# Landslide susceptibility zonation using the analytical hierarchy process (AHP) in Himachal Pradesh, India

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***Abstract***

*This research aims to develop Map of landslide susceptibility with the Analytic Hierarchy Process (AHP) technique for the Himachal Pradesh Region India, as part of a planning initiative for urban development in Himachal Pradesh from 2021 to 2035. For creating landslide susceptibility maps, several data sets including slope, elevation, aspect, Precipitation, curvature, land use, and land cover were utilized. All of these parameters were manually processed in the GIS system to generate suitable thematic layers for the maps. Historical landslide data relevant to the research area were analysed to ascertain the relative importance of these thematic levels with respect to the incidence of landslides in order to derive the necessary weights. After applying the AHP method in GIS, the resultant maps underwent weighted overlay operations to obtain sensitivity maps. These were identified as regions of very high (11.06%), high (19.41%), moderate (23.03%), low (28.70%), and very low (17.80%) landslide sensitivity. Compared to the waterfall index, 82.58% of the historical landslides occurred within the moderate to extremely high landslide risk zones. The study outcomes assist in identifying potential landslide areas and serve as a guide for further development works in the region.*

***Keywords:*** *AHP, Slope, Curvature, LULC, Elevation*

## 1. Introduction

The state has a long history of disastrous natural events and the amount of natural catastrophes occurring in the state and ranging from mild to severe in strength hinders the development of the state and puts pressure on budget resources [6]. The state has a long history of disastrous natural events and the amount of natural catastrophes occurring in the state and Planning Commission 2005 [7].

Landslides are among the most dangerous risk in the mountainous areas mainly in Himachal Pradesh because of the destruction they cause to bridges, roads,bio-engineering structures, railways dams, infrastructure, houses and the environment. Therefore, a Landslide Hazard Zonation (LHZ) that stratifies zones that hold potential disaster risk must be established. [8]. Stricto sensu, landslide inventory is and serves as a nucleus in whatever system is set, be it termed as susceptibility, risk zoning or hazard zoning. It comprises the position, type, volume and distance of sliding, status of sliding land as well as the date of activity within a defined region. Moreover, physiographic elements of the zone such as slope, aspect, geology, relative relief, drainage, pattern of rainfall as well as land use are also great aid for definition of the zone of slope failure [9].

Some academic and research institutions, as well as government organizations, have previously worked on mapping landslide hazards and susceptibility. The only method used to validate these models was ground truth survey, which was not likely accurate [10]. GIS tools have been useful for creating models that pertain to the mitigation of landslides in relation to spatial planning, hazard mitigation, sediment yield estimation, among others [11]. Similar studies were conducted on the creation of a landslide model for the hazard zonation of the Giri river watershed in the Yamuna basin using remote sensing techniques and multicriteria decision analysis in GIS [12].

## 2.Material and methods:

### 2.1 Study area:

The scope of the study the northern part of India, including the state of Himachal Pradesh (Fig. 1 and Fig 2) where its latitude is between 30°22′N to 33°12′N and its longitude is between 75°47′E to 79°04′E. There are 49 cities and towns in the state, which is divided into 12 districts. The area is primarily hilly in nature having an altitude between 350 meters to 7000 meters above sea level. This area of the western Himalayas, which spans approximately 55,673 square kilometres, is characterized by rugged topography, marked differences in altitude, and complex geological structures. The boundaries of Himachal Pradesh with superimposed landslide locations are indicated in red in Figure 2. These landslide locations are spread over the different physiographic zones but have higher concentration in the southern, eastern, and central districts dictated by human activity and geomorphic impacts with the lowest stability. The region is distinguished by a combination of tall mountain ranges, deep valleys, steep slopes and glaciated regions. There is a clear trend in the value of elevation with distance from the study area: approximately 350 meters within the Shivalik foothills to over 6800 meters in the Great Himalayan Range. Landslide occurrence and loose quaternary sediment and strong rainfall or snowmelt areas show the strongest link to steep slope gradients and heightened level of rainfall or snow melt. Himachal Pradesh exhibits tremendous geological diversity with rock formations ranging from Precambrian to the Quaternary period which include, weathered schists, phyllites, quartzites, and alluvial-colluvial deposits found at the floor of valleys. The factors of active fault lines, seismicity, and tectonic uplift contribute to the overall slope instability. The variability of lithology coupled with weak structural zones worsens the susceptibility to mass movement. The region is also subject to a semi-humid or humid continental monsoon, whereby precipitation takes place from June to September due to the southwest monsoon and occasionally in winter due to westerners. The volume of rainfall also varies from region to region, receiving as low as 800mm in drier regions and over 3000mm in regions exposed to orographic lift. This pattern is predominant in areas where landslides are prone to occur, especially where sediments are loosely packed. The landslide points serve as a mark for both ancient and contemporary slope failure incidents and are governed by both natural (intense rainfall, geology, orographic slopes) and human-made influences (road construction, deforestation, urbanization). River basins subjected to such spatial alterations utilize these lands in formulating sustainable development strategies and come up with landslide susceptibility models along with strategies for risk mitigation of disasters.

### 2.2 Methods

The approach for this research is demonstrated in Fig. 3 which includes the steps: data gathering, factor analysis, creation of the databases, AHP analysis and creation of the landslide Susceptibility Mapping. This study's main focus is on assessing landslide susceptibility in the region and providing mitigating recommendations.

### 2.3 Data collection

For the purpose of this study, 216 slope disaster points were collected. from NASA's Global Landslide Catalog (https://www.nasa.gov/landslide/), which capture documented landslide events such as sliding, collapsing, and debris-flowing (as referred to “landslides” in this study). Of these, 70% were set aside for model training and 30% for testing. Furthermore, ArcGIS Spatial Analyst toolbox was used to derive slope, aspect, and elevation from digital terrain data.

### 2.4 Definition of conditioning factors

Based on correlating literature and the study area's characteristics, defending the area has been decided as the triggering factors for landslide risks [13]. The rationale for conducting this study is to inform risk identification and mitigation in upcoming developmental activities within Himachal Pradesh, we do not need to worry about data accessibility being uncomplicated or inexpensive when considering relevant factors [14]. This paper aims to determine particular triggering factors for landslides using the basic conditions of the region’s altitude, slope, aspect, and profile curvature. The type of region’s vegetation affects water accumulation areas, intensity of human activity, and elevation. Landslides are indirectly associated with evaluation sensitivity factors and relegated as a common denominator of using sensitivity factors

[15]. The stress field's distribution within the clivus is influenced by a slope gradient. One may say that stress at the clivus toe maintains a positive relationship with slope magnitude, hence leading to determining the possibility of slope instability. Hence, greater stress at the toe of the clivus elevates likelihood. Furthermore, a slope gradient impacts the infiltration process. Therefore, we can conclude that the slope gradient is a significant topographic factor influencing landslides [16]. Surface fragmentation, rainfall infiltration, and solar energy absorption are bluntly hydrostatic in nature and control slope stability at various aspects which are critical to landslides [17]. The curvature influences limits sediment transport by gravity, hence called erosion control [18]. Because of the study site lies in Himachal Pradesh, factors such as rainfall, erosion, precipitation, infiltration, and anthropogenic activities greatly affect the dynamics of loess slope instability [19]. For this reason, land use and precipitation are also selected as trigger factors alongside land use and precipitation. For characterizing landslide condition factors, there is no persistently appropriate resolution., as factors including slope and land cover condition spatial resolution have yet to be standardized for susceptibility model. Previous investigations applied the grid cell resolution of 30 m was preferred because it not only represents topographic features effectively, but also mitigates computational overload [20]. In this study, all the landslide condition factors were set to 30 m resolution. Primary thematic datasets for spatial analysis of landslide susceptibility in Himachal Pradesh include: slope, aspect, elevation, land use/land cover (LULC), precipitation & curvature. In contrast to other classification methods, break classification employs the largest gaps to improve inter-class distinction, meaning that there is no bias through subjective judgement [21]. Derived classes were cumulated into 3 main orthogonal classes for ease of reference and computation; these are defined as low, ranging from 207-809 meters, moderate, spanning from 809-1528 meters, and high, which extends from 1528-3754 meters, capturing variations in contour across the terrain. Slope is the primary factor that determines a slope's stability, which is also considered the important factor for the stability of slope [22], was divided into six categories: 0–12°, 12–25°, 25–35°, 35–50°, and greater than 50°. Classification of Aspect was done into nine directional classes—north, northeast, west, northwest, east, southeast, south, southwest and an additional flat category, to account for differences in solar radiation and moisture retention, which affect slope maintenance. Curvature was simplified into three forms, concave, linear, and convex, that greatly influence the rate of water accumulation and drainage, which in turn leads to slope failure. Normalized precipitation data was clustered into four categories, which depict the spatial distribution of rainfall intensity that can induce landslides via saturation processes. The LULC data was reduced into six dominant classes of: Forest, Cultivated Land, Grassland, Wetlands, Artificial Surfaces, and Others that represent diverse conditions of land cover and anthropogenic activity relevant to erosion and slope stability. A strong foundation for the analysis of landslide susceptibility for the entire study region is provided by these improved variables taken together.

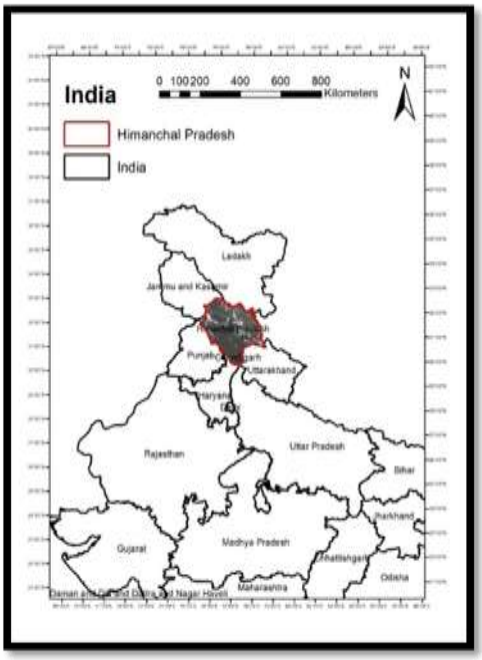



Figure 1. Study Area Map

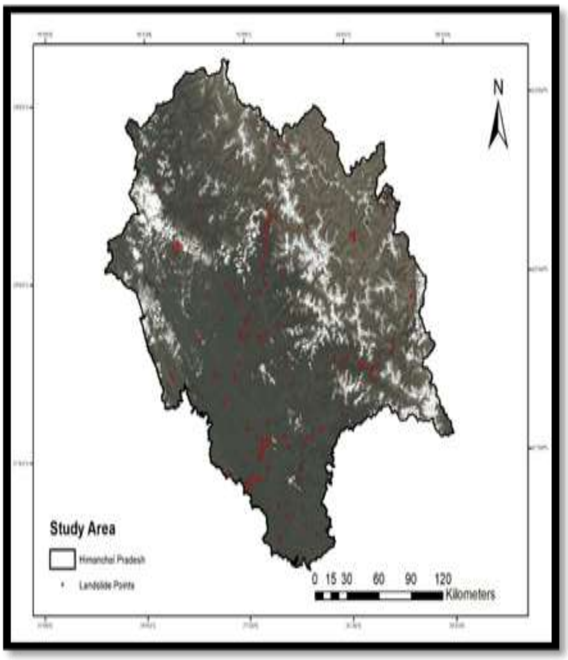



Figure 2. The Distribution of Landslides in the Study Area

**3.Methodology framework:**

Himachal Pradesh's landslide susceptibility mapping approach expands on the integration of multi-criteria decision analysis, machine learning, and geospatial data. The derivative data for aspect slope and curvature were computed from the high-resolution digital elevation model data (SRTM, 30 m), while land use/land cover (LULC) data was obtained from ESA World Cover (10 m). Precipitation data was acquired from the ERSINN-CDR dataset which estimates rainfall using remotely sensed data and artificial neural networks. The NASA Global Landslide Catalog provided a total of 216 landslide inventory points. Elevation, slope, curvature, aspect, LULC, and precipitation geo-environmental factors were extracted and organized into a geospatial database. The layers were categorised into a set with the natural breaks method to minimise within-class variation and enhance between-class separation. To measure the significance of each element in relevance to the probability of a landslip, weights were allocated to each factor use the Analytical Hierarchy Process (AHP). Using GIS overlay analysis, the refined and weighted layers were combined to create landslide susceptibility maps. To find the model's capability to identify risk-prone locations, the landslip inventory was divided into training and testing datasets. This approach enables a coherent framework for quantifying and spatially visualizing landslide risk, characterizing the landslide risk evaluation process as data-driven and organized.

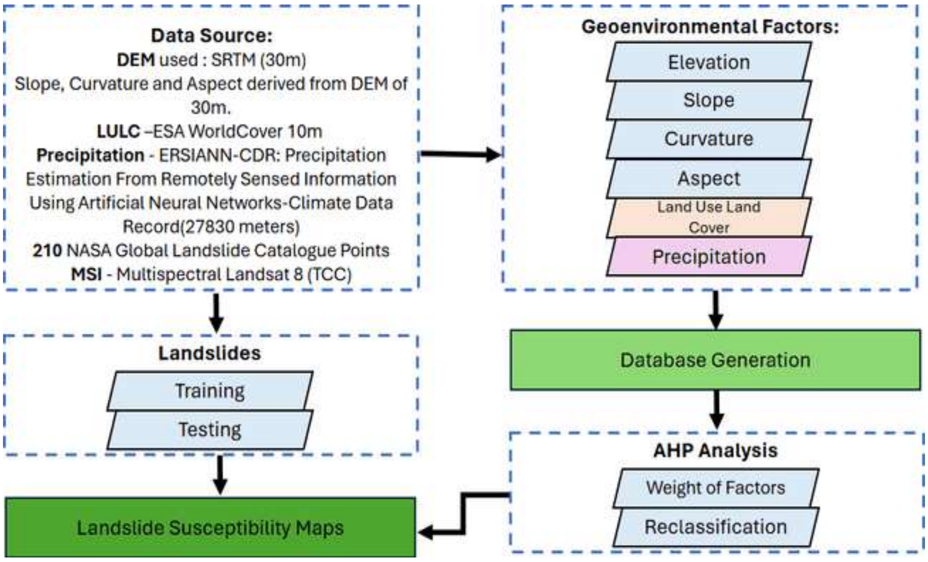



**Figure 3. The framework of methods**.

### 3.1 Analytical hierarchical process (AHP)

Analytic Hierarchy Process (AHP) is the mathematically based technique for multi-criteria decision analysis (MCDA) [23] [24]. It is founded on comprehensive analyses of the nature, context, drivers, and interrelations of complex decision-making issues [25] [26]. AHP offers a simple answer for structured approaches, complex mathematics, multiple objectives, and criteria through its algorithmic approach to decision-making, even when comparatively scant quantifiable information is available [27] [28]. For instance, it can serve the quantitative estimation of the precursors' analytical assessment of geological hazard triggers [29] [30].

This study designed a method employing the Analytic Hierarchy Process, consisting of three distinct sequential processes:

1. Construct the Pairwise Matrix for each landslide-inducing factor.
2. Determine the weight for each element.
3. Verify the Consistency Ratio to ensure the accuracy of results.

As described in the earlier definitions, classification of every trigger factor is done at the pairwise level and pairwise matrix is created as stated below:

$$M = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 1 & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & 1 & \dots & \dots \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n1} & a_{n2} & \dots & \dots & 1 \end{bmatrix} \quad [1]$$

$$aij = \frac{weight\ of\ attribute\ i}{weight\ of\ attribute\ j} \qquad [2]$$

The consistency ratio (CR) is determined using the formula:

$$CR = \frac{\lambda_{max} - n}{n-1} . \frac{1}{R1} \qquad [3]$$

Where:

-aij denotes the verdict of the i-th factor with respect to the j-th factor (the set of values from 1-9).

-n is the number of factors.

-RI is the Random Consistency Index.

When H is rational, CR <= 0.1. If the consistency ratio (CR) of the matrix exceeds 0.1, the entire pairwise matrix requires modification. The landslip susceptibility map for the research area was generated by integrating the following factors: aspect, elevation, profile curvature, soil, slope, lithology, land use, and river density. Upon confirming that the validated judgement matrix exhibited a consistency ratio (CR) of less than 0.1, the weight value for each factor was calculated.

## 4. Results

### 4.1 Landslide conditioning factors

The distribution of landslip spots in Himachal Pradesh indicates a significant correlation with both anthropogenic and morphological causes. With respect to morphology, concentration of steep regions [31] is a, especially along ridges and escarpments, showing the impact of height and steepness on their distribution. With regards to human factors, urban sprawl, farming activities, and the construction of road infrastructure are very much linked to the development of slope failure [32]. Also, water-related factors like distance from water bodies and rainfall contribute greatly to landslide events. [33] To accomplish comprehensive landslide susceptibility mapping for the area, the study used 216 landslide data points from the NASA Global Landslide Repository, allocating 30% for validation and 70% for model training partitions (Fig. 2). Thematic maps were produced based on selected triggering factors including slope, aspect, profile curvature, land use land cover (LULC), and precipitation (Tables 2, 3; Figs. 4). The slope was divided into five ranges, where the medium (12-25°), very high (25-35°), and high (35-50°) slope classes total more than 78% of the affected areas and suggesting that areas with slopes between 12° and 50° are most prone (Fig. 4). In terms of aspect, westward-facing slopes were found to have the highest incidence of landslides (17.14%), followed by south and southwest aspects (15.71% each), while horizontal and north east ward-facing slopes experienced the least impact. Concerning profile curvature, most landslides occurred in range with very high curvature (-0.001 to 0.001), which contributed 80.88% while high curvature zones contributed 17.62%. From the LULC analysis, it was also noted that very sparsely vegetated or bare areas (39.52%) along with built up regions (21.43%) were the most susceptible, with grasslands (17.14%) following in the high zone. Moreover, precipitation showed prominent effect where areas receiving 2.5–3 mm and 3 – 3.84 mm of rainfall exhibited the highest land slide susceptibility of 38.09% and 30.95% respective.

**Table 1: Preference scale between two parameters in AHP**

| **Importance Scale** | **Definition** |
|---|---|
| 1 | Equal Importance |
| 3 | Moderate Importance |
| 5 | Strong Importance |
| 7 | Very Strong Importance |
| 9 | Extreme Importance |
| 2,4,6,8 | Intermediate values between two adjacent Decisions |
| Reciprocals | Used for inverse Comparison |

### 4.1.1 Normalized weight for conditioning factors

These results illustrate a blend of relief, land use and weather elements influencing landslide hazards throughout Himachal Pradesh. Consistency ratio(AHP)" within the section "Analytic Hierarchical Process (AHP)". A normalized weight values shown in Table 1 were computed using the individual Eigen values from each theme and with a CR value of 0.00. In the same way, Table 2 presents the normalised weights of several features for each theme, where all functionalities were below 0.00 CR and thus, passed the coherence test.

### 4.1.2 Landslide susceptibility assessment

To generate the landslip susceptibility map for the research area, through different triggering factors, the impact of each landslide triggering factor is combined and analysed. Fig. 4 illustrates: weight in relative matrix, from Table 2 the pairwise matrix's weight order of the six landslide factors. These factors include: Elevation, Slope, Aspect, Curvature, Land Use Land Cover and Precipitation.

**Table 2. Parameters and factors for mapping landslide susceptibility**

| **Factors** | **Classes** | **Degree of Precedence** | **Training Data %** | **Weight** |
|---|---|---|---|---|
| | 0-1000 | Medium | 22.38 | |
| | 1000-2000 | Very High | 43.81 | |

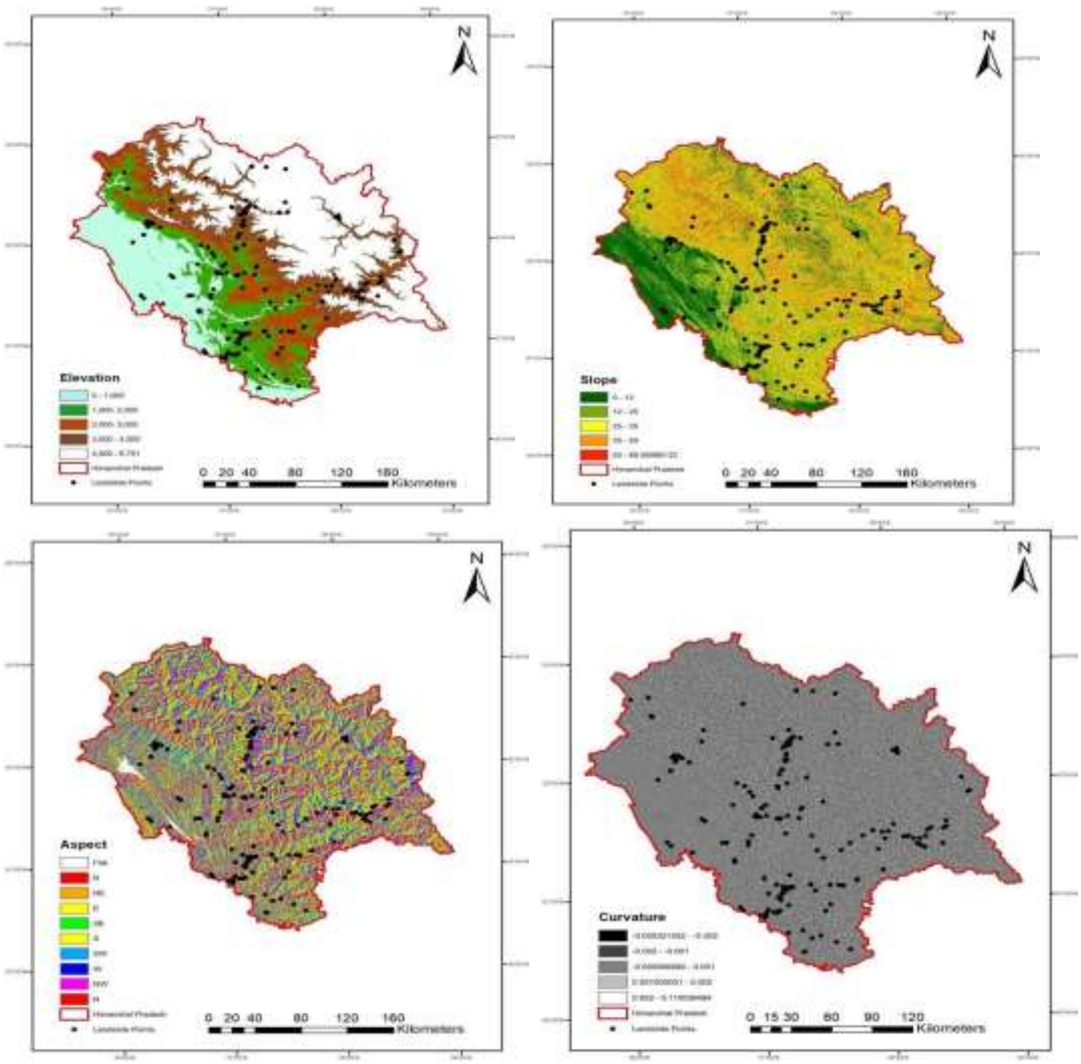
| | | | | |
|---|---|---|---|---|
| Elevation | 2000-3000 | High | 17.14 | 0.2 |
| | 3000-4000 | Low | 12.38 | |
| | 4000-6751 | Very Low | 4.29 | |
| Slope | 0 -12 | Low | 17.61 | 0.25 |
| | 12-25 | Medium | 23.81 | |
| | 25-35 | Very High | 27.14 | |
| | 35-50 | High | 27.14 | |
| | 50-90 | Very Low | 4.3 | |
| Aspect | Flat | Very Low | 0.48 | 0.1 |
| | North | Low | 10.47 | |
| | Northeast | Very Low | 9.5 | |
| | East | Low | 8.1 | |
| | Southeast | Medium | 10.95 | |
| | South | High | 15.71 | |
| | Southwest | High | 15.71 | |
| | West | Very High | 17.14 | |
| | Northwest | Medium | 11.94 | |
| Curvature | -0.066 - -0.002 | Medium | 1.4 | 0.1 |
| | -0.002 - -0.001 | High | 17.62 | |
| | -0.001 - 0.001 | Very High | 80.88 | |
| | 0.001 - 0.002 | Low | 0.1 | |
| | 0.002 - 0.11 | Very Low | 0 | |
| LULC | Tree Cover | Medium | 12.38 | 0.2 |
| | Shrubland | Low | 1.9 | |
| | Grassland | High | 17.14 | |
| | Cropland | Low | 1.9 | |
| | Buildup | Very High | 21.43 | |
| | Bare/Sparse Vegetation | Very High | 39.52 | |
| | Snow-Ice | Low | 4.29 | |
| | Permanent Water Bodies | Very Low | 0.48 | |
| | Herbaceous Wetland | Very Low | 0.48 | |

| | | | | |
|---|---|---|---|---|
| | Moss and Lichen | Very Low | 0.48 | |
| Precipitation | 1-1.5 | Very Low | 6.2 | 0.15 |
| | 1.5-2 | Low | 6.7 | |
| | 2-2.5 | Medium | 18.06 | |
| | 2.5-3 | Very High | 38.09 | |
| | 3-3.84 | High | 30.95 | |

**Table 3. AHP model attributes of landslides with pairwise comparison and weight values relative to each other**

| Factor | Elevation | Slope | Aspect | Curvature | LULC | Precipitation | Normalized Weight(NW) |
|---|---|---|---|---|---|---|---|
| Elevation | 1 | 4/5 | 2 | 2 | 4/5 | 4/3 | 0.19 |
| Slope | 5/4 | 1 | 5/2 | 5/2 | 1 | 5/3 | 0.23 |
| Aspect | 1/2 | 2/5 | 1 | 1 | 2/5 | 2/3 | 0.09 |
| Curvature | 1/2 | 2/5 | 1 | 1 | 2/5 | 2/3 | 0.09 |
| LULC | 5/4 | 1 | 5/2 | 5/2 | 1 | 5/3 | 0.23 |
| Precipitation | 3/4 | 3/5 | 3/2 | 3/2 | 3/5 | 1 | 0.14 |

The characteristics, elevation profile curvature, land use cover, and slope size of susceptibility indicate that the landslip susceptibility map generated using the AHP calculation method is valid. After analyzing the cumulative landslide susceptibility map generated using The Analytical Hierarchy Process (AHP), it can be noted that the study area in Himachal Pradesh comprises 5 levels/grades of susceptibility zones: very low(6.37% ), low(21.98%),moderate (27.97%), high (27.40%), and very high (16.28%). These categories denote a particular ranking order of susceptibility to landslide risk in Himachal Pradesh. Data regarding landslides, categorised into training and validation datasets, was employed to evaluate the precision of the susceptibility model. For the training dataset, landslides were recorded at the following frequencies: 3.86% in the very low, 16.11% in the low, 21.44% in the moderate, 31.03% in the high, and 27.56% in the very high zone. In the validation dataset, the landslide distribution was as follows: very low 4.66%, low 12.73%, moderate 22.05%, high 34.47%, and very high 34.47%.These results provide significant proof that there exists a correlation between the incidence of landslides and the tendency for landslide categories. In addition, as previously expected, normalized landslide density is higher in the regions with more susceptibility, proving that the model developed with AHP is indeed valuable for spatial analysis of landslide risk assessment in sensitive areas in the case of vulnerability evaluation and hazard triage on the region in question.



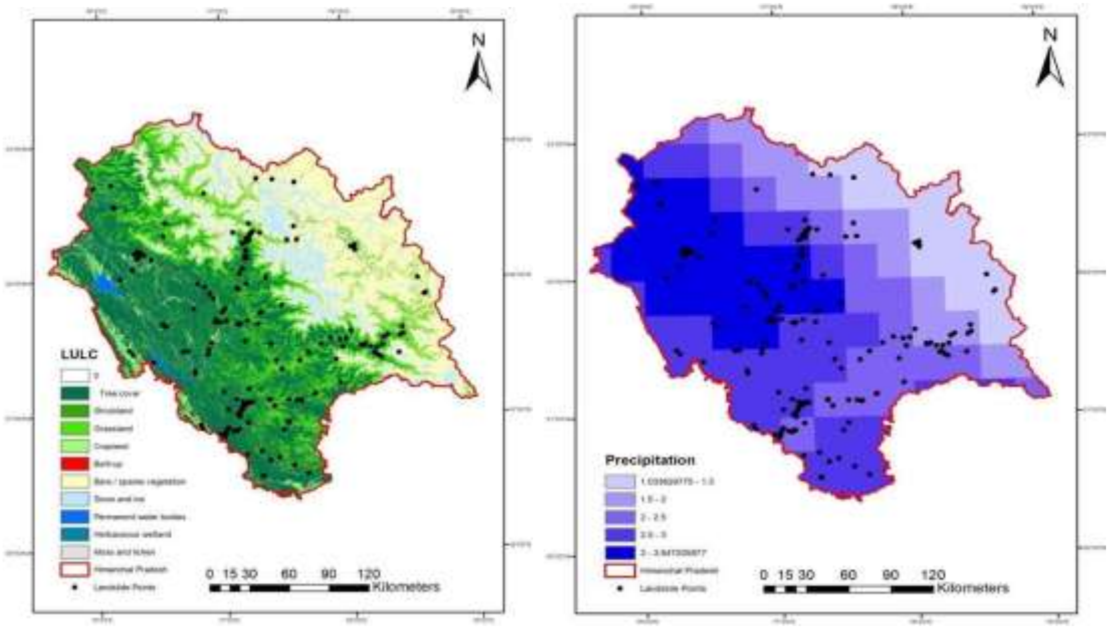



**Figure 4. Interdependence of Landslides in the Himachal Pradesh Region with Elevation, Slope, Aspect, Curvature, LULC, and Precipitation Maps.**

## 5. Discussion causes of landslides

The Himachal Pradesh region, characterized by complex mountainous terrain and fragile geological conditions, exhibits landslide mechanisms influenced significantly by both natural geomorphic features and intensified human activities [34] [35]. Engineering construction, particularly in hilly regions, often leads to the disturbance of natural slopes and alteration of the stress distribution within the soil and rock layers [36] [37]. Excavations at the toe of slopes—common in road widening and building foundations—cause localized stress concentrations and uneven settlement of the fill material, triggering instability in the slope structure and enhancing the likelihood of landslides [38] [39].

Human-induced modifications such as deforestation, road development, and expansion of urban settlements contribute to changes in surface runoff, slope loading, and natural drainage systems [40] [41]. These modifications increase water infiltration during monsoons, weakening slope material and facilitating slip surface development. Moreover, critical infrastructure like roads and pipelines are often aligned along steep gradients and fragile slopes, where slope cutting and mechanical vibrations from construction machinery and heavy vehicular traffic further destabilize the terrain, often reactivating old landslides or initiating new ones [42]. Geomorphologically, the most landslide-prone zones in Himachal Pradesh are located along the steep valleys, escarpments, and ridge slopes, especially where the terrain is dissected by river systems [43]. The terrain's inherent instability is exacerbated by intense rainfall and snowmelt, which saturate the slopes and reduce soil cohesion. Under these conditions, The formerly stable slopes become vulnerable to collapse due to elevated pore water pressure and diminished shear strength, resulting in the recurrent incidence of landslides during and following the rainy season [44] [45].The interplay between human activities and natural geomorphic and hydrological processes markedly enhances landslip susceptibility in the region, highlighting the necessity for meticulous land-use planning, slope management, and construction practices in Himachal Pradesh.

### 5.1 Reliability of landslide susceptibility map

The whole area is classified under five surface susceptibility classes: Very Low (5.40%), Low (13.53%), Moderate (29.81%), High (33.29%), and Very High (17.97%). The classification suggests that a significant portion of the state, particularly central and southern mountain belts with steep slopes and high precipitation, falls under high and very high susceptibility zones—together accounting for over 51% of the total area. These regions correspond to marked escarpments, river valleys, and areas of dense human habitation or road intersections that are often subject to landslides. The lower and very low susceptibility levels are mostly situated within the more stable, low-lying relief regions like intermontane basins and plateaus, which have gentle slope gradients and minimal concentration of runoff. In contrast, slope and elevation emerge as dominant factors controlling the susceptibility pattern, especially in the western flank of the Himalayas, which features sharp changes in terrain and experiences high levels of road infrastructure, rainfall, and unstabilizing precipitation infusion. Curvature and land use/land cover, especially sparse vegetation and built-up areas, also have a drastic impact on slope behavior, with over 60% of landslide records attributed to these areas. The risk estimation for landslides assumes human activity and surface geometry are critical components in concerning regions because areas of high curvature and intense land use modification pose the greatest risk. Outcomes from the study were constant with other research with respect to available literature on mountain areas with frequent lands slide activity [46] [47] [48], for instance which blend steep topographic relief, hydrological loading, and anthropogenic alteration of the underlying surface, noting that the combination of such factors predisposes an area to land slide [49] [50]. Therefore, controlled zoning, slope protection works, and rational drainage system design are needed to optimize the landslide hazard potential in critically exposed regions of Himachal Pradesh.

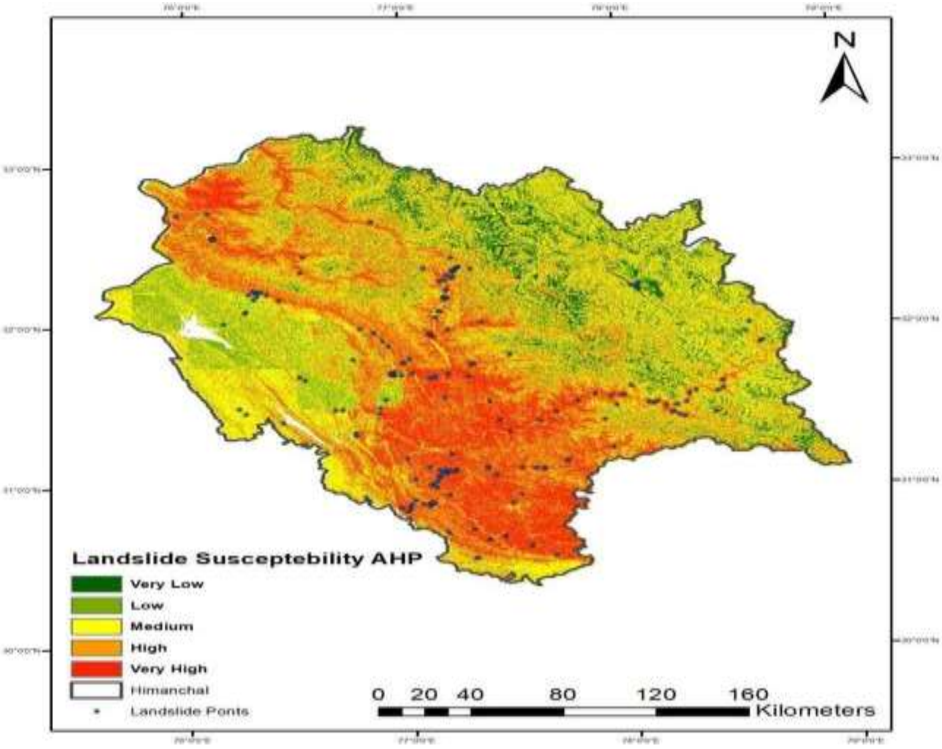



**Figure 5. Landslide susceptibility map of Himachal Pradesh using AHP Method**

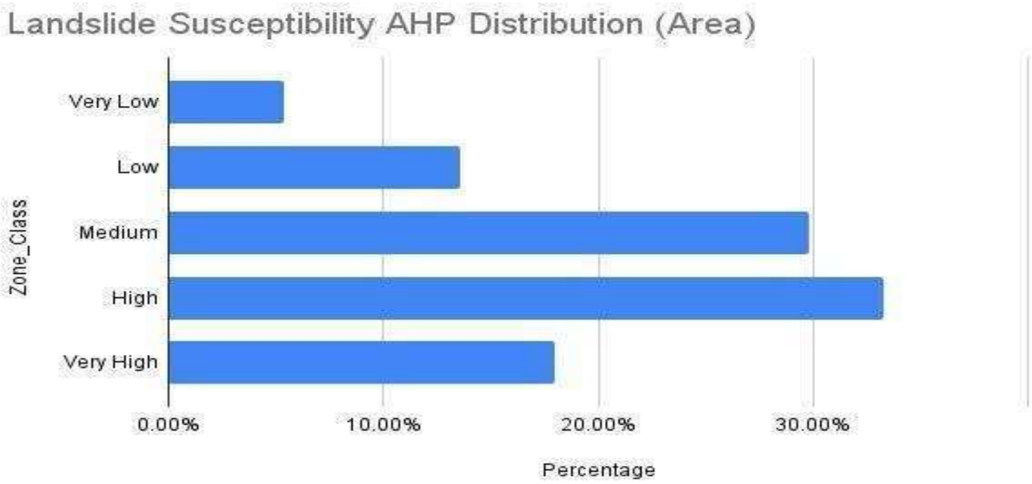



**Fig.6 Area-wise Distribution of Landslide Susceptibility Zones Using AHP Method**

## 6. Conclusions

The landslip susceptibility map of Himachal Pradesh was developed with the AHP approach to enable the study and categorisation of regions prone to slope instability, as illustrated in Table 4, Fig. 5, and Fig. 6. Results suggest that slope, elevation, precipitation, land use/land cover (LULC), curvature, and aspect are predominant parameters of the region's landslides. Out of these, slope and elevation emerged as the most dominant, where steep gradients as well as elevation induced hydrological circulation systems were the preconditions for landslide occurrence. Anthropic factors such as unregulated building of roads, farming on slopes, deforestation, and large scale infrastructural development increases susceptibility to the region. The five-level landslide susceptibility maps which this region used to rely on are integrated into one and show steep rivered valleys with dense population anthropogenically modifying land along the steep mountainous terrains, like parts of Kangra, Mandi, Kullu, and Chamba districts, are the most vulnerable. These areas can aid in planning infrastructure but require special care in order to engineer construction, irrigation activities, and avoid landslides.

In comparison to other Indian states, this map portrays Himachal Pradesh as more vulnerable due to insufficient planning marked by no to minimal evidence based construction guidance during natural disasters termed as sustainable development. However, planner aligned outcomes achieved in this study focused on hypothesized Indian Himalayas backed previous research alongside broadened scope offering adaptable strategies in assessing landslide risks for other mountainous and geologically sensitive regions.

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