Name	Sohail Ahmad
ID no	7699
Section	A
Department	Civil Engineering
Semester	8th
Instructor	Hamza Mustafa

GEOSPATIAL MODELLING OF POTENTIAL SNOW AVALANCHE HAZARD ZONES IN HUNZA BASIN ALONG CPEC ROUTE

Abstract

The topographical and changing climatic conditions of the Hunza, make this region more susceptible towards the natural hazards. Snow avalanches are one of the hazards that posed great threat to communities and CPEC infrastructure near snow covered mountains of Hindu Kush Himalaya HKH region. The aim of this study to map the snow avalanche susceptible zones using Geo-informatics techniques. Analytical Hierarchy Process AHP based geospatial model was used. Study area was divided into five zones (a) Very Low (b) Low (c) Moderate (d) Moderate to High and (d) High with the spatial coverage was 18.3%, 31.7%, 23.9%, 16.6% and 9.4% respectively. The AHP model showed the promising results with the statistical value of AUC was found to be 0.8. This avalanche susceptibility can help the decision makers for sustainable planning and development of infrastructure growth and safe traveling across the CPEC route.

Introduction

The topographical and changing climatic conditions of the Hunza basin make this region more susceptible towards the natural hazards including snow avalanches, Glacial Lake Outburst Floods (GLOFs) and flash flood that will adversely affect the communities and China Pakistan Economic Corridor CPEC infrastructure. Snow avalanches posed great threat to communities residing near snow covered mountains of HKH Region. Harsh climate and the snow avalanche hazard is responsible for the great number of life loss called 'white deaths'[1]. In the upper Indus basin of Pakistan many causalities happened due to deadly snow avalanche hazards[2]. On April 7, 2012 about 180 military personnel's were buried alive under the snow avalanche and around twelve personnel's killed on February 3, 2016[3]. Also the 45% deaths happen due to avalanches and sever climate in Shyok basin. So it is important to map the snow avalanche susceptible areas that will help safe traveling, local government and decision makers to displace the communities and design the CPEC infrastructure and also proved to be useful for the army in selecting the suitable camp site on the snow covered mountains. Keeping this in mind this study was designed to map the snow avalanche susceptible areas in Hunza basin using GIS based modeling and remote sensing techniques. This will help the communities, local government, decision makers and engineers to understand the geomechanical behavior of the area and formulate the remedial strategies for the hazard mitigation.

Materials and Methods

Study area

Study area along KKH from Khuramabad to Gircha village was selected in Hunza basin. In this region significant glaciers are present like Passu and Batura glaciers. Total ten small villages are present along the Karakoram Highway KKH i.e., Burit, Khuramabad, Passu, Janabad, Karaiabad Khyber, Khyber, Chalapan, Morkhun, Gojal and Gircha village. This region is dominated by the solid precipitation and less experienced liquid precipitation.

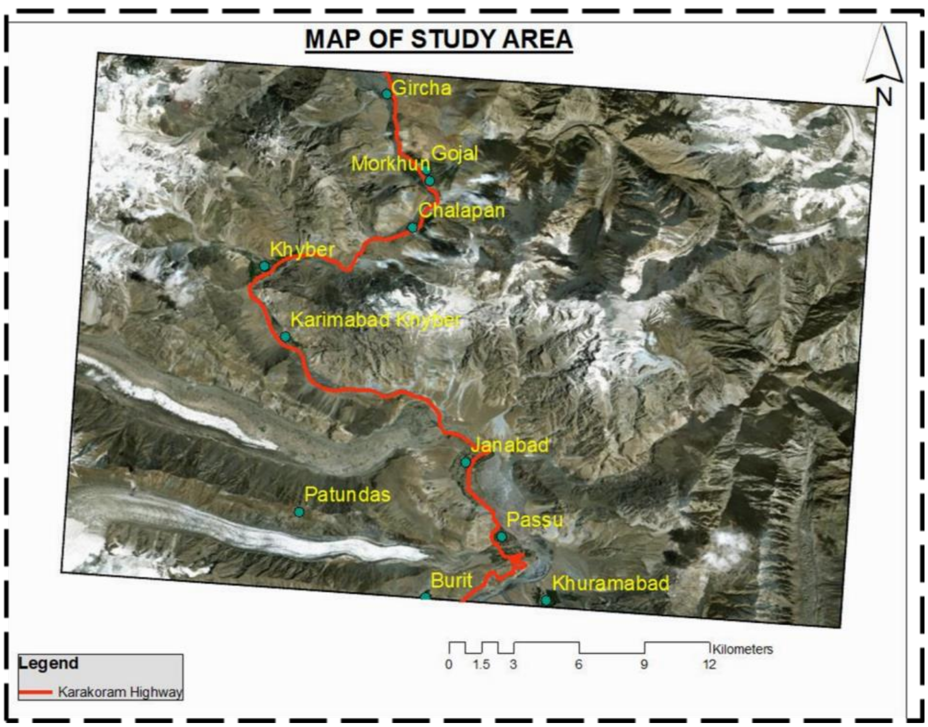

Figure 1. Study area map of Hunza along KKH from Khuramabad to Gircha village.

Methodology

Modeling capabilities using GIS and remote sensing helps to process and integrate the heterogeneous, high spatiotemporal and up to date data for the hazard evaluation and its analysis and its management[4]. Analytical Hierarchy Process AHP model has been successfully applied for the assessment of natural hazard and evaluation of complex geomechanical problems[5]. In this paper AHP model has been used for mapping and assessment of snow avalanche prone areas. The detailed methodological flow chart shown in Figure 2.

Landsat images and Advanced Spaceborne Thermal Emission and Radiometer ASTER Global Digital Elevation Model GDEM data were used with the cell resolution of 30x30m. These datasets were downloaded and extracted for the study area. The Landsat images were atmospherically and geometrically corrected by applying the different convolution filters for removal of noise and haze and image rectification was applied to geometric correction of the images. The preprocessing of ASTER GDEM data was done by identifying the sinks and these sinks were filled by interpolation technique with the filter window of 3x3. Using DEM the topographic features of the study area were extracted i.e., slope, Aspect, Elevation and curvature (Figures 3 – 6).

These topographical features were segregated into different classes that help to decide which class is potentially dangerous or no influence towards snow avalanche hazard. These classified layers were integrated in AHP model that computed the Consistency Ratio CR. The CR defines satisfaction level of consistency for factor weights in pairwise comparison and the value of CR should be less than or equal to 0.1. If CR is greater than 0.1, it depicts that the decision maker is less consistent and the factor weights in pairwise comparison matrix need to be reviewed.

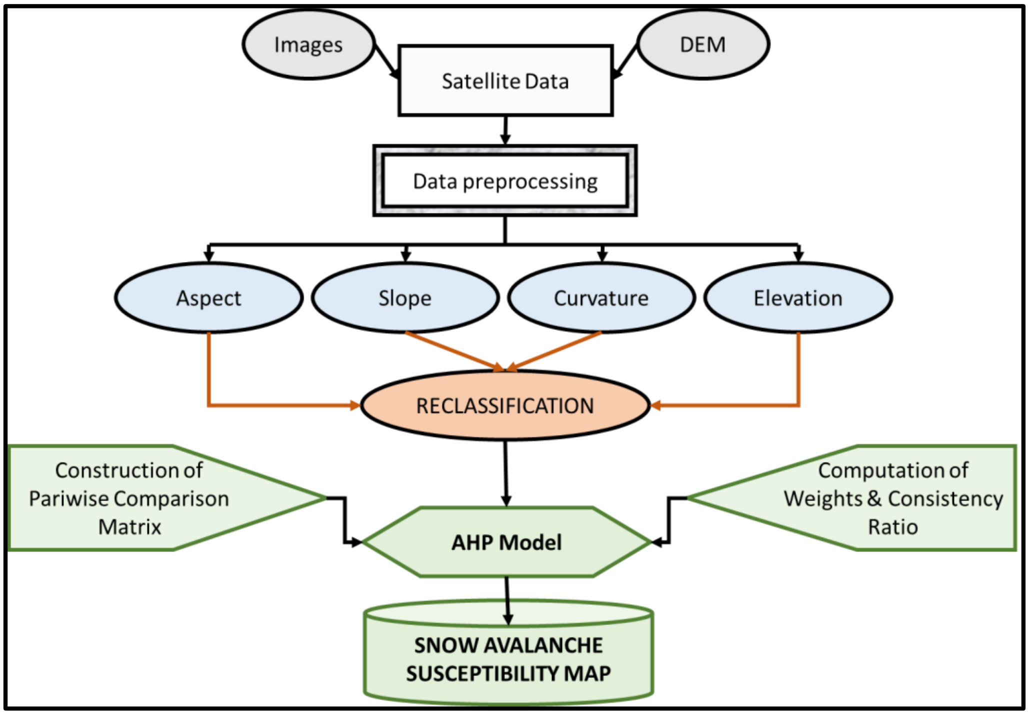

Figure 2. Detailed methodological flow chart.

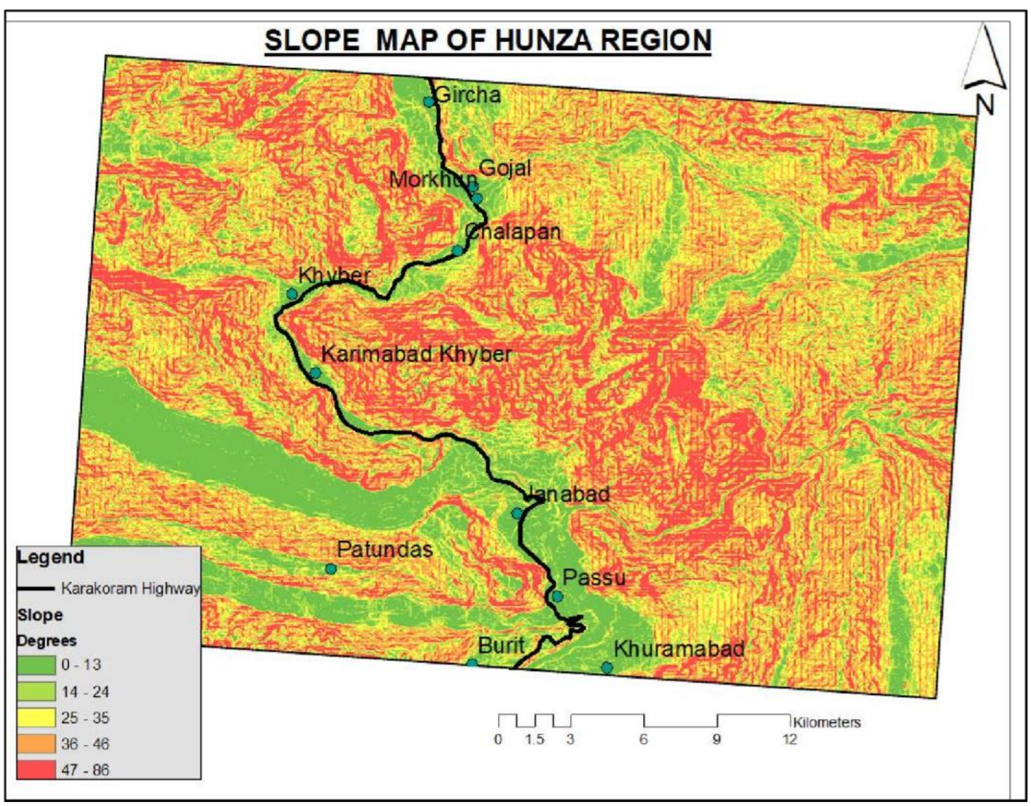

Figure 3. Slope map of Hunza along KKH from Khuramabad to Gircha village.

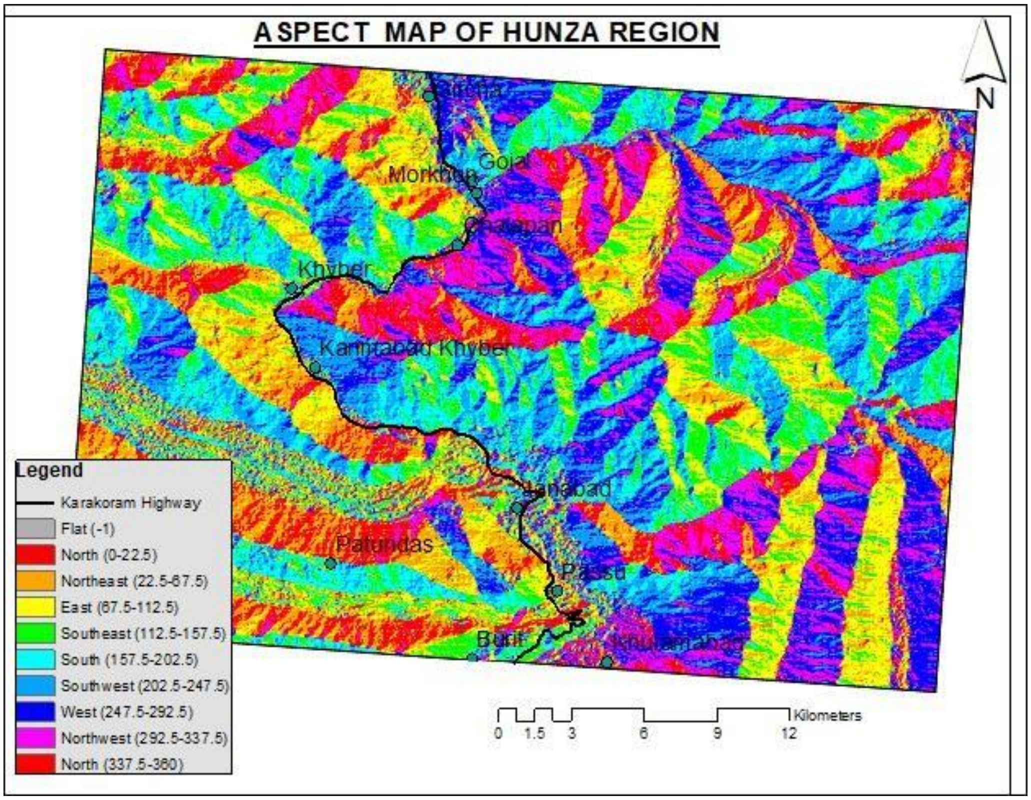

Figure 4. Aspect map of Hunza along KKH from Khuramabad to Gircha village.

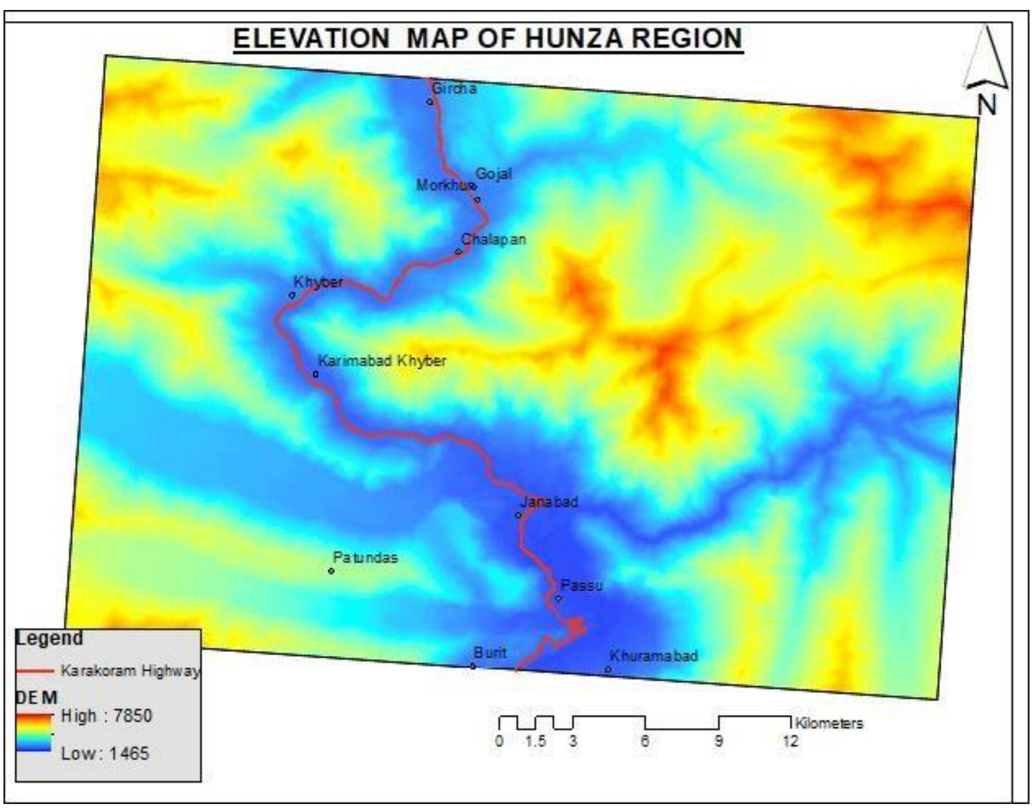

Figure 5. Elevation map of Hunza along KKH from Khuramabad to Gircha village.

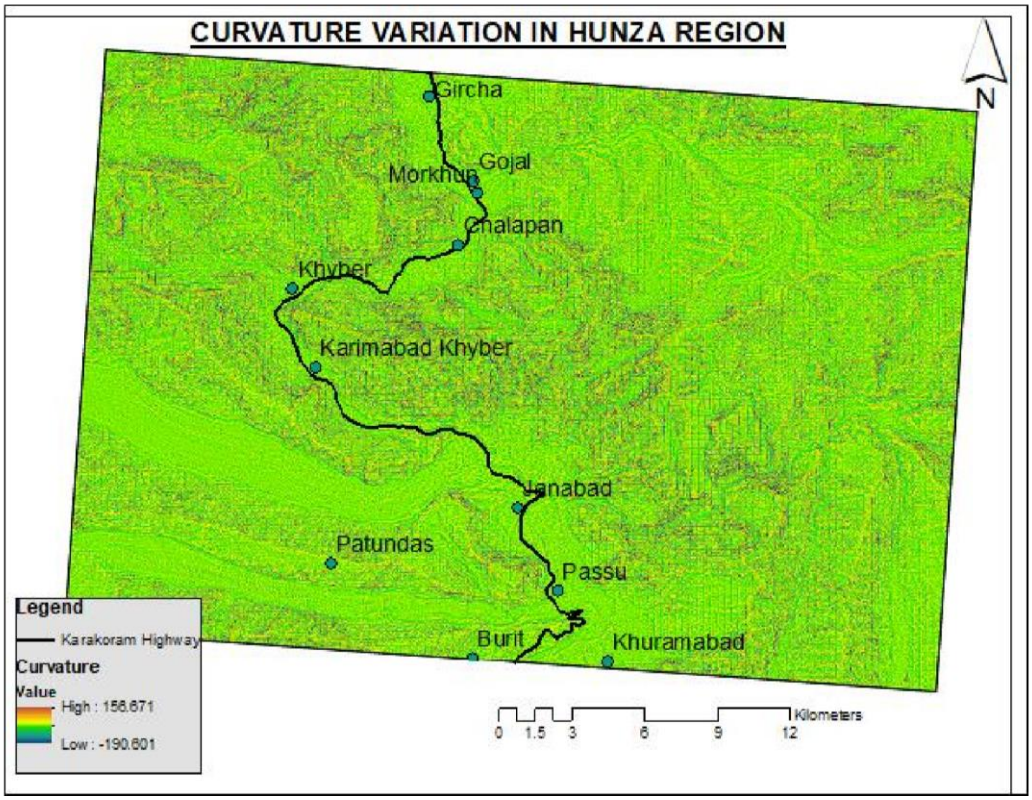

Figure 6. Curvature map of Hunza along KKH from Khuramabad to Gircha village.

Result and Discussion

The slope factor has the maximum weight value which was 0.51, which was found to be a major factor followed by elevation with the weightage of 0.3. Aspect factor was found to be least important as the weightage was 0.09 while, the weight value for Curvature was found to be 0.1. This showed the equal but less importance of aspect and curvature factor in snow avalanche occurrence. While the most significant factor was found to be slope in snow covered mountains of the study area.

Based on the AHP model the snow avalanche susceptibility results were divided into five zones i.e., Very Low, Low, Moderate, Moderate to High and High. Total area covered by each zone is shown in Table 1. The spatial map of snow avalanche zonal distribution is shown in Figure 7.

Table 1. Percentage of area covered by snow avalanche susceptible zones.

Sr. #	**SUSCEPTIBLE ZONES**	**AREA COVERED (%AGE)**
1	Very Low	18.29
2	Low	31.72
3	Moderate	23.93
4	Moderate to High	16.61
5	High	9.42

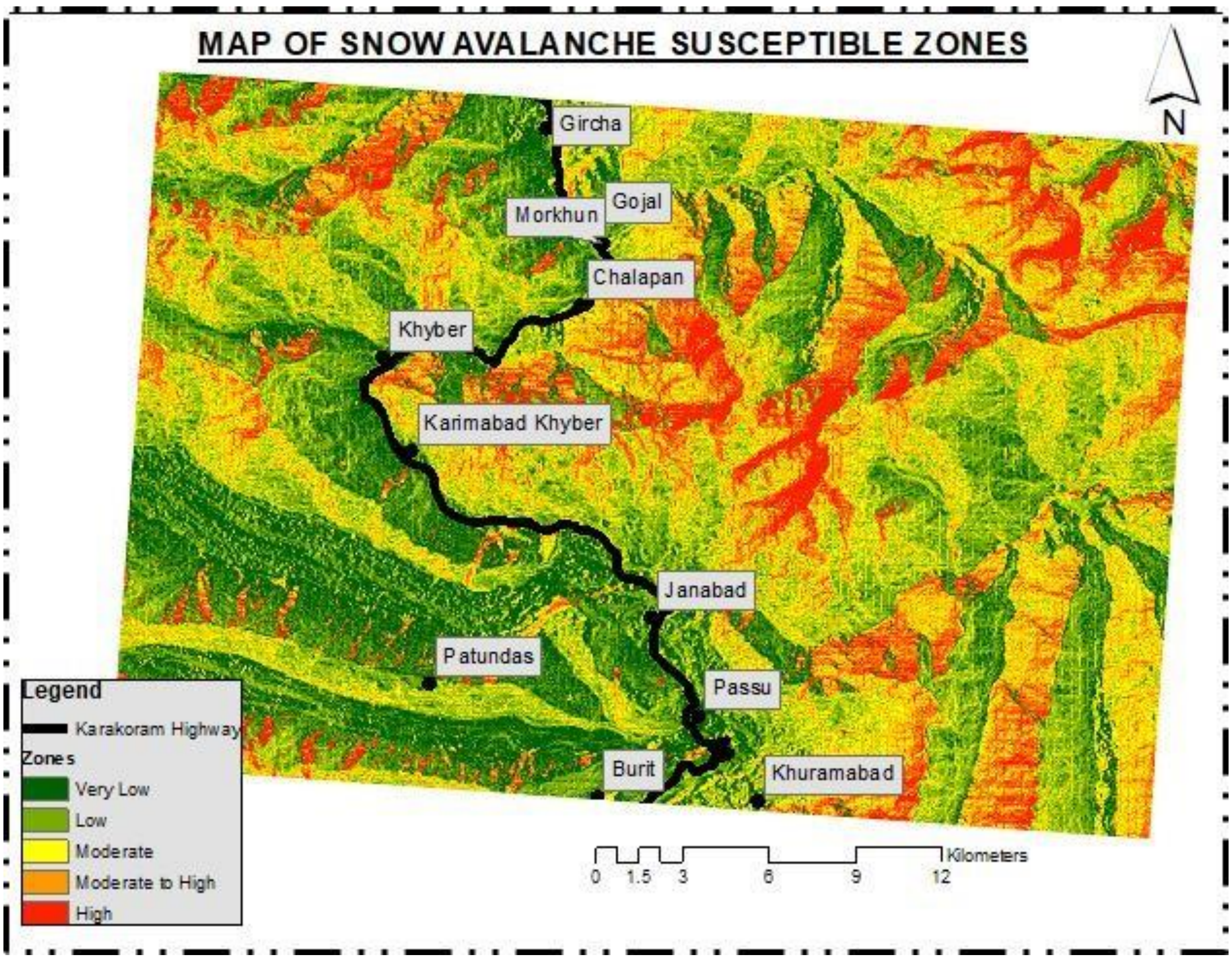

Figure 7. Avalanche susceptibility map of Hunza along KKH from Khuramabad to Gircha village.

The results were validate using the Receiver Operating Characteristics - Area under the Curve ROC- AUC method. This statistical method used to assess the performance of measurements. The ROC-AUC is plot of the possibility of true positive versus false positive observed avalanche susceptibility. Area Under the Curve AUC represents the accuracy. The higher the value, the more the results would be reliable. The AUC value was found to 0.8. Which demonstrates the reliable generated results generated from the AHP model Shown in Figure 8.

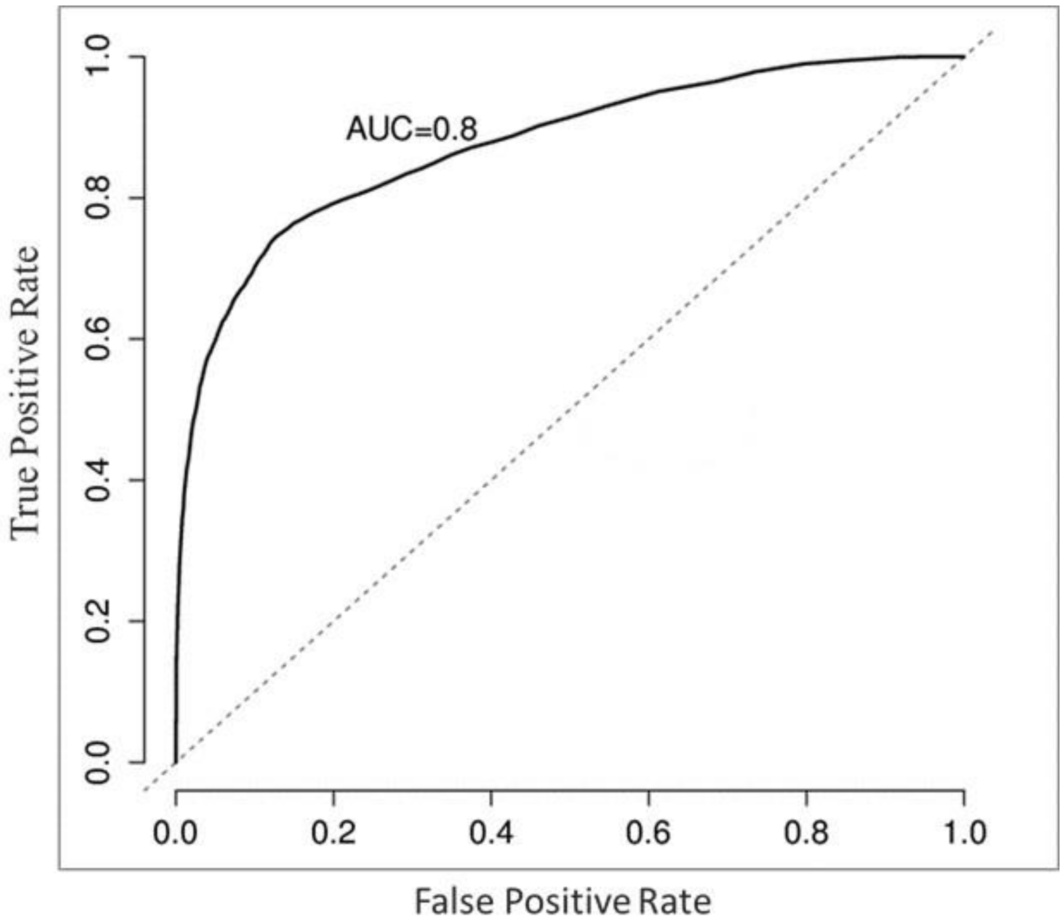

Figure 8. ROC AUC for snow avalanche susceptibility along KKH from Khuramabad to Gircha village.

Same study should be conducted for the whole Upper Indus Basin of Pakistan to map and investigate the avalanche prone areas. This methodology proved to be useful and reliable so this methodology should be followed to help the decision makers and engineers to design the remedial measures.

References

1. Singh A, Ganju A. Earthquakes and avalanches in western Himalaya. Proceedings of the 12th Symposium on Earthquake Engineering; India: Indian institute of Technology Roorkee. 2002. p. 1–8

2. Pakistan weather portal 2012 Avalanche in Pakistan- Tragedy at Himalayas. Available from: http://pakistanweatherportal. com/2012/04/08/avalanche-in-pakistan-tragedy-athimalayas

3. Mahboob, M. A., Iqbal, J., & Atif, I. (2015). Modeling and simulation of glacier avalanche: A case study of gayari sector glaciers hazards assessment. *IEEE Transactions on Geoscience and Remote Sensing*, *53*(11), 5824-5834.

4. Frohn, R. C., & Lopez, R. D. (2017). *Remote sensing for landscape ecology: new metric indicators: monitoring, modeling, and assessment of ecosystems*. CRC Press.

5. Malinowska, A. A., & Matonog, A. (2017). Sinkhole hazard maping with the use of spatial analysis and analytical hierarchy process in the light of mining-geological factors. *Acta Geodynamica et Geromaterialia*, *14*(2), 159-173.