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LANDSLIDE MANAGEMENT PLAN FOR MITIGATION AND ADAPTATION TO LANDSLIDES RISK ZONES OF MANDI DISTRICT, HIMACHAL PRADESH

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Abstract

The mandi district of Himachal Pradesh witnessed damaged to life, road ,infrastructure and landscape .The current study generates knowledge about landslide influencing factors and generates landslide hazard zonation maps using GIS, which is based on Analytical Hierarchy process method in which their weightage will be given to the parameters according to their importance in the landslide hazard. The research was conducted on a portion of Mandi district in Himachal Pradesh, India, which is most important landslide hazard area. With the help of landslide inventory, a range of landslide triggering geo-environmental factors were chosen for landslide hazardous mapping, including slope, relative relief, soil, Land Use and Land Cover (LULC), lithology, drainage density, and earthquake hazardous. The study area's slope gradient, slope aspect, curvature, and relative relief map were created using a digital elevation model. Also, in this study analysis part of different element at risk will be our outcome which will help to focuses on the building damage, injured and fatalities rate. Further it is analyzed spatially at the regional Scale itself and susceptibility is done on these three parameters in which it distinguishes the highest to low in which strategies and proposal is given to most vulnerable.

Keywords: Landslide hazard zonation, Satellite data, Landslide preparedness.

1. Introduction to Study Area:

The Mandi district is situated between 31°42′25″ Northern latitude and 76°55′54″ East longitudes .The boundary of the district is allied with Kullu on the north-east, Kangra on the northwest, Hamirpur & Bilaspur in the west, Solan district in the southwest and Shimla district in the south. Mandi located at the banks of Beas river. In terms of number of villages, there are 3348 village in Mandi . Mandi is 5th largest district in the state and 2nd and 3rd in terms of population and sex ratio.

1.1. Geology and Weather Condition

The rock formations mainly comprise of igneous and metamorphic rocks from Precambrian to Quaternary period. The Formation of the district belongs to the Jutogh, Shali/ Largi and Shimla Group. Intrusion of granites and gneisses are observed in meta-sediments of Largi and Shimla Group. The sedimentary rocks namely, sandstone, shale, siltstone, conglomerate etc of Dharamshala/Sabathu Group and Siwalik Group of Tertiary age are observed in western and southern parts sediments.

Mandi has a moderate climate in valley regions and temperature on hilltops. Variation in average minimum and maximum temperature is in the range of Profile of Mandi District, Himachal Pradesh7 degree Celsius to 35 degree Celsius. Cold climate is experienced throughout the year in the higher elevation regions whereas Balh valley and other low elevation are hot in summer.

Winterarrives in middle of November and extents to the middle of March, the period in which snow falloccurs down to elevation of 1300 m.. Monsoon in the region emerge from the last week of June or early July and till the middle of September. In the monsoon period from July to September,region receives precipitation in the form of rainfall. High variation is observed in the annual average rainfall from place to place in the district, which range from 700 mm to more than 2000 mm at Joginder nagar.

1.2. Regional Connectivity:

In recent times, Mandi has also gained importance as a hub for regional connectivity. The district is strategically located on the National Highway 3, which connects Delhi to Leh in Ladakh. It is also well connected to other major cities in the region, such as Chandigarh, Shimla,and Manali, through a network of well-maintained roads.

The district also has an airport, the Kullu-Manali Airport, which is located in Bhuntar, about 10 kilometers from Mandi. This airport has regular flights to major cities in India such as Delhi, Mumbai, and Chennai, making it easier for people to travel to and from Mandi. Additionally, the district has a railway station, the Joginder Nagar Railway Station, which connects Mandi to the rest of the country through the narrow-gauge Kangra Valley Railway. This railway line is a popular tourist attraction and offers scenic views of the surrounding mountains. The improved connectivity in Mandi has helped to boost tourism and trade in the region. The district is now a popular destination for adventure sports such as trekking, camping, and river rafting. The improved transportation infrastructure has also made it easier for businesses to transport goods to and from the district, leading to increased economic activity.

2. Need:

The Himalayan mountains of Himachal Pradesh mostly suffer landslides during monsoons and also in high intensity earthquakes. Due to unstable steep slopes of various Himalayan ranges, has been increased in recent decades due to different activities , like road cutting and due to development .The study area has large exposure to the slope failures due to its physiographic and climatic conditions. The rainfall, the tectonics, and other anthropogenic activities like road construction are the main causes of landslides in the study area that disturb the high-rise mountains. The main classes of landslides are rock falls, rockslides, debris flows, rotational type failures happen along the highway and settlements . This highway road corridor section needs a lot of construction works like excavation, retaining walls, and embankments etc. Every year These works disrupt traffic flow and cause instabilities, which sometimes lead to the life and property losses. The hazard zonation maps prepared in the current study will be helpful for the engineers to identify major landslides in Mandi District for the present improvements and future mitigation.

3. Scope of the Study:

Scope of this project is to identify the major loopholes and causes of landslides with the help of ArcGIS mapping which will help us to find the weak areas and point where construction of highways should be taken more precautions .by making zones on the bases of the analysis the areas will be pointed down and according to that risk perception data will be there to find out the areas and preparedness for the future disaster management plan will be prepared . It will help to create data base of landslide risk zones maps .

4. Objectives:

The objective of the thesis based upon how we can achieve the aim so given below is their how step bystep we can achieve the aim

- To understand the existing scenario of landslide through reports and governmentdocuments
- To collect the data from the different sources and analysis or evaluatethe occurrence oflandslide
- To prepare strategy to manage landslides and enhance the disaster preparedness foreffective response by minimizing indirect (manmade)and direct risk (natural).

5. Data Collection:

The data used in the study were Cartosat satellite data on the scale of 1;500000 from bhuvan as well as from USGS digital elevation data .The topography maps and data of rock types , structural, lineaments ,slope, geomorphology , rangeland ,land use and landslide data were collected from survey of India .Some primary survey also has been done to analysis the understanding of the people towards the landslide there education level and through which median they get information of landslides.

6. Methodology:

1. Collecting data: This includes gathering information on the topography, geology, soils, and land use of the study area. Aerial photographs, satellite imagery, and topographic maps can also be used to help identify potential landslide-prone areas.
2. Conducting field observations: Field surveys are conducted to identify and document past landslide events and their characteristics, such as location, type, and size. The observations can also help identify features that may contribute to landslide hazard, such as steep slopes, soil type, and vegetation cover.
3. Developing a landslide inventory: A landslide inventory is a detailed record of all known landslides in the study area. This can be developed using field surveys, aerial photographs,and other data sources.
4. Analyzing data: The data collected is analyzed to identify patterns and relationships that can help identify areas that are most prone to landslides. This can include creating maps ofslope gradients, soil types, and land use.
5. Creating hazard models: Hazard models are developed using data on the potential triggers of landslides, such as rainfall, soil moisture, and seismic activity. The models can be used to predict the likelihood of landslides occurring in specific areas.

Mapping hazard zones: The final step is to map the landslide hazard zones based on the information gathered and analyzed. These maps can be used to identify areas that require mitigation measures, such as stabilizing slopes or other improvements.

7. Analysis and Data Presentation

As we know that landslides have many type which can be divided into different type as per their nature . In mandi district the maximum number of landslides happen was debris and rock Fall with 35 n followed by rock cum debris and earth movement which comes with 29% and 0% because the 5 inciden till now .

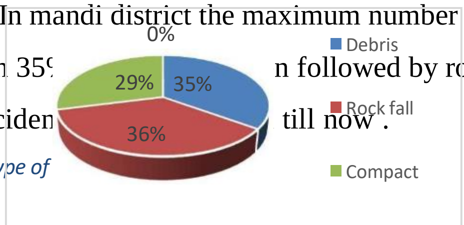


Figure 1:Type of

7.1. Recent Trends of Landslide

Recent trends also distinguish is the factor is rising by the years or it is decreasing. In addition, it tell the number and magnitude of that factor which we want to study. Landslide in the Himachal Pradesh is evation and slope is prime factor by which the number of this disaster is increasing and affecting the

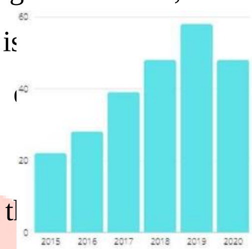


Figure 2 trends of landslide

and habitants. Talking about the study area only from the data that is given by t 2015 year it is increased by the 39% till 2020this due to so many of the anthropogenic factor, soil infiltration decreases and also climate changes impacting the landslides.

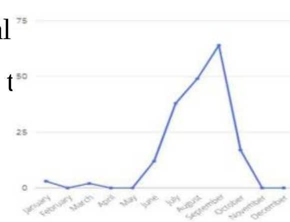
7.2. Elevation of the Area

The study area constitutes varieties in the elevation as they having mountains, which is having the distance from seawater that is 461m-3668m consists. The highest peaks of elevation comes

under Thunag Joginder nagar and outer eastern part of mandi and the medium level of elevation comes in sundarnagar and sargakgat sub -districts.The Beas is the largest river in the Mandi district, and it is the Mandi's' heart and soul. It drains the entire Mandi valley proper between the Dhauladhar and Himalayan ranges, and thus commands the largest and most important portion of the district, together with its tributaries. The Beas river originates in the Rohtang La region .

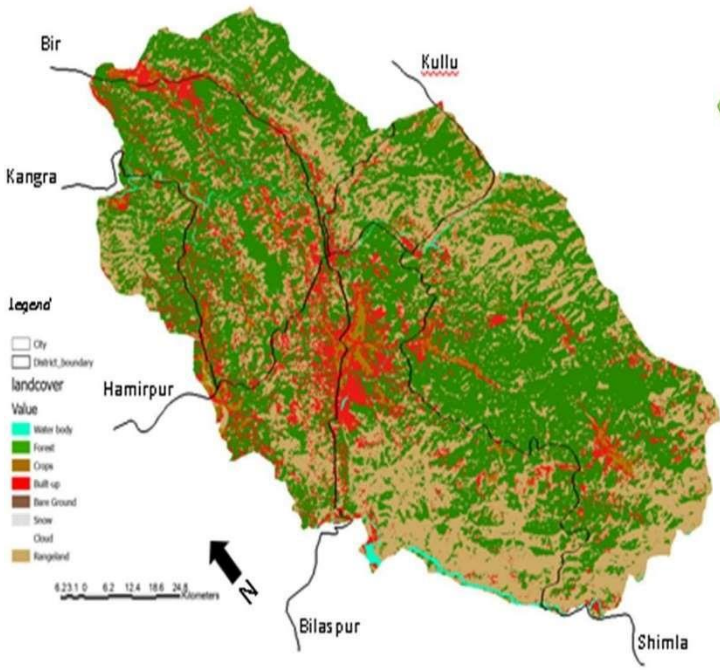
7.3. Occurrence of Landslide (Months)

As earlier it is stated the occurrences of landslide completely depends upon the natural nic factor mainly in the natural factor it includes the sub factor like triggering factor which cause t ainfall in further it concludes its duration and



slide

intensity which affects area cause landslide mainly in the study part of our area most of the intensity and occurrences of landslide is starting from the month of June in which it has moderate of occurrence and then its number and magnitude increased in the month of July august September and then decreased in the October. Sometimes in the month of January and February the occurrence of landslide is their, but number is low.



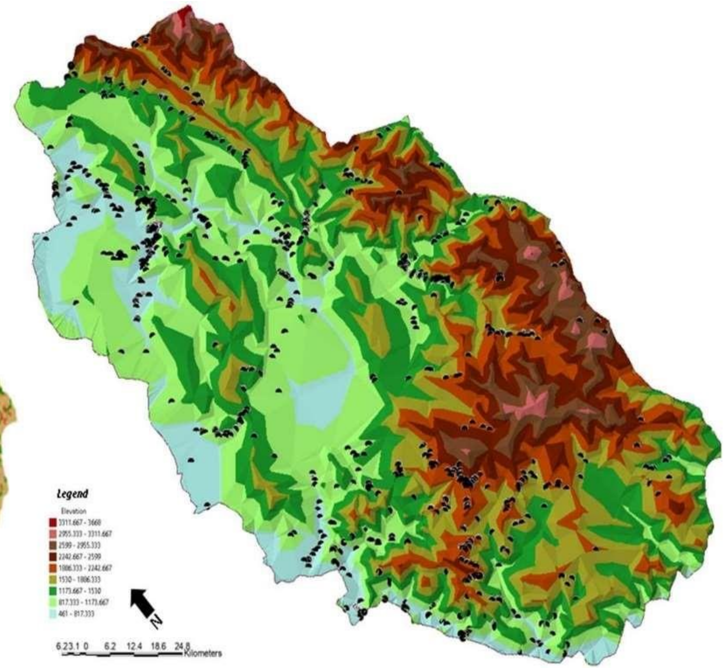


Figure 3: Landcover Map of Mandi district

Figure 4: Existing Landslide Map of Mandi district

7.4. Land Cover

Land cover means the type of land is covered or utilized by which type of use. Land cover is done for the region to show the built up area it doesn't goes to which type of built up land is it

.From the landcover map we can understand that

the maximum number of land is under forest with 52% and rangeland cover 33 % of the land

.Other than built up show in red color which cover 12 % of the landcover . As max number of built-up is along road and valley areas due to its slope as

slope is lower in those regions. The crop land and bare ground can be seen in map with 2%and 1 % out of 100%.

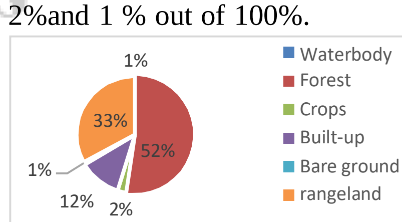


Figure 6: Landcover Distribution

7.5. Parameter Data Interpretation & Analysis

For LHZ mapping, a spatial database describing landslide-inducing variables such as slope gradient, curvature, slope aspect, relative relief, lithology, lineament density, drainage density, LULC, and soil cover are used to model information importance and frequency ratios. The LULC and landslide inventory map were created using the LISS-III image and Google Earth.

7.5.1. Slope Analysis

Slope analysis done to know which part of area is having high slope, which will hazards in terms of various disaster. Further , it divided into various part according to their present availability in terms of type of angle.

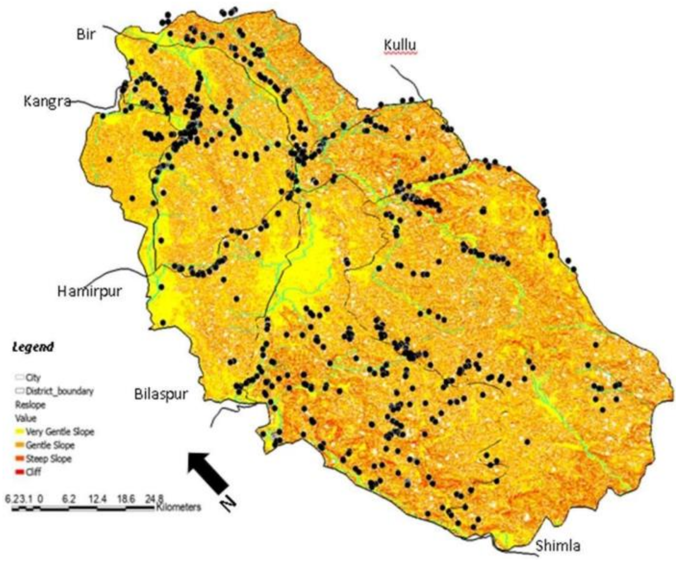


Figure 5:Slope Analysis Map

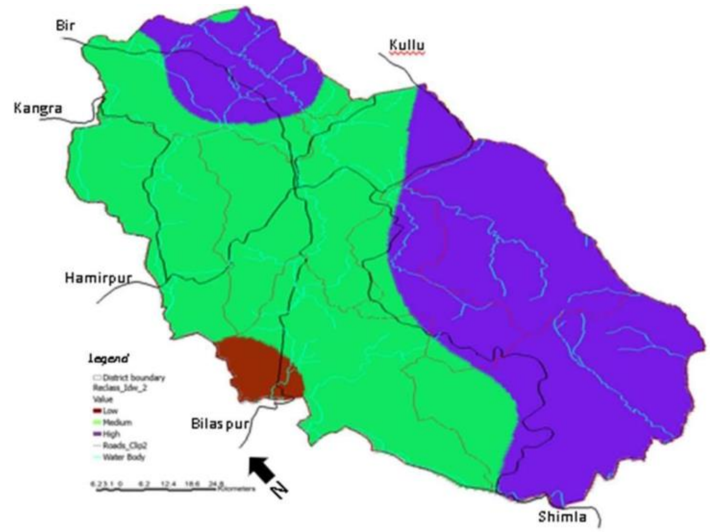


Figure 1:Relative Relief

huge when 50% of the land and number of landslide are dominated .

7.5.2. Relative Relief :

Relative Relief is very important map as the parameter of landslide hazardous map .The natural relative relief, which is a change in elevation, resulting in the occurrence of landslides, affects conditions. As you can see in figure 8 . In this study, relative relief was found to range from 317 to 2747 meters. Low (317- 1594 m), moderate (1594–1946 m), and high (1946–2747 m) relative relief levels have been assigned to the map. The maximum are of mandi district comes under moderate level and it covers 53% of the area and in high level it cover 45% of the mandi district and 2 % of the cover is by low level .

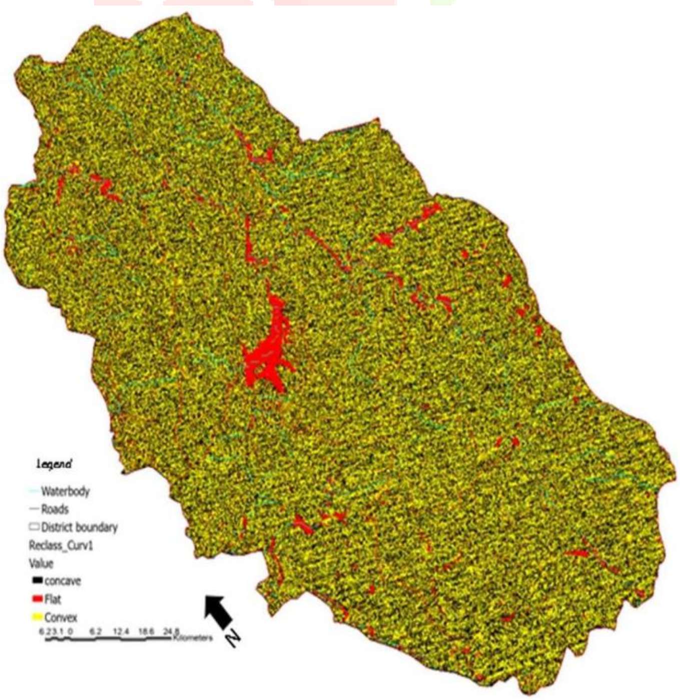


Figure 9: Curvature Map

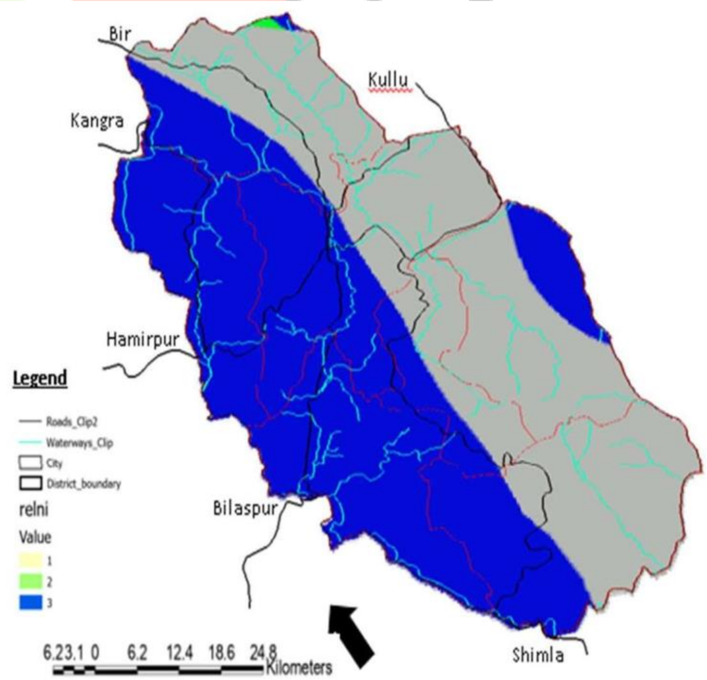


Figure10: Soil type Map

The curvature is the random plane intersection with surface. In fig.9 you can observe The inflow and outflow of the water are controlled by the curvature of slope. The curvature map of the study area is classified into concave, convex, and flat categories. Maximum of the curvature analysis distinguish on the concave area which is having 47% and then it is having 40% of convex curvature .

As show in the map with red color which shows flat with 13% of total area . The major flat area is mandi town which is situated on the bank of beas river and further the flat are on the north- west direction is the stream area of beas river which goes to pong dam reservoir .

7.5.3. Soil Type / Rock Type Analysis

The properties of soils, including Eutric Cambisols, Dystric Cambisols, and Lithosols, can have an impact on their susceptibility to landslides.

Eutric Cambisols are characterized by having a high nutrient content and good soil structure, which can help to increase the stability of the soil. However, Eutric Cambisols that have been heavily disturbed or have been subjected to intense rainfall or other environmental stresses may be more prone to landslides.

Dystric Cambisols, on the other hand, have a lower nutrient content and may have a less stable soil structure, which can increase their susceptibility to landslides. The presence of rock fragments in Dystric Cambisols can also contribute to their instability, as these fragments may act as potential sliding planes or weak points in the soil.

Lithosols are soils that are predominantly composed of rock fragments, with only a thin layer of soil covering the rock. Because of their rocky nature, Lithosols are generally less susceptible to landslides than soils that are predominantly composed of finer materials. However, Lithosols that are heavily weathered or have been subjected to intense erosion may be more prone to landslides.

Overall, the properties of Eutric Cambisols, Dystric Cambisols, and Lithosols can all play a role in their susceptibility to landslides, with factors such as soil structure, nutrient content, and the presence of rock fragments all contributing to the soil's stability or instability.

Rock Type

These rocks are typically composed of sandstones, shales, and conglomerates, and are generally more resistant to weathering and erosion than older sedimentary rocks. As a result, Neogem sedimentary rocks may be less susceptible to landslides than older sedimentary rocks.

Paleogem sedimentary rocks were deposited during the Paleogene period, which occurred between 66 and 23 million years ago. These rocks are typically composed of limestones, sandstones, and shales, and may be more prone to landslides than Neogem sedimentary rocksdue to their age and the potential for weathering and erosion.

Undivided Paleozoic rocks are those that were deposited during the Paleozoic era, which occurred between 541 and 252 million years ago. These rocks can vary widely in their lithology, but typically include sandstones, shales, and limestones. The susceptibility of Undivided Paleozoic rocks to landslides can depend on factors such as their age, lithology, and structural characteristics, with some formations being more prone to landslides than others

Rock Type	Formation Period	Lithology
Neogem Sedimentary	23 to 2.6 million years ago	Sandstones, shales, conglomerates
Paleogem Sedimentary	66 to 23 million years ago	Limestones, sandstones, shales
Undivided Paleozoic	541 to 252 million years ago	Sandstones, shales, limestones, coal, and various igneous rocks
Undivided Precambrian	More than 541 million years ago	Granite, gneiss, schist, various metamorphic rocks

Table 2:Age and Formation of rock

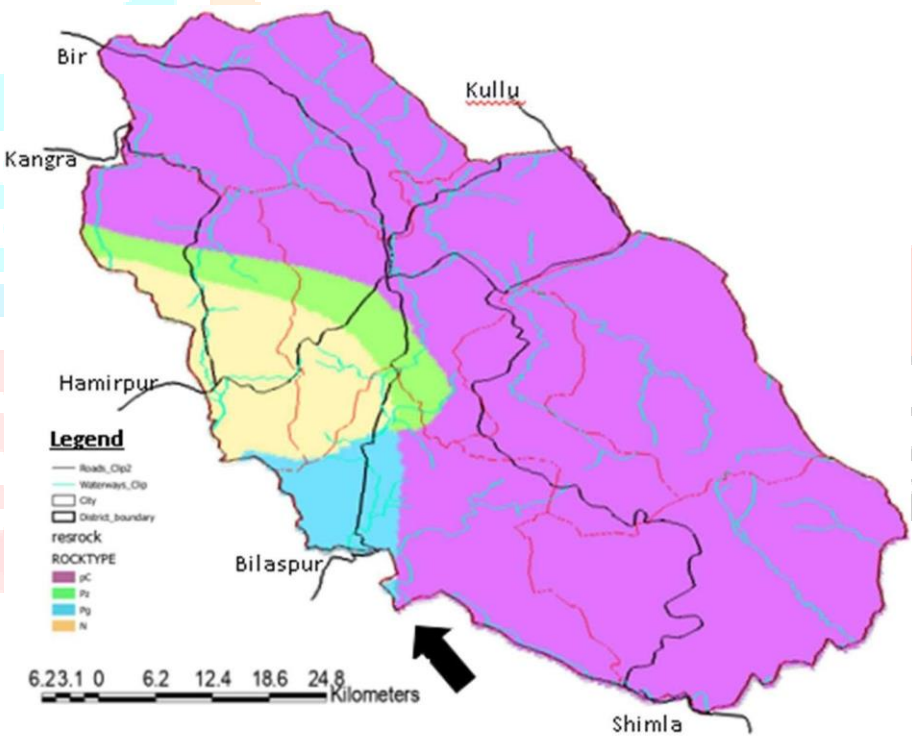


Figure 11 :Rock Type Map

7.1.1. Lineament / Hydrological Analysis

Linear features indicative of zones which are weak and hence these features tend to have a probability towards failure. Tectonic features such as thrust, faults comes under linear features, sometimes a drainage may also be associated with a lineament as it is easier for water bodies to run down an already weakened track. The interpretations of lineaments based on topographical elevation data The location of a lineament is mainly identified by: Change in altitude/level.,

Change in gradient. Change in pattern, Occurrence of Minimum/ Maximum as shown in fig.12. Sedimentary rocks such as fractures, faults, and rock cleavages play a significant role in pore formation. Due to the extreme extensive shear stress caused by active faults, the risk of landslides has increased. To obtain the lineaments in the study area, the NRSA, Department of Space, Government of India, digitized published geological maps and literature data.

The low value of drainage texture is defined in the high hydrological potential zone because it is depending on the drainage density. Low value of drainage texture is also signifying the low drainage density, means low surface runoff.

The district's climate varies from semi-tropical to semi-arctic. Winter lasts from December to February, and summer lasts from March to June, with wet months from July to September.

Between July and September, the district receives the most rainfall. The district received 1106 mm of rain in 2012.From the above graph it is shown maximum rainfall days in particular month which is starting from June July August September in which maximum days 30 in the September while in July it is from 20-25 days u can see the in month if 20 days raining it will impact the area as they don't have any drainage which will lowered the impact of landslide.

Precipitation rate also maximum in this month from June to September it is increased then again decreasing as the monsoon is mostly on this month's only.

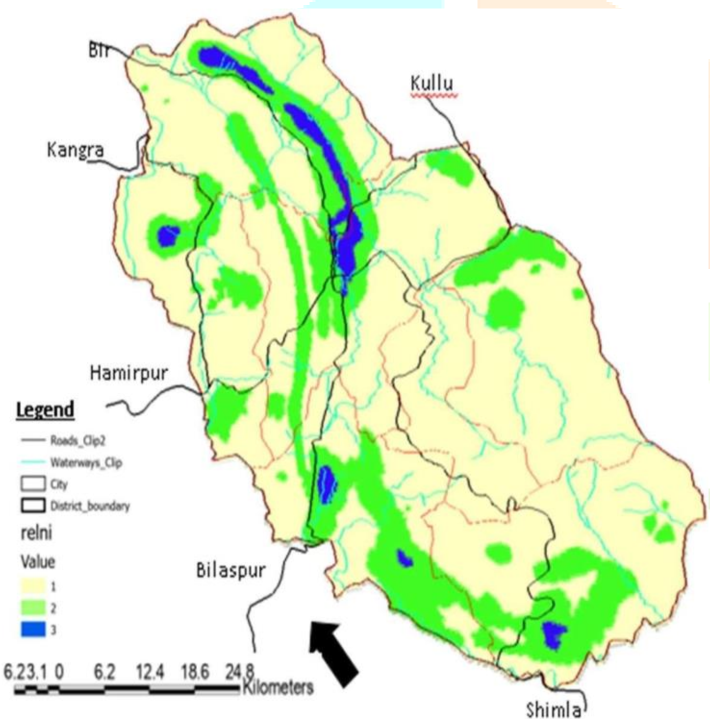


Figure 12: Lineament Map

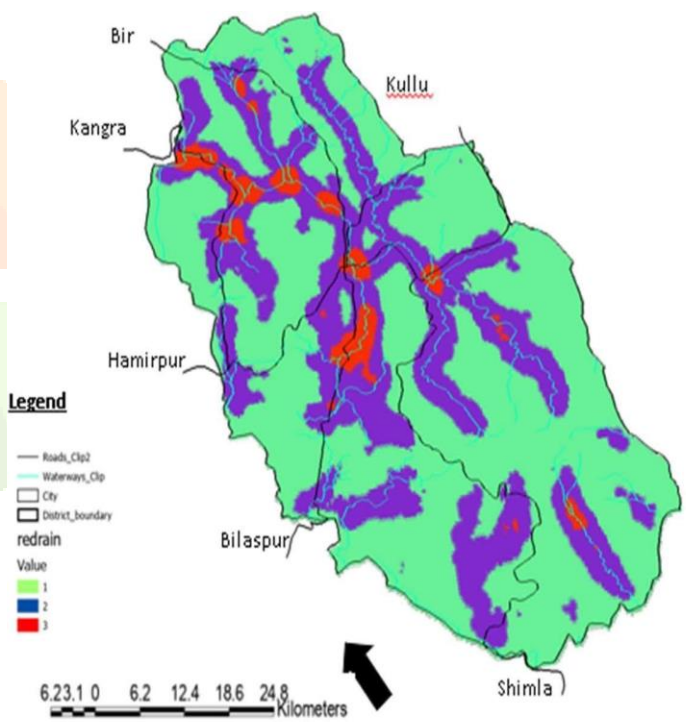


Figure 13: Drainage Density

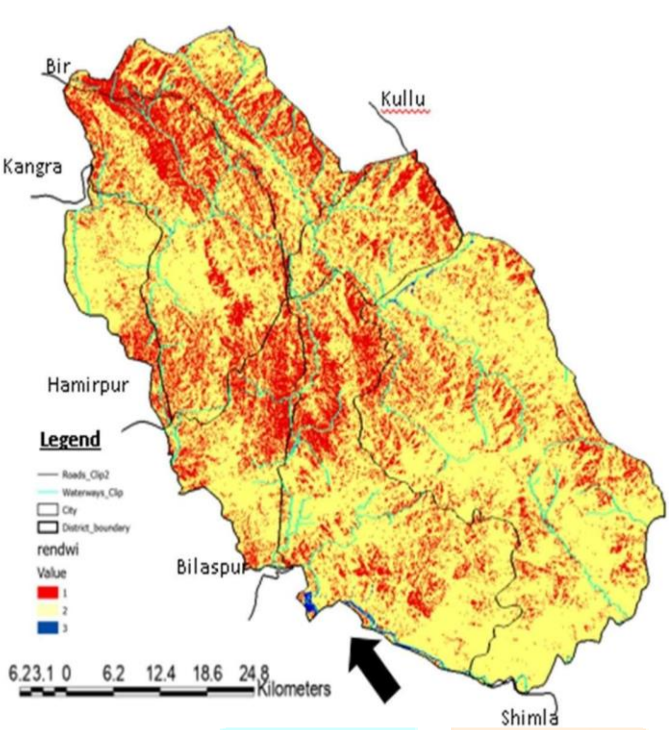


Figure 14: NDWI Map

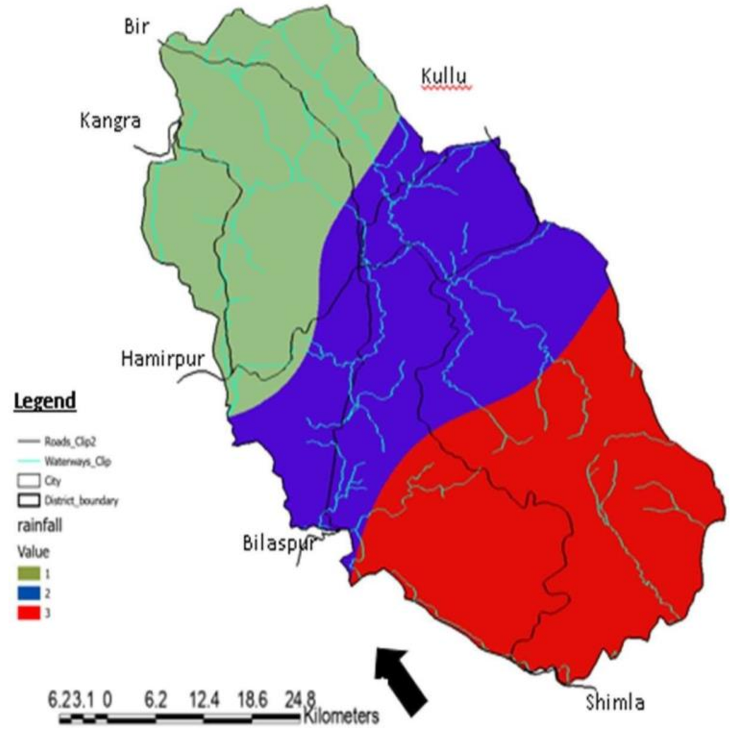


Figure15: Annual Rainfall Map

8. Numerical Ratings:

To identify potential landslide areas, a numerical rating scheme was developed to organize factors by their relative importance. The scheme assigned a numerical ranking on a 1-9 scale to each factor based on its level of importance, and weights were assigned to factor classes on a 0- 9 ordinal scale to indicate their influence on landslide occurrence. The scheme was modified based on literature and field observations.

In the study area, the most important factor for landslides was high drainage density, followed by high lineament density due to highly fractured and jointed formations. Steeper slopes were given higher weightage than gentle slopes, while lithology weightage was assigned based on the susceptibility of rocks to landslides. A fault buffer zone of 250 m was considered due to signs of instability observed along faults. Barren slopes were found to be more susceptible to erosion than forested areas, so maximum weightage was assigned to barren slopes. Other land-use classes were weighted between barren slopes and forested areas. In some locations, slope instability was influenced by erosion and toe cutting along major streams.

9. Results

9.1. Low Hazard Zones

The low hazard zone comprises areas where the combination of various controlling parameters is unlikely to have a significant negative impact on slope stability. Slope angles are generally steep, around 30 degrees, and the vegetation is relatively dense. This zone includes flatlands and areas with gentle slopes and is mainly found on hard and compact rock types. Human activities are minimal or absent in this zone. There is no evidence of instability or risk, and no significant mass movement is expected unless major changes occur. Therefore, this zone is suitable for carrying out developmental schemes. It covers approximately 790 sq. km, which accounts for 20% of the total study area.

Table 3:Weightage and Rating of Different Categories

Paramete r	Category	Rating	Remarks
Lithology	Lundivided Precambrian rock	4	Due to wind & rain it will lower strength
	Undivided palezoic rock	7	Weathering impact is slightly
	Palaeogem sedimentary rock	6	weathering impact is more
	Neogem sedimentary rock	5	weathering impact is medium as mix
Soil type	Eutric cambisol	5	Moderately infiltration
	Dystric cambisol	6	No infiltration or slow
	lithosol	2	Moderately infiltration
Landuse	Agriculture land	6	Less impacted to landslide
	Barrel land	2	More impact of this land due to availability of loamy coarse and sand
	Forest	3	Soil type will impact infiltration result in landslide
	Intermixture forest	7	Impactful category as runoff increased due to this
	Built up area	5	No impact
Slope	Gentle slope	1	Runoff accelerate more
	Cliff	7	Less runoff
	Very gentle slope	9	Runoff accelerate more
	Steep slope	4	Less runoff
Curvature	Concave	3	Weathering and rainfall
	Convex	7	Weathering and rainfall
	Flat	4	No impacted if there is availability of drainage
Relative relief	Elevation 317-1594m	3	No impactful
	1594-1946m	9	Impacted most of it
	1946-2747m	6	Moderately

Lineament	High	9	Matching of fault line fractures and rock cleavage availability
	Medium	7	Only 2factor is coming in this
	Low	5	1 factor included
Hydrology 1 Stream Density	High	2	Create more to take flow of debris during hug rainfall
	Medium	1	Moderately
	Low	0	No impacted
Drainagedensity	High	9	No impacted if its their
	Medium	5	Partial availability of it
	Low	3	Non-availability
Rainfall	High	2	No impacted if its their
	Medium	1	Partial availability of it
	Low	0	Non-availability
NDWI	High	2	No impacted if its their
	Medium	1	Partial availability of it
	Low	0	Non-availability

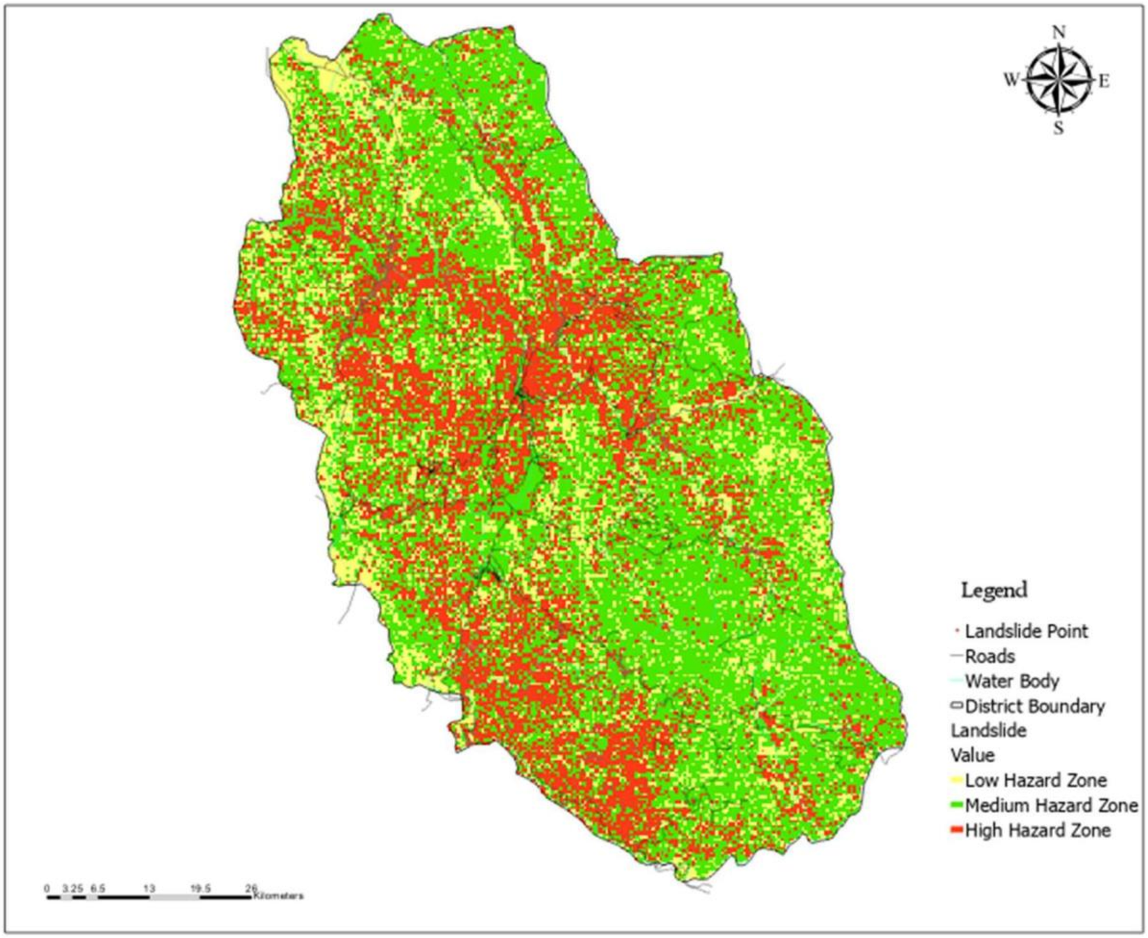
9.1. Medium Hazard Zone

The moderate hazard zone encompasses areas with moderately dense vegetation, moderate slope angles, and relatively compact and hard rocks. Although steep slopes may exist in this zone, the orientation of the bedrock and absence of loose debris and human activity make the slopes less hazardous. The moderate hazard zone is widely distributed across the study area and includes several human settlements. It covers an area of 1975 sq. km, which represents 50% of the total study area.

9.2. High Hazard Zone

Geologically, the very high hazard zone is extremely unstable and is constantly under the threat of landslides, particularly during and after heavy rainfall. This is due to the presence of steep slopes with loose and unconsolidated materials, as well as evidence of active or past landslips. The zone also encompasses areas located near faults and tectonically weak zones. The surface of this zone is characterized by land subsidence, which is observed in many parts of Mandi district. In addition, this zone includes areas with intense road-cutting and other human activities.

Therefore, the very high hazard zone is mostly found in settlement areas, particularly in the southern and eastern parts of the district. It covers an area of about 1185 sq. km, which represents 30% of the total study area. Due to the high susceptibility of this zone to landslides, it is strongly recommended to avoid any human-induced activity here. Such areas should be entirely avoided for settlement or other developmental purposes and preferably left for the



regeneration of natural vegetation to attain natural stability over time.

Figure16: Landslide Hazard Zone

Figure 17: Some Photo of Rock falling Zones

10. Conclusion:

Landslide is now becoming worst disaster and year by year, it is increasing at globally level rapidly. Although more large landslides make the headlines and can result in substantial loss of life and property destruction, it is important to remember that even small, inconspicuous, and slow-moving failures can cause significant damage to buildings and facilities. Landslides are a global hazard that affects 15% of the earth's surface. It causes death and criminal destruction. Landslide risk mitigation is a critical phase in minimizing the event's consequences. The most essential thing is to assist those in need. People are often forced to live in unhealthy environments. People fleeing under environmental risk must recognize and calculate the risk, as well as try and avoid such situations and respond in the event of a crisis. For management positions, it is important to elect and nominate responsible people with strong knowledge and special education. Municipal authorities are in charge of establishing laws to mitigate the impact of potential slope failures. In landslide-prone areas, land-use regulations are expected. The lack of such policies, as well as risky anthropogenic impacts, are the primary causes of slope failures. It makes no difference whether a collapse is due to heavy rain, earthquakes, or a volcano. The consequences of a landslide can be devastating. Hundreds of individuals could lose their homes or even their lives as a result of the storm. It is important for local governments to understand which areas are vulnerable to landslides and to take effective steps to reduce their exposure to certain dangers.

11. Planning Strategies:

1. Develop and implement land use regulations that restrict development in landslide hazard zones or require specific design and construction standards to mitigate risk.
2. Consider implementing a monitoring system to detect changes in the landscape, such as land subsidence, ground movement, or water infiltration.
3. Develop an emergency response plan in case of a landslide, including evacuation routes and emergency shelters.
4. Educate the public and property owners about the risks associated with living in landslide hazard zones and how to minimize those risks.
5. Work with other agencies and organizations, such as emergency management, public works, and land use planning, to coordinate efforts and resources for mitigating landslide hazards.
6. Consider developing a program to incentivize property owners to take proactive measures to reduce landslide risks, such as providing financial assistance or tax incentives.

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