
Journal of Information and Optimization Sciences

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tios20

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**To cite this article:** Sandeep Panchal & Amit Kr. Srivastava (2022) Expert based landslide susceptibility mapping for energy infrastructure planning, Journal of Information and Optimization Sciences, 43:3, 635-641, DOI: 10.1080/02522667.2022.2054999

**To link to this article:** https://doi.org/10.1080/02522667.2022.2054999

Published online: 05 May 2022.

*Journal of Information & Optimization Sciences*
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 43 (2022), No. 3, pp. 635–641
DOI : 10.1080/02522667.2022.2054999

# Expert based landslide susceptibility mapping for energy infrastructure planning

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**Abstract**

Landslides are a significant problem in the hilly region. Objective of this study is to prepare landslide susceptibility map of Almora district, India using expert weightage technique. The topography characteristics, geological characteristics and drainage characteristics of the region are considered as causative factors of landslides. The weightage to factors and sub-factors is assigned by expert opinion. Geographic information system is used to convert the causative factor maps in layers. The expert weightage are based on the judgment of expert and the historical landslide data. The weighted layers are overlaid in GIS environment and the final output map shows the landslide susceptibility in increasing order. The landslide susceptibility index varies from 7 to 45 in the region. Lower landslide susceptibility index (LSI) shows lower probability of occurrence of landslides and hence higher suitability for development of new infrastructure projects. The landslide susceptibility map can be used by planners and engineers.

***Subject Classification:*** *General 00A71.*

***Keywords:*** *Landslide susceptibility mapping, Geographic information system (GIS), Expert opinion, Remote sensing.*

## 1. Introduction

Due to the excessive development in hilly regions, the construction activities are on full swing. These anthropogenic activities increase the landslide event in developing regions [1-2]. Landslides are responsible

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for the various problems like traffic jam, property damage, loss of lives etc. Occurrence of landslides is accelerated by the triggering factors like earthquake, erosion, rainfall etc [3-4]. The climate change is also accelerating the triggering factors which will increase the frequency of occurrence of landslides in future [5]. Landslide susceptibility maps can be useful for planning the suitability of new infrastructure projects including the energy projects.

Almora is a district in Uttarakhand province in India. The area of the region is around 3144 sq km. The population of the region is around 6.5 lakh [5]. Around 50% of the study area is covered with forests [6]. The average elevation above mean sea level is 1638 m. The study area is popular among tourists because of its natural beauty. In 2010, rainfall induced landslides caused the death of around 80 people [7]. The landslides of 2010 affected the kilometers of road corridors. So, it is essential to plan the further anthropogenic activities with care.

Geographic information system (GIS) is a very efficient tool for storage, manipulation and overlaying of data [7]. GIS has been used for preparation of the layers of causative factors. Inputs can be varied easily in GIS environment which helps in obtaining accurate output. Landslide susceptibility maps are very efficient tools in planning and mitigation of landslide hazards.

The methods of landslides susceptibility mapping can be classified in qualitative and quantitative terms [8]. The mathematical models for landslide susceptibility mapping establish a relationship among landslide probability and causative factors of landslides [9]. The weightage of the causative factors and sub-factors is based on the opinion of the expert. So, the decisions can be taken from the practical knowledge and field data. The expert based ranking method is easy to implement in GIS environment.

In this study, landslide susceptibility map of Almora district has been prepared with the help of weightage assigned by experts. The historical data of landslides helped the expert in deciding the weightage of causative factors and sub-factors.

## 2. Characteristics of the study area

The various factors responsible for occurrence of landslides in the region are considered in this study. The major factors are slope, aspect, curvature, relief, geology, lithology and drainage density. It is evident that as the slope increases, the susceptibility towards landslide also increases.

Aspect is the direction of slope which affects the erosion characteristics of the hills [10]. South west and west directions are more prone to landslides in the study area [10]. Concave curvature is more susceptible towards landslide while flat curvature is least susceptible towards landslide [11]. Relief is responsible for the environmental and vegetation changes. As the relief changes the characteristics of vegetation changes [10-11]. The factors that are digitized from the Survey of India (SOI) maps are drainage, geology, lithology and faults. The study area is covered majorly by Almora group which is of Proterozoic age. Maximum number of landslides have been occurred in the region which belongs to Almora group. Jaunsar group covers a small region but it is highly susceptible towards landslide.

Mica, chlorite schist and phyllite are the major lithological units that are found in the region. Quartzite, shales and conglomerate also cover a significant area. The regions with higher drainage density are more prone to occurrence of landslide [9-11]. The streams causes erosion of soil masses and induces instability in the slopes [11]. The distance from the fault is also considered as a major factor of occurrence of landslide.

## 3. Methodology

We have used expert rating method for landslide susceptibility mapping. The causative factors are extracted from digital elevation model (DEM) and Survey of India (SOI) sheets. Table 1 shows the weightage of causative factors.

The data is converted into raster format using conversion tool and divided into sub-factors. The expert rating is assigned to each factor and sub-factor. The ratings are given on the scale of 1-10. The ratings are assigned by reclassification of the layers. The extracted layers are overlaid using weighted linear combination to obtain the landslide susceptibility map. The landslide susceptibility map is divided into four categories i.e. low, moderate, high and very high susceptibility.

## 4. Results and Discussion

The weightage calculated in the previous section are assigned to each sub-factor by reclassification of the data in GIS environment. The weightage in the grids are added and an output map is obtained which shows the cumulative effect of different causative factors considered in this study. The output map is based on the landslide susceptibility index which is a numerical index combining the impact of different causative

**Table 1**

**Expert weightage of causative factors**

| Causative Factors/Sub-factors | Weightage | Source of Data |
|---|---|---|
| Slope Gradient | | Digital Elevation Model |
| 0-<15 | 1 | |
| 15-<30 | 3 | |
| 30-<45 | 6 | |
| 45-<60 | 8 | |
| More than 60 | 9 | |
| Aspect | | |
| Flat | 1 | Digital Elevation Model |
| North | 3 | |
| Northeast | 4 | |
| East | 2 | |
| South East | 2 | |
| South | 4 | |
| South West | 7 | |
| West | 6 | |
| North West | 3 | |
| Curvature | | |
| Flat | 1 | Digital Elevation Model |
| Concave | 3 | |
| Convex | 7 | |
| Relative Relief | | |
| Low | 3 | Digital Elevation Model |
| Moderate | 6 | |
| High | 5 | |
| Very High | 4 | |
| Fault Distance | | |
| Low | 7 | SOI Map |
| Moderate | 3 | |
| High | 1 | |
| Drainage Density | | |
| Low | 1 | SOI Maps |
| Moderate | 5 | |
| High | 7 | |
| Very High | 9 | |

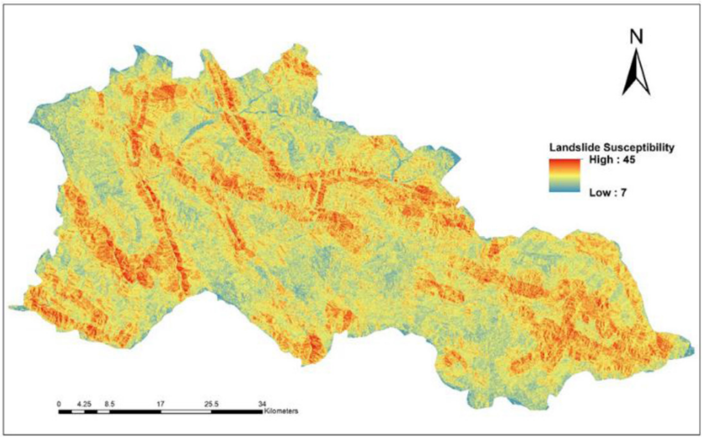


**Figure 1**

**Landslide Susceptibility Map**

factors.If w represents the weightage of different causative sub-factors. Landslide susceptibility index is given by the equation 1.

$$\begin{aligned}\text{Landslide Susceptibility Index (LSI)} \\ = \; & w_1 * \text{Slope} + w_2 * \text{Aspect} + w_3 * \text{Curvature} + w_4 \\ & * \text{Relative Relief} + w_5 * \text{Drainage Density} + w_6 \\ & * \text{Distance from Faults}\end{aligned}$$

The landslide susceptibility map is shown in figure 1. The landslide susceptibility index varies from 7 to 45. The lower values of landslide susceptibility index represents the lower susceptibility of region towards landslides and higher suitability for development of new projects.

## 5. Conclusion

The landslide susceptibility map for Almora district in India is prepared using expert weightage in this study. The expert weights given in this study depends upon the subjective judgment of the expert. However, landslide inventory is helpful in deciding the realistic weightage. The landslide susceptibility map is prepared at regional level and it will be helpful for planning purpose. The output of the study can be improved by considering more causative factors. Further, other qualitative models like analytic hierarchy process (AHP), fuzzy logic and neural networks can be applied for improving the output.

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