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# Landslide Hazard Mapping of Bagh District in Azad Kashmir

**Sadaf Javed**

Department of Space Science, Institute of Space Technology Islamabad, Pakistan

*Email: nomi4all786@gmail.com

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**Abstract:** Landslide is a process which comprises creep movement, flow movement, rockfalls, snow avalanche and soil flow on a slope. Human beings in hilly regions face catastrophe in the form of land sliding specifically during rain time period. This paper will inspect the study of landslide hazard areas detection from NASA's Shuttle Radar Topography Mission (SRTM)'s Digital Elevation Model and moderate resolution Landsat-8 imagery over the district of Bagh in Azad Kashmir by applying hazard evaluation technique of average weighted overlay method with 6 factors in GIS environment. The outcome of this calculation is an area in the form of hazardous zones in eastern, north-eastern and south eastern of Bagh district in AJK. Landsat-8 imagery is considered effective for observing topographies over a large area while SRTM DEM (1arc second) with large global coverage provides elevation data with 30-meter resolution. GIS technique like assigning weights (weighted overlay method) on different parameters of the landslide can be helpful to policy makers and disaster management departments to overwhelm the serious situation during the hazard.

**Keywords:** Landslide, SRTM, DEM, landsat-8, remote sensing, GIS.

## Introduction

A landslide also known as a land slip, is a form of mass wasting that includes a wide range of ground movements, such as rockfalls, deep failure of slopes and shallow debris flows. It is a natural problem of the hilly zones and has been experimental and documented for several countries globally (Akgun and Serhat, 2008). The documented ancient landslides occurred in Honan Province in Central China in the decade of 1700 BC (Schuster et al., 1986). The problem of landslides has affected widespread loss and damage to human life and assets all over the world (Ercanoglu and Gokceoglu, 2004). In addition to the loss of life, landslides put an end to domestic and commercial progress in addition to food production, wood land and adversely impact on water quality in water courses (Dai and Lee, 2001). Unusual negative impacts on human life and on commercial doings causing from landslides are witnessed all over the globe (Lee et al., 2004). Throughout the 1990's, approximately 9% of tragedies were due to landslide hazard (Clerici et al., 2002). In many countries, the financial loss and deaths due to landslides are more than usually documented and cause a yearly loss of belongings greater than that from any other ordinary catastrophe, containing earthquakes, droughts and storms (Schuster et al., 1986). During the last decade, it is almost done to find researchers and case studies on landslide vulnerability valuation (Lee et al., 2004). In recent times, many probable models have been projected (Clerici et al., 2002). The logistic regression model has been used for landslide detection recording along with geotechnical and factor of safety constraint models to examine the affected zones (Akgun and Serhat, 2008). Data mining using fuzzy logic, artificial neural network and decision tree models have also been useful in Geographical Information Systems (GIS) as a new landslide susceptibility valuation method (Dai and Lee, 2001).

## Materials and Methods

Area of Bagh district is situated in Azad Kashmir (AJK), which is considered as country's rugged area. The area is bounded from 73º 47' 30.48" E to 73º 79' 18" E longitude and from 33º 58' 24.6" N to 33º 97' 35" N latitude. (https://en.wikipedia.org/wiki/Bagh, Azad Kashmir). The district is enclosed by Muzaffarabad district from Northside, Poonch district from South, Pindi and Abbottabad districts from west (Fig. 1).

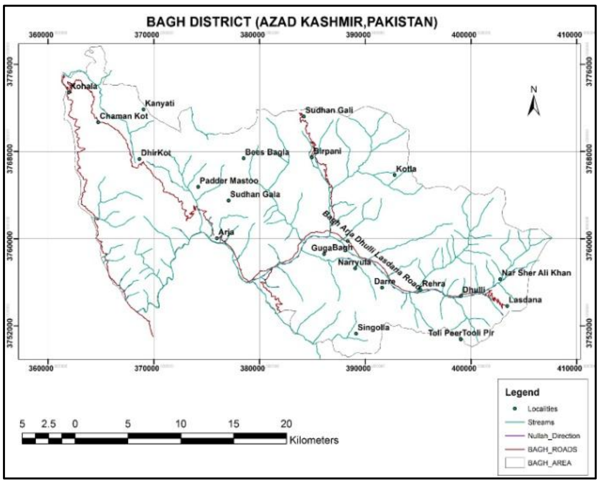


Fig.1 Map of study area.

The resources include Landsat 8 satellite imagery (15 meters resolution after pan sharpen) of 30 March 2016, Shuttle Radar Topography Mission digital elevation model (SRTM-DEM) and shape files of roads, canals, settlements, drainages (earth-explorer and diva-GIS). The objective of the research work is to present Landslide Hazard Zones (LHZ) along parts of Bagh district in Azad Kashmir. Earlier, even a small part of this area has not been considered for its susceptibility to landslides and their alleviation. In order to encounter the native geological surroundings and environmental considerations, preparation of the LHZ map of the study area is predominantly established on the geoenvironmental features like geological structure, slope and aspect characteristics, vegetation, soil and hydrological conditions. The methodology is divided into two groups: one is landslide record which is based on some prominent factors and second is landslide hazard zonation mapping based on landslide records (Dai and Lee, 2001).

**Geological parameters**

First and the foremost factor for the slope firmness investigation is the slope position. Because the slope position is clearly linked to landslides and is very helpful in making landslide vulnerability maps (Ercanoglu and Gokceoglu, 2004). Aspect is another important factor and few weather-related issues like rainfall direction, heat energy, and geological structure of the region influence the slope firmness (Lee et al., 2004). Landslides are critically organized by the physical belongings of the land surface (Ercanoglu and Gokceoglu, 2004). It was essential to determine the geographical characteristics appropriately. Hence, the slope, aspect and geological mapping of the study area were needed to be mapped prior to the final hazard zonal map preparation.

**Indices**

Indices are dimensionless measures resulted from the mathematical transformation of an image. Indices are amalgamations of surface reflectance at two or more wavelengths aimed to highlight a specific thing. NDVI, NDWI and SAVI indices were calculated to complete the landslide inventory for risk assessment (Nefeslioglu et al., 2008). The most extensively used index is Normalized Difference Vegetation Index (Nefeslioglu et al., 2008). Equivalent cell values in the two bands are first deducted and this change is then stabilized by dividing by the sum of two brightness values. The standardization inclines to lessen objects connected to instrument noise and most brightness properties still are detached (Nefeslioglu et al., 2008). Further, NDWI is used to increase water index in a specified image (Schuster et al., 1986). Furthermore, the soil-adjusted vegetation index map was made as adjustment of the Normalized Difference Vegetation Index to correct for the effect of soil intensity when vegetative cover is little (Clerici et al., 2002). The SAVI was found to be a significant footstep that can refer to active soil-vegetation systems from remotely sensed data.

**Landslide hazard zonation by GIS modeling approach**

The final step in this study was an attempt to make use of the Model Builder tool of ArcGIS to generate landslide hazard zonation of the study region with the help of GIS modeling. The contributory elements participated for LHZ map preparation by GIS Model Builder were slope, aspect, geological structure of the area, NDVI, NDWI, and SAVI. In GIS modeling methodology the initial step was to drag all the feature maps into the model builder window. Later, rasterization process was applied by utilizing conversion tool within Model builder environment. Afterward, these six contributory feature maps were reclassified. For instance the sub-classes for the slope features are 0–11, 12–23, 24–36, 37-48 and >49 degrees. Consequently throughout the slope class in the model builder the numerals for the sub-classes were corrected by reclassification procedure. Additional processing requisite in the model builder was to allocate the landslide susceptibility index (LSI) numerals for the diverse contributory features subclasses (Table 1). After the LSI numerals were allotted to all contributory features sub-classes, the ultimate step was to create the concluding weighted sum raster by utilizing the weighted sum in the overlay tool. Finally, the weighted sum raster was divided into six different hazard zones by applying manual breaks, grounded on judgment and terrain form. The cell numerals that were divided into six distinctive regions are no hazard zone, very low hazard, low hazard, medium hazard, high hazard, and very high hazard zones with reclassified cell numerals of 0–2, 3, 4, 5, 6 and 7, correspondingly (Table 2).

Table 1 Landslide susceptibility values assigned for contributory maps.

| Sr.no. | Feature maps | Index values % |
|---|---|---|
| 1 | Slope | 20 |
| 2 | Aspect | 10 |
| 3 | Geology | 30 |
| 4 | NDVI | 20 |
| 5 | NDWI | 10 |
| 6 | SAVI | 10 |

Table 2 Landslide hazard zones and corresponding total landslide susceptibility index (TLSI) values.

| Landslide hazard zone | Zone designation | TLSI value range |
|---|---|---|
| Very low hazard | VLH | 3.00–3.99 |
| Low hazard | LOH | 4.00–4.99 |
| Medium hazard | MH | 5.00–5.99 |
| High hazard | HH | 6.00-6.99 |
| Very high hazard | VHH | 7.00> |

## Results and Discussion

Landslide inventory for risk detection mapping was generated with the help of above mentioned geological parameters and indices. All basic factors were included, which played a major role in a landslide in hilly areas. Slope and aspect both play an elementary role in material flow as slope provides speed and aspect indicate the direction of that steepness. The slope was calculated from SRTM DEM with a pixel resolution of 30 meters and it classifies slope angles from 0 to 49.54 degree. Map of slope (Fig. 2) shows greater values at the eastern side of the region with dark gray shades towards south and map of aspect (Fig. 3) have a total range of values between 0 to 346.68 degree which is eastern and western zones of the region. The effects of these values indicate the flow of land sliding is worst during the rainy season and earthquake shocks (Hoek and Bray, 1981). Further, geological map of Bagh district (Fig. 4) was more important in terms of earth crust structure of the area as the map shows that southeastern part of the region is comprised of metamorphic and igneous rocks, while eastern region is totally made from Tertiary sedimentary rocks. Both types of rocks are less resistant (except igneous rocks) against earth movements in the form of the earthquake and land sliding. Vegetation, water, and soil Indices (Figs. 5-7) play a vital role in identifying and highlighting these features on the land surface because a combination of all factors is very helpful in making landslide inventory. NDVI values (0.117 to 0.276) were found greater at the same region, where crust belongs to sedimentary and metamorphic rocks and same was the case with NDWI (-0.124 to -0.143) and SAVI (0 to0.40). Finally, landslide susceptibility index (LSI) in ArcGIS is a very powerful approach used to assign weights to six parameters. All were reclassified and assigned equal weights in % (Table 1, 2). The results of landslide hazard zonation mapping were used to detect high-risk areas of landslide hazard. The map of landslide hazard zonation (Fig. 8) clearly demonstrates that landslide hazard areas are eastern, southeastern and northeastern parts of Bagh district in Azad Kashmir, which are the areas of sedimentary and metamorphic rocks. As far as geological characteristics of these rocks are concerned these are less resistant rocks against earth vibrations and disturbances.

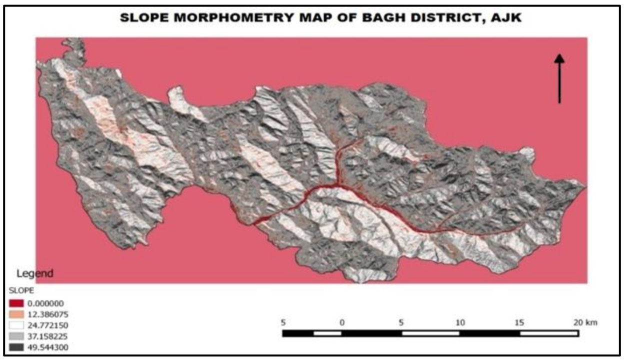


Fig. 2 Slope map of Bagh district, AJK.

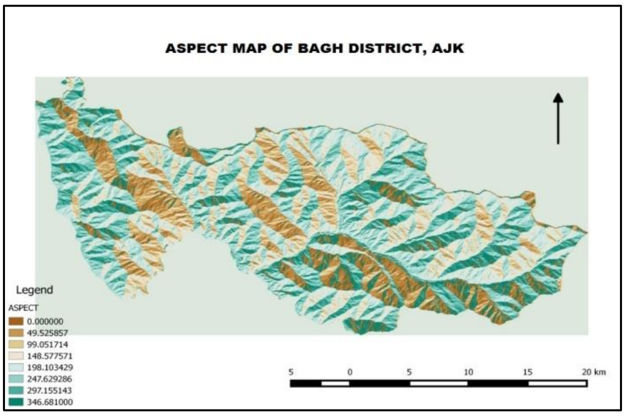


Fig. 3 Aspect map of Bagh district, AJK.

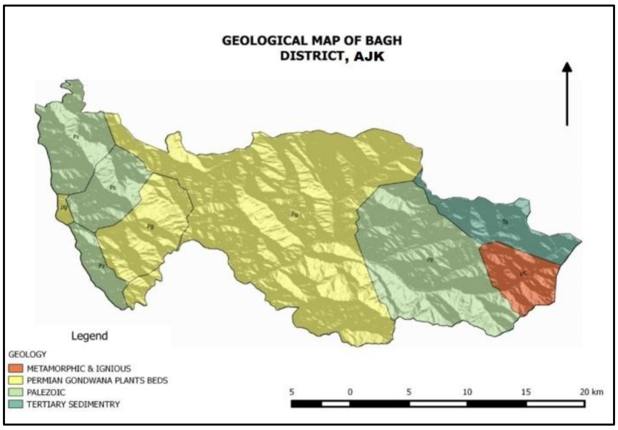


Fig. 4 Geological map of Bagh district, AJK.

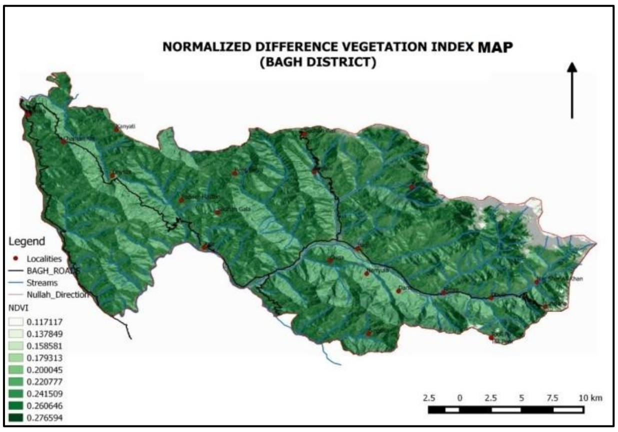


Fig. 5 NDVI map of Bagh district, AJK.

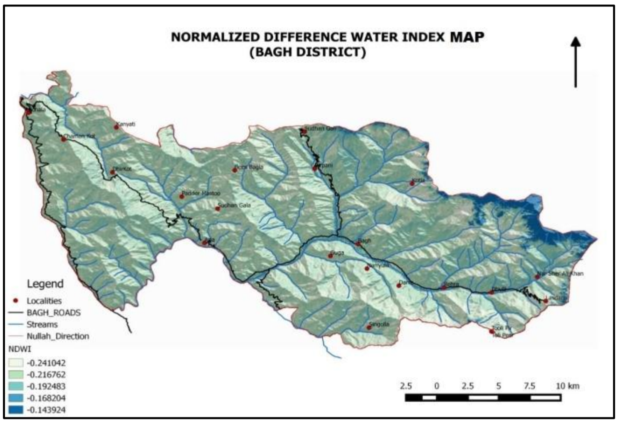


Fig. 6 NDWI map of Bagh district, AJK.

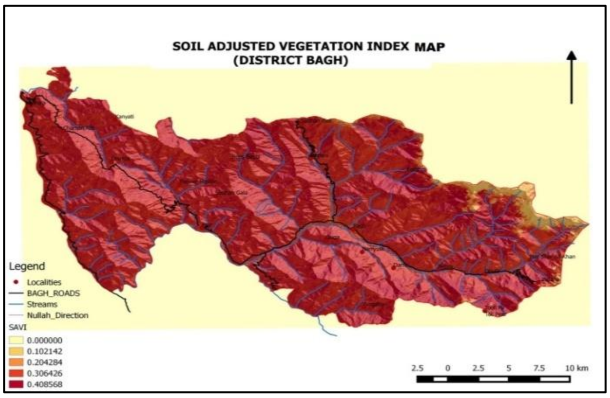


Fig. 7 SAVI map of Bagh district, AJK.

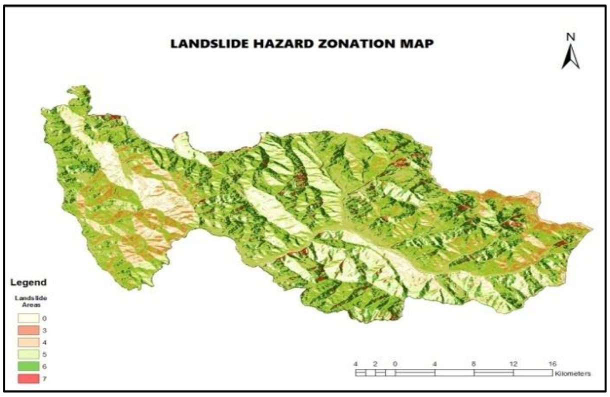


Fig. 8 Landslide hazard zonal map of Bagh district, AJK.

## Conclusion

Landslide detection maps made in this study are the outcome of an amalgamation of numerous causes accountable for landslide vulnerability and every aspect has relative significance to possible landslide movement. In the present work, six land slide contributing elements, namely slope, aspect, geology, vegetation index, water index, soil index, were analyzed. Consequently, landslide-dangerous zones were examined with the help of landslide susceptibility index and the final map was produced by using landslide contributory elements. It is recommended that local communities must be shifted from high-risk areas towards safer zones and proper management plans should be made with great care.

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