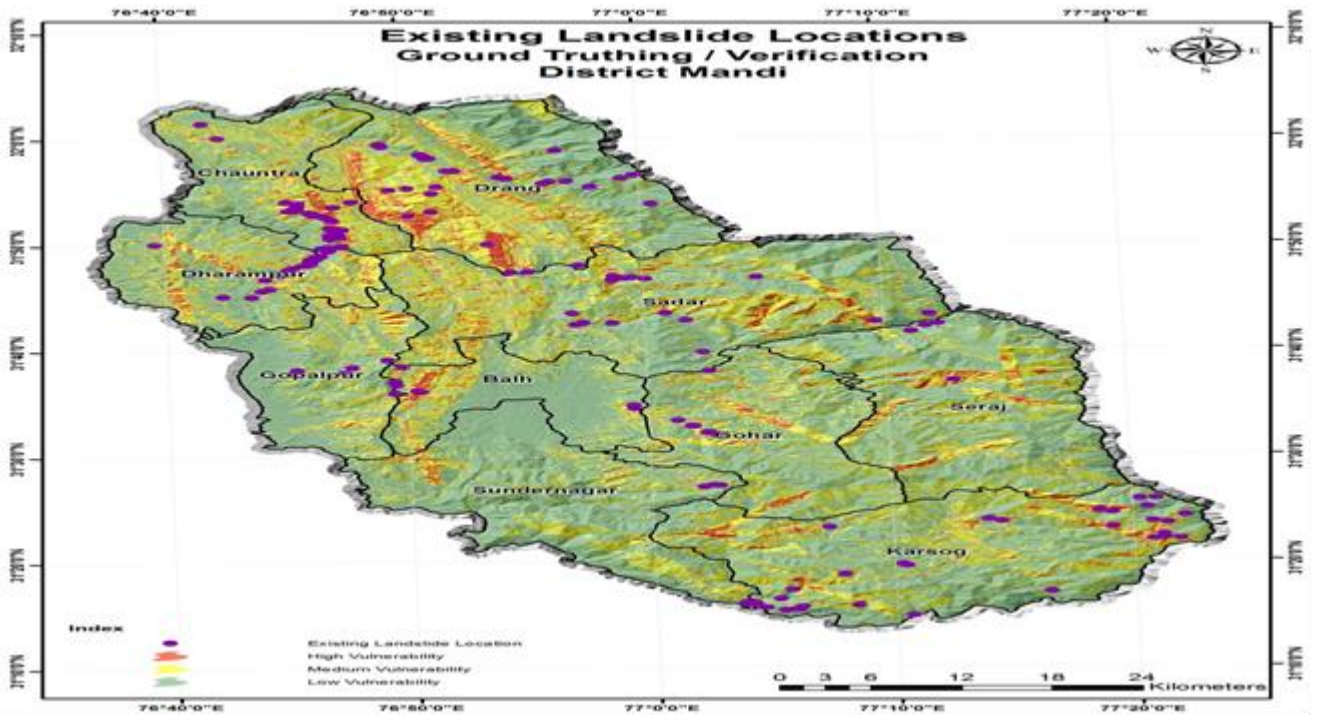


Fig. 9

Photo Plate 2

Unconsolidated debris and boulders resulting mass movements nearby (a) Bahi (b) Kufru - Morchakka of Chauntra block (c) Kotla, Kandha Pattan of Dharampur block and (d) Harabaag of Drang block

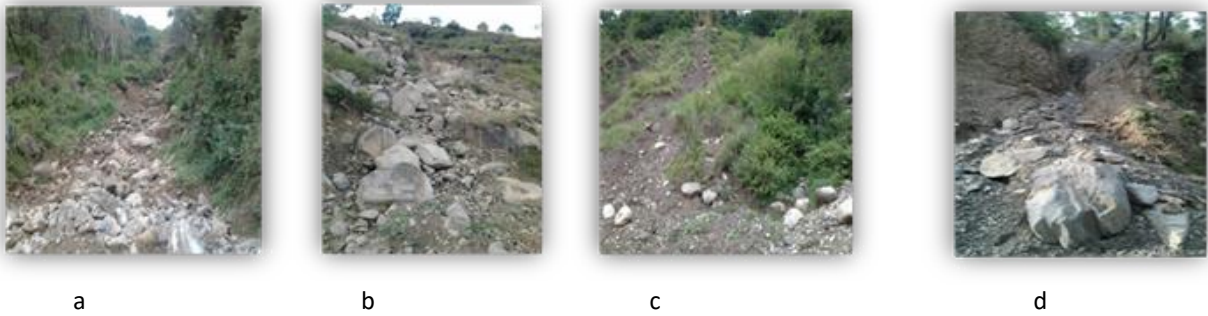


Photo Plate 3

Weathering of rocks leading to debris slide nearby (a) Gumma of Drang block (b) Bargta, Tattapani of Karsog block (c) Sarasakan of Dharampur block and (d) Gallu of Drang block

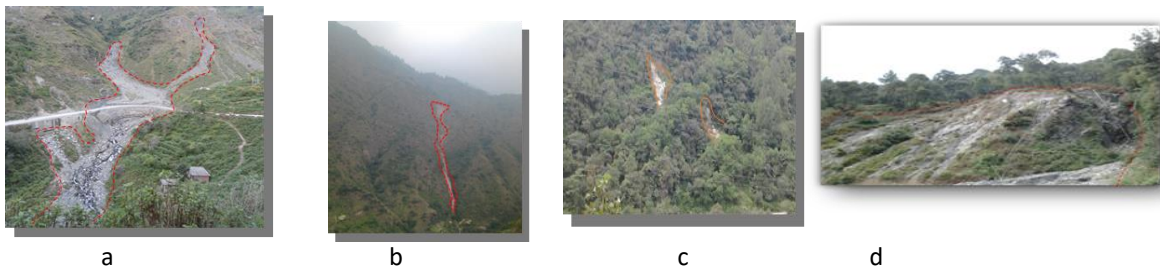


Photo Plate 4

Subsidence of land due to penetration of water during Monsoon nearby (a) Gumma (b) Harabaag of Drang block (c) Shivdhwala of Dharampur block (d) Chowk Gallu (e) Kalehru of Chautnra block (f) Sarohli (g) Hyolag of Dharampur block



a



b



c



d



e



f



g

Photo Plate 5

The visible landslide impact on vegetation cover nearby (a) Dabrehal (b) Aal of Chauntra block (c) Chharang of Drang block (d) Chail – Chowk of Balh block (e) Chakka of Chauntra block and (f) Kathyun of Karsog block



a



b



c



d



e



f



Photo Plate 6

Landslide affecting the Uhl River

DATA, METHODOLOGY AND TOOLS

The present study is based on both primary and secondary data. Primary data mainly include the field survey to verify the results on the ground with the help of Assisted - Global Positioning System (A-GPS) mobile phone to get the geo-tagged images and GARMIN Global Positioning System (GPS) for spatial location of existing landslides with in the study area. Secondary data is concerned with the use of remote sensing and GIS to identify potential landslide zones, it involves the generation of thematic maps relating to the causative factors. These thematic maps have been derived from Survey of India (SOI) toposheet number 53A9, 53A10, 53A13, 53A14, 53A15, 52D12, 52D16, 53E1, 53E2, 53E3, 53E4, 53E6, 53E7 at 1:50,000 scale; the Geological Survey of India (GSI) maps, National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) maps and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM).

All thematic maps have been classified into sub - themes and assigned ranks accordingly. Overlay analysis technique has been applied in the present study which allows us to apply weights to several inputs and combine them into a single output. Thus, generated vector layers has been processed in GIS environment using Union tool which calculates the geometric union of any number of feature classes and feature layers. The output feature class contains polygon representing the geometric union of all the inputs as well as all the attribute fields from all the input feature classes. At last resultant values has been summarized and categorised into three categories i.e. low vulnerability, medium vulnerability and high vulnerability. Figure - 2 is

depicting the data preparation and methodology framework for the present study. Data on past landslide events with its devastating impacts has been collected from online archive of the tribune newspaper, Geological Survey of India and SAARC – SDMC.

DATA PREPARATION AND METHODOLOGY FRAMEWORK

Following tools have been used to collect, process, prepare the database and analysis:

Assisted – Global Positioning System (A-GPS) based mobile phone: A-GPS works using cell tower data to enhance unwavering quality and precision when in poor satellite signal conditions and also provides geo-tagged images. A-GPS is dependent on internet connectivity.

Global Positioning System (GPS): The Global Positioning System (GPS) is a space-based satellite navigation system that provides locational information (latitude, longitude and altitude).

ArcGIS: Environmental Systems Research Institute's ArcGIS is geographic information system (GIS) software for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications and managing geographic information in a database.

RESULTS & DISCUSSIONS

Study area is centrally located district of Himachal Pradesh. According to 2011 Census, Mandi has a population of 999,777 and the density is 253. This has registered an increase of 25 percent person per square kilometer over 2001 census. The entire topography of the

district Mandi is hilly except Balh area in the Sundernagar and Chauntra in Jogindernagar which are fertile valleys. The density of above 250 may be treated quite high for a hilly district having high elevation and steep slopes. Balh valley of the district Mandi is located in the lesser Himalayan ranges having an average altitude of about 780 meter from mean sea level and slope direction is north north east. District Mandi is comprises of an intricate mosaic of mountain ranges, hills and valleys. It is primarily a hilly district with altitudes ranging up to 4025 meter from mean sea level. Generally elevation of the study area is increasing from west to east and from south to north. The south western part consists of Shiwalik ranges having scarped slopes. Study area is well drained by two major river systems Beas and Satluj Rivers. About 70 per cent of the total geographical area of the district Mandi is drained by river Beas and its tributaries in the northern part. Southern part of the district is drained by the Satluj River and its tributaries.

Keeping in view the complex topography and other physico – climatic factors the present analysis, a rating scheme to various parameters responsible for landslide occurrences has been developed. The previous work has been also considered for this rating system. A numerical rank ranging from 0 to 9 scale has been assigned to all the physico – climatic factors. Weight to parameters has been given from 0 to 9 as per their influence and relative importance to slope failure occurrence. The area obtaining higher weight indicates higher probability of landslides. Different parameters has been sub – categorized and assigned weight as per the probability of toward landslide.

Twelve parameters have been considered for identifying the landslide vulnerability as depicted, in Fig.3 after overlaying various physical parameters, study area has been categorised into three major zones of landslide vulnerability. The spatial analysis shows that about 6 per cent of the total geographical area of district Mandi is under high vulnerability while another 31 per cent area is having moderate risk of landslide. These zones of high and moderate risk vulnerability house more than 1/3 of population of the district. On the basis of selected parameters and 29 per cent of the total population is living within the area. Rest of the population is living in the area about 63 per cent of the total geographical area has low vulnerability to landslide occurrence. The landslide vulnerability analysis has been further carried out at block level which gives vulnerability status of every block of the district.

BLOCK WISE VULNERABILITY TO LANDSLIDE

Administratively, district Mandi has nine Tehsils, seven sub-tehsils, ten Community Development Blocks, five Local Urban Bodies (two Municipal Committees and three Nagar Parishads), 473 Panchayats constituting 2877 Wards, ten Panchyat Samities, and a Zila Parishad. There are five Forest Divisions in the district Mandi. For present study Community Development Blocks has been taken as a spatial unit to analyse the block wise vulnerability to landslide. Such as in India all works related to development are implemented administratively block wise.

Chauntra Block

Chauntra Block is situated on north part of the district Mandi. The area is the part of Beas river catchment which drains into Beas River through small khad and nallas. It lies in sub mountain low hill sub – tropical zone. Major soil of the area is brown hill soil. The texture of soils of the area varies from sandy loam to loam. Permeability and the water holding capacity differs with the texture. Gneissic rocks give rise to sandy loam soils. Shale and slates give rise to clayey and loamy soils. As it falls in sub-tropical zone the area experiencing all types of well-marked seasons. The winters are from December to February, both inclusive and is characterized by rain in low area and snow fall in Dahaula Dhar mountain range and are cold and it gradually changes over from winter to summer. The total geographical area of Chauntra block is about 238 square kilometer. The overlay analysis of 12 parameters reveals (Figure 4) that nearly half of the geographical area is either highly vulnerable (about 8 percent) or moderately vulnerable (39.54 percent) in the block while remaining 52 percent is lesser vulnerable. This may be attributed to valley type location having gentle slope. Vulnerability to landslide in the area has also been depicted graphically in figure 5.3. Out of total (about 281) settlement locations of the Chuantra block nearly half of the settlement locations falls under high and moderate landslide vulnerable zones. On the other hand nearly half of the village locations have less susceptibility to landslide incidences (Fig. 7 & 8).

Darang Block

Darang is the North East administrative block of district Mandi and the total geographical area of the block is about 524 square kilometer. It is hilly area where in Ghoghardhar contains the natural salt mines of ‘Gumma’ and ‘Drang’ and is covered with forests. The vulnerability map (Figure 4)

shows that more than 1/10 of this block is highly vulnerable while about 38 percent area falls under medium landslide vulnerability. The remaining more than half area has low vulnerability to landslide incidences and can be said safer. The block wise landslide vulnerability of the district has also been depicted through diagram (Figure 5). There are around 277 community locations in this block, out of which 48 locations falls under high vulnerability landslide zone. There are as many as 113 villages which have moderate vulnerability while another 116 village locations may be considered in the low vulnerability area. The village locations have been mapped and shown in figure -7 and represented graphically in Fig. 8.

Dharampur Block

Dharampur falls in mid hill sub humid zone and situated on the North West part of the district Mandi. The total geographical area of the block is about 267 square kilometer. Similar to other blocks, about 1/3 of the total geographical area is moderately vulnerable zone and about 7 percent is highly vulnerable to landslide occurrences. The rest about 60 percent of total geographical area of the block has low vulnerability in term of landslide incidences (Figure 4 & 5). There are more than twenty thousand families living in about 275 villages of the block (2011 Census). It may be observed that similar to the area, 1/3 of the total villages have moderate to high vulnerability while the remaining area treated under low vulnerability zone owing to their physico – cultural characteristics. This may also be visualised in Fig. 7.

Sadar Block

Sadar developmental block of district Mandi is situated on Middle East part of the district. Sadar block of district Mandi possess moderate to steep sloping valleys and extend over an area of about 601 square kilometer. According to Landslide Hazard Vulnerability map (Figure – 4) vulnerability to landslide in the Sadar block of district Mandi is high in about 6 percent of its geographical area and yet another 37 percent area of the Sadar block is has moderate vulnerability to landslide occurrences. The remaining area is of low vulnerability (Figure 5). In this block about 40 percent villages have moderate high vulnerability while the rest have low vulnerability (Fig. 7 & 8).

Gopalpur Block

Gopalpur block of district Mandi is located in Middle West part of the district and falls in temperate and sub-tropical zone with moderate to steep slopes. The total geographical area of the block is about 220 square kilometer. Owing

to geo-physical conditions and developmental objectives, the Gopalpur block has less than 30 percent of geographical area which is moderate to high vulnerable and remaining 70 percent is more or less stable (Figure 4). It was interesting to note that out of 283 villages in the block, only 4 were highly vulnerable and 67 falls in moderate vulnerable region. More than 200 villages occupying more than 71 percent of geographical area of the block have registered low vulnerability (Fig. 7).

Balh Block

Balh block is located in the central part of district Mandi and surrounded by Sadar block from North, Gopalpur block from West, Gohar block from East and Sundarnagar block from South. Balh block falls in outer Himalayan region with moderate to steep slope topography where deep to shallow stone embedded and loam to clay soils are found. The total geographical area of the block is about 221 square kilometer. The Landslide Hazard Vulnerability map (Fig. 4) reveals that only about 5.6 percent geographical area of Balh block is highly vulnerable and about ¼ is having medium vulnerability to occurrences of landslides. Remaining 2/3 area has a low vulnerability. There is a high population density of 520 people per square kilometer which 455 in 2001 (Figure 6). There have been less than 200 villages in the block (Figure 7 & 8) and only 11 villages falls under high vulnerability zone and other 46 villages have moderate vulnerability to occurrences of landslide. Village locations have been mapped and also presented graphically (Figure 7 & 8).

Gohar Block

The Gohar development block is situated at South – West part of the district Mandi which falls in Mid-Mountain (Inner Himalaya) with moderate to steep slope. The block is surrounded by the Seraj, Karsog, Sundarnagar, Balh and Sadar blocks. The total geographical area of the block is about 358 square kilometer. As per the landslide vulnerability map (Figure 4) the Gohar developmental block has little above 1/3 of its geographical area under medium to high vulnerability. In it only about 4 percent area of the block is more vulnerable and nearly 2/3 of the geographical area falls under low vulnerability region. The geographical presentation has been also given in figure - 5. There are around 235 villages in the block out of which 11 have high vulnerability and 68 villages have medium vulnerability. Remaining 156 villages lies in the low vulnerability region (Fig. 7 & 8).

Seraj Block

Seraj Block is located in South – East part of the district Mandi and it falls in Mid-Mountain Inner Himalayan region with moderate to steep slopes. The total geographical area of the block is about 497 square kilometer. In term of landslide hazard vulnerability (Figure 4) the similar picture as that of Gohar block emerge in Seraj block as well. Little above 1/3 of its area is under moderate to high vulnerability of landslide and the remaining 66.44 percent area has a low vulnerability to landslide incidences. Vulnerability to landslide in the area has also been represented graphically (Figure 5). The density of population is much less than the district average (Figure 6). Out of the total 249 villages of the block 10 are highly vulnerable and 76 have moderate vulnerability from landslide point of view (Fig. 7 & 8).

Sundernagar Block

Sundernagar block is located in South – Eastern part of the district Mandi. The area falls in mid-hills sub-tropical zone with low to moderate slopes. Middle part of the Sundernagar is a flat terrain having fertile soil. Average altitude ranges from about 650 meter to 2650 meter from mean sea level. The total geographical area of the block is about 413 square kilometer. As illustrated in figure – 4, vulnerability to landslide in the Sundernagar block has least area under highly and moderately landslide vulnerability zone (20.57 percent). More than $\frac{3}{4}$ of area falls under low vulnerability to landslide incidences. There are around 498 inhabited villages in the block, out of which 9 are having high vulnerability to landslide, 78 settlements location have medium vulnerability while 411 villages are in the low vulnerability zone (Figure 7 & 8).

Karsog Block

Karsog is the southernmost block of district Mandi which falls in Mid-Mountain Inner-Himalaya. Some part of the block is densely covered with forest. Topography of the area is mostly undulating and rugged where soil varies from sandy loam to clay loam with predominance of sloppy areas and stones. The slope in the area is moderate to steep and varies from about 15 degree to 65 degree with some areas even more sloppy. The total geographical area of the block is about 586 square kilometer. The Landslide Hazard Vulnerability map (Figure – 4) shows that about 36 percent of the area of Karsog falls under high and moderate vulnerability zone of landslide occurrences. Among all the block of the district, there are highest number of 815 villages in this block. Out of this 30 villages have high vulnerability and 214 is moderately vulnerable to landslides while 571 village

locations are in the low vulnerable area (Figure 7 & 8).

GROUND VERIFICATION AND FIELD OBSERVATIONS

Landslide often occurs at a specific location with certain geological and topographical conditions. In order to understand this, a landslide hazard vulnerability map has been prepared and categorised as per vulnerability to landslide from low to high. Major landslide affected areas were examined and few GPS points (Appendix – II) and photographs were taken to validate the inventory maps (Figure 9) with the help of Global Positioning System (GPS). Each block of the district Mandi has been visited to verify the results of overlay analysis. Though, the study area has witnessed a number of landslides of various dimensions in the past and some of them are clearly identified during field investigation yet they are covered with fresh vegetation. Most of the landslides can be viewed in the form of debris flow in nature. However few rockslides besides the major roads were checked during the field investigation. The presence of scarps and transverse cracks are useful for determining whether area is potential for future activity or not.

LANDSLIDE INCIDENCES AS A RESULT OF ROAD CONSTRUCTION AND ROAD WIDENING

Occurrence of landslides and landslips due to development activities like construction of roads and road widening is a common feature in the hilly state. Many a time's hills are cut in an 'unscientific manner' by the Public Works Department (PWD) and private contractors resulting in loosening of soil. During road widening, hills are cut and the upper portion is left unbalanced. No thought is given to what would happen to such imbalanced structure, especially during monsoon. Every year one or the other stretches of the roads are blocked due to landslide or huge rock mass causing loss to life & property. Travelling on the main Sarkaghat- Jogindernagar state highway which is crucial for residents of Jogindernagar, Sarkaghat and Dharampur, have become nothing less than a nightmare for commuters. The long stretches of roads have been damaged by landslides and rain turning these into slushy potholes. The widening work on the Sarkaghat-Jogindernagar highway has worsened the condition of the road between

Dharampur and Jogindernagar and the 12-km-long stretch of the road has become prone to landslides. Village Basahi, Chhaka, Chirh, Chimnu and Neri are very much vulnerable to landslide in this area because of road widening work. These villages are located nearby the road where boulders and rock fragments are continuously moving downward. Around the Chakka village (Photo Plate 1d) grassland has subsided due to road widening work as it has become weak during monsoon and water penetrated. Near Chirh (Photo Plate 1b), Basahi (Photo Plate 1c) and Chimnhu (Photo Plate 1e) village a huge mass of land came down and damaged the road because of the undercutting of slope. It also damaged the vegetation existed over there. There was another landslide on link road from Shimla – Karsog highway near Bhalog (Photo Plate 1a) village which damaged the already constructed road. Another landslide recorded on Shala link road near Barjohru of Gohar block (Photo Plate 1f). This landslide occurred due to the absence of retaining wall and during monsoon it damaged 50 meter stretch of road.

UNCONSOLIDATED DEBRIS AND BOULDERS RESULTING MASS MOVEMENT

In few places it was observed that unconsolidated debris is moving downward during or immediately after heavy rain. This type of landslide has been seen near Bahi (Photo Plate 2a), Kufru – Mochakka (Photo Plate 2b), villages of Chuntra block, Kotla village (Photo Plate 2c), of Dharampur block and Harabag village (Photo Plate 2d) of Drang block.

WEATHERING OF ROCKS LEADING TO DEBRIS SLIDE

Several parts of the study area suffer from rock falls. Few such rock falls occurred nearby Alsindi, Tattapani (Photo Plate 3b), Sarasakan village (Photo Plate 3c), Gallu Village (Photo Plate 3d) and near Gumma (Photo Plate 3a) on Mandi Pathankot Highway. Every year these slides damage the road segments as this process is unabated for the past many years.

SUBSIDENCE OF LAND DUE TO PENETRATION OF WATER DURING

Monsoon season while loose and unconsolidated material works as a catalyst for landslide. During the rainy season, the landslides are very common and frequent, which take a considerable toll of human lives and cause irreparable loss to roads, agricultural land and damages to

buildings, houses and other built-up structures. Problem of landslide is very common and frequent in district Mandi during monsoon season. Almost every year the district is affected by one or more major landslides affecting the society in many ways. The frequency of landslides has increased in the recent past due to extensive road construction and other haphazard developmental activities. The abrupt and continuous rainfall mechanism adds to the problem of landslides. It induces shallow landslides, mostly soil slip and debris flows, initiated by a transient loss of shear strength resulting from the increase in pore-water pressure, caused by intense rainfall on loose surface soil underlying finer less permeable bedrock. Such type of case has been seen near Harabag (Photo Plate 4b), Gumma (Photo Plate 4a) of Drang block, Shivdhwala (Photo Plate 4c), and Hyolag village (Photo Plate 4g) of Dharampur block, Neri Langna, Sarohli (Photo Plate 4f), Kalehru (Photo Plate 4e), Chawk Gallu (Photo Plate 4d) and Samor villages of Chauntra block. In Kalehru village of Chauntra block due heavy rainfall of 72 hours in monsoon water penetrated to surface soil and then burst with lot of debris and boulder. It damaged two houses and washed away agriculture land of the villagers. Near Harabag road was blocked as a huge landmass came down due to heavy rainfall.

IMPACT OF LANDSLIDES ON VEGETATION COVER

During ground verification it was observed that many forest areas in Dabrehal (Photo Plate 5a), Aal (Photo Plate 4b), Chharang (Photo Plate 4c), Chail Chawk villages (Photo Plate 5d) have been damaged by landslide. It has been seen that when landslides occur on forested slopes, in extreme rainfall and wind events, they may be larger and more destructive than on non-forested slopes. In particular, they are likely to evolve in to debris flows which deliver large volumes of sediment and woody debris. The landslides have been affecting grassland and forest with lesser density and the open forest more than that of densely forested area. The grassland affected by landslides has been witnessed in village Chakka (Photo Plate 5e) and Kathyun (Photo Plate 5f).

LANDSLIDE AFFECTING THE UHL RIVER

A massive lake was formed on Uhl River as a result of the fall of debris which blocked the Uhl river on 9th September, 2014 night. The location is on Kamand – Riyadgi road, 15

kilometer from District Headquarter (Photo Plate 6).

RESULTS

District Mandi is entirely a hilly region except Balh area in Sundernagar and Chuantra area in Chuantra block. The total geographical area of the district is about 3950 square kilometers which constitutes 7.095 per cent of the total geographical area of the Himachal Pradesh. In general, there is an increase in elevation from south to north with moderate to steep slope that varies between 15 degree to more than 45 degree slope angle. Altitude also varies from 1000 meter to above 4000 meter from mean sea level. Topographically, the Mandi district can be divided into two main categories. First, Shivalik (Outer Himalaya) region contains the Balh valley, Baldwara and Joginder nagar area. Deep to shallow stone embedded and loam to clay soils are found in this zone. Secondly, Mid-mountain (Inner Himalaya) region contains the areas of Chachiot, Karsog, and Seraj and part of Drang blocks fall in this region. The series of parallel ranges are divided by longitudinal valleys. There is continuous increase in the height from valley to hills. Dhaula Dhar range covers a part of Suket area and runs with the Eastern boundary of district from North to South. Nagru is the highest peak with an elevation of around 4400 meters from mean sea level. Ghoghar Dhar contains the salt mines of Gumma and Drang and fully covered with forest. Sikandar Dhar comprises of Kamlah range and Lindi Dhar which runs from North-West boundary of Suket. Dhar Vairkot range starts from Rewalsar and extends towards Suket. Thus, the study area has vulnerability to landslide and every year it is experiencing the incidences. All 10 blocks of the study area has been travelled and found that area is facing different types of landslides such as landslide incidences as a result of road construction and road widening. In some places unconsolidated debris is moving downhill side and weathering of rocks also caused debris slide in the unstable slopes. Rainfall is the main factor for accelerating the landslides in the study area and number of landslide cases has been seen during the field survey. In the study area landslide also affecting the forest, vegetation,

grassland and agriculture land. Next chapter of the dissertation is summarizing the whole research work and concluding with few policy imperatives.

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