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Research Article

Geospatial Analysis of Landslide Susceptibility and Zonation in Shahpur Valley, Eastern Hindu Kush using Frequency Ratio Model

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Abstract: This study dealt with geospatial analysis of Landslide Susceptibility (LS) and resultant zonation in Shahpur valley, eastern Hindu Kush (HK) using Frequency Ratio Model (FRM). Geologically, HK region constitutes the youngest mountain system. In the study area, landslide is a recurrently occurring natural event. Every year, landslides incur significant property and human losses. The extent of damages is expected to multiply in future due to overgrazing, deforestation, increase in population and infrastructural expansion over the fragile slopes. In the HK region, Shahpur valley was selected as the test area to apply FRM using geospatial technique and explore various factors for determining LS. Initially, a reconnaissance field survey was conducted for preparation of landslide inventory map. SPOT5 pan sharpened image of 2.5 m was used to map various sizes of activated landslides and its subsequent locations were verified in the field. The selected LS factors including surface geology, slope gradient, proximity to fault lines, land use, slope aspect, proximity to roads and proximity to stream/river were used. The relationship between landslide and determining factors were spatially analyzed using FRM. As a result, the Frequency Ratio Score (FRS) was calculated for each factor. Based on cumulative FRS, landslide Susceptibility Indices (LSI) were developed and classified into very high, high, moderate, low and very low LS zones. The central part of the valley was found to be highly susceptible to landslide hazard as both natural and anthropogenic factors were prevalent in this region. Finally, the LS zones were validated by the success rate curve approach.

Keywords: Landslide, frequency ratio model, geospatial, landslide susceptibility, Hindu Kush

1. INTRODUCTION

This paper deals with the geospatial analysis of Landslide Susceptibility (LS) and to develop zones of low to high susceptibility in Shahpur valley, Hindu Kush (HK) using Frequency Ratio Model (FRM). Globally, the frequency and trend of landslide events are on rise [1, 2]. Landslide is considered as one of the devastating disasters in term of damages and human casualties [3]. Every year hundreds of people are affected by landslides and it also put tremendous pressure on individuals, community and national economy [4]. The Hindu Kush Karakorum Himalayan (HKKH) region is highly susceptible to landslide occurrences due to its geological structure, topography, climate and growing human interventions [5-7]. In HKKH region, it is estimated that on average every year property loss of US$ one billion occur due to extreme natural events, out of which over 30% is attributed to landslides [8-10]. In the HKKH region, during 1990 to 2005, an increasing trends of landslide events has been recorded [9] and it was predicted that it will further escalate in future due to the growing human interventions over the fragile slopes and an increase in extreme weather events [11].

In HKKH region, landslide is a recurrently occurring natural phenomenon [5, 12]. The ever

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increasing population has forced the dwellers to potentially fragile slopes for habitation, terraced farming and infrastructural development [13]. In addition to population growth, decrease in forest cover and rapid expansion in infrastructural development over the unstable slopes have further aggravated the landslide risk [10, 14]. Parallel to human intensifying factors, the immature geology, wide range of diurnal and seasonal temperature and precipitation have categorized the Hindu Kush region as the worst landslide affected area [10, 15]. It is hard to predict occurrences of landslides; however, it can be assessed through its history and potential causative factors for determining susceptibility zones.

Scientific community has worked on LS and its zonation in different part of the world [16, 17]. Landslide is controlled by perceptible contributing factors, which can be interpreted through field survey and satellite image interpretation [9]. LS aims to foresee, where the slope failures has potential to activate [18]. Topography, geomorphological factors and removal of vegetation cover are considered as the most important landslide triggering factors [17]. Landslide Susceptibility Zonation (LSZ) classifies the target area into homogeneous zones according to probability of landslide occurrence [19, 20].

Now-a-days, geospatial technology has been widely used as an effective tool for LS analysis and resultant susceptibility zonation [21]. The scope and application of geospatial techniques have been boost-up due to its spatio-statistical capabilities

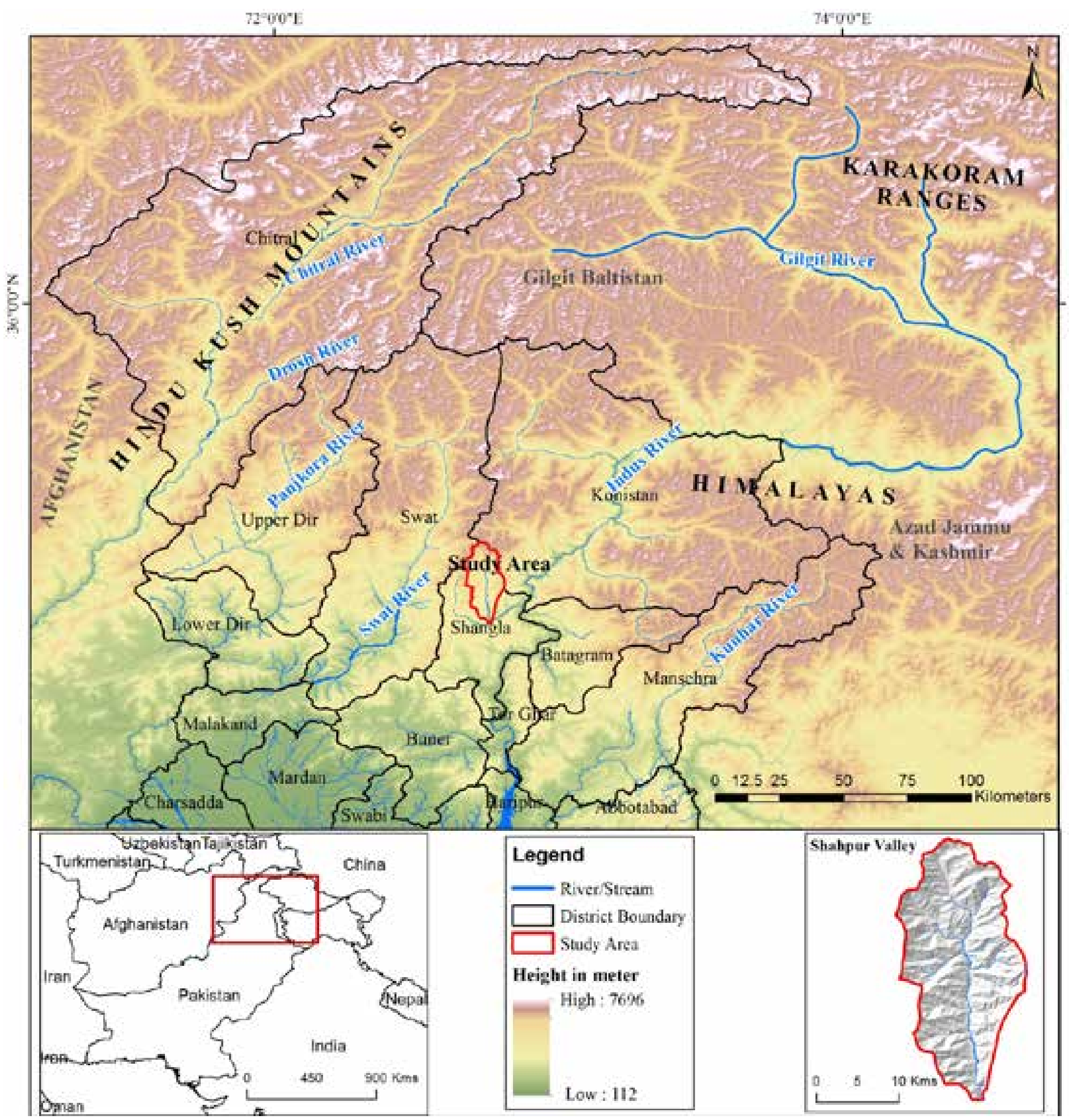

Fig. 1. Location of Shahpur valley in Hindu Kush Mountain system.

and potentials of handling large dataset [22, 23]. LSZ plays an important role in land use planning to minimize the potential impacts of future landslides [24]. Frequency Ratio Model (FRM) is an empirical quantitative approach for LSZ [25]. It provides spatial correlation between location of past landslides and associated triggering factors [17, 26].

Shahpur valley is located in the offshoot of eastern Hindu Kush Mountain [27]. Geographically, Shahpur valley stretches between latitudes 34° 52′ 31″ to 35° 9′ 35″ North and longitude 72° 40′ 10″ to 72° 48′ 44″ East (Fig. 1). Total area of Shahpur valley is approximately 259 km^2. Climatically, the study area falls in humid to sub-humid zone and receives ample amount of rainfall from summer monsoon, whereas in winter the higher altitude receive snowfall [28]. The climate of the area remains mild to warm in summer and cool/ cold in winter. The average annual rainfall varies from 1200mm to 1600 mm. The surface terrain has great variation that ranges from 879 m in the south to over 4,400 m in the north (Fig. 2). In the upper reaches, the slopes are steep, whereas the lower part of the valley has comparatively gentle slopes. Shahpur valley has immature lithology and dominated by unconsolidated material. In order to achieve this goal, three objectives were set-up. To assess the impact of selected causative factors on landslide and to analyze the significant of Frequency Ratio Model in landslide susceptibility zonation. And finally to draw the landslide susceptibility zonation map. In the study area, landslide is a recurrently occurring phenomenon and usually it incur heavy property and human losses.

2. MATERIALS AND METHODS

In order to achieve the study objectives, LSZ using FRM has been applied in GIS environment. To test the FRM, Shahpur valley was selected for detailed insight analysis and to grasp the governing landslide susceptibility factors, which frequently trigger the slope failures. Many factors are involved in slope failure processes and LS assessment in an inter-disciplinary context. LSZ is largely depends on the accuracy of data, selection of appropriate parameters, analytical techniques and the methodology used to process the acquired data.

In the present research, attempt has been made to develop LSZ that ranges from low to very high susceptibility in Shahpur valley. Initially, the inventory of past landslides was acquired and their causative factors were explored from the landslide victims and local population. In this regard, a spatial data layer of past/activated landslide events/sites were identified and digitized on SPOT Satellite image of 2013. For preparing landslide inventory, a detailed field investigation was also carried out to verify the site and situation of activated landslide. To get the opinion and indigenous knowledge about the causative factors that initiate landslides, a Focus Group Discussions (FGDs) were also conducted with the key stakeholders in the study region.

In this study, surface geology, proximity to stream, land use, slope aspect, slope gradient, proximity to fault line and proximity road network were selected as determining factors, which eventually activate a potentially unstable slope. The data pertaining to landslide triggering factors were acquired from relevant government line departments, community and non-governmental organizations. For surface geology and tectonics, the Geological map of North Pakistan was used [29, 30]. The spatial database for administrative boundaries and settlement was extracted from topographic sheets (scale 1:50,000) of Survey of Pakistan. SPOT Satellite image having 2.5 m spatial resolution was acquired from SUPARCO. Spatial features of road network were acquired from the office of Communication and Works Department, Peshawar. In order to get, land use spatial database, supervised classification was applied on satellite image. Similarly, ASTERGDEM 30 m has been used for extracting digital terrain, slope aspect, slope angle and hydrology of Shahpur valley. Parallel to this, a detailed field survey was also conducted for ground verification.

ArcGIS has been used for preparing landslide inventory and generation of thematic layers of selected parameters. The basic assumption in LSZ was that the factors which influence the occurrence of landslide events in the past would be the same to trigger new landslides in future. Following this assumption, a relationship was determined between

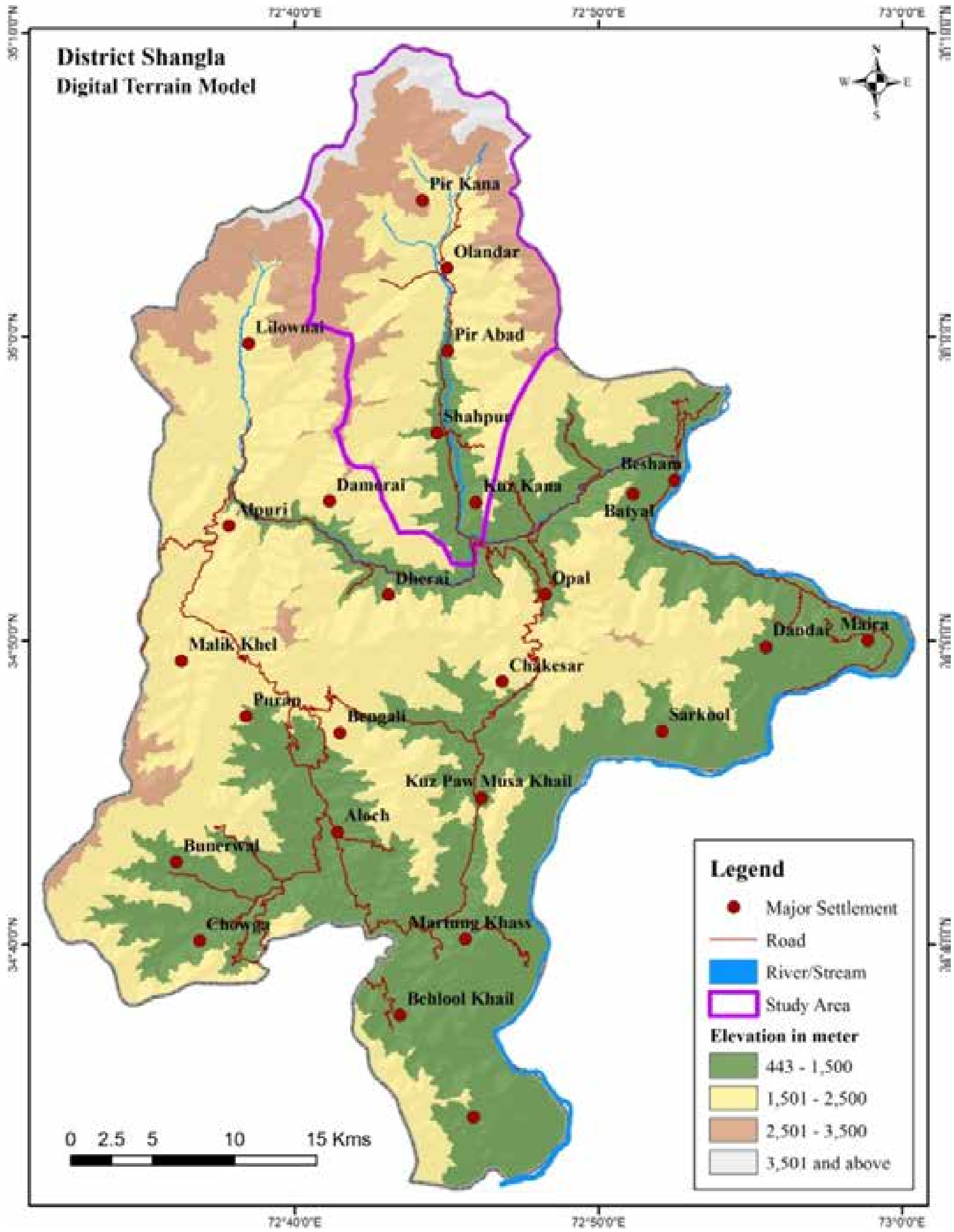

Fig. 2. Location of Shahpur valley and the surface terrain as extracted from ASTER GDEM.

causative factors and spatial distribution of activated landslides. Such relationship was quantified using Frequency Ratio Model (FRM) as applied by many researchers [21, 25, 31, 32]. In FRM, a statistical value was calculated for each class of a factor map using Eq. 1

$$FR= \frac{N_{pix(Si)}/N_{pix(Ni)}}{\sum N_{pix(Si)}/\sum N_{pix(Ni)}} \qquad \text{Eq. 1}$$

Where $N_{pix\ (Ni)}$ is the total number of pixels in the entire study area having class i, $N_{pix\ (Si)}$ is the number of pixels containing class i, $\sum N_{pix\ (Si)}$ is the total number of pixels containing landslide in the study area, $\sum N_{pix\ (Ni)}$ is the total pixels in the study area.

The FR value was calculated for all the classes of the selected factors including surface geology, proximity to thrust and fault line, land use, slope gradient, slope aspect, proximity to roads and proximity to stream. In a FR scale, a score greater than 1 (one) indicates strong and positive relationship between landslide occurrences and the concerned class of the factor map and high landslide susceptibility, whereas a score less than 1 (one) is an indication of negative relationship and low susceptibility to landslide. The FR value for each class of a factor map was obtained from the relationship between all landslide locations and each class of a factor map. The Landslide Susceptibility Index (LSI) was calculated by summation of each factor map using value of FR. As a result, LSZ map was developed based on LSI. Finally, the LSZ map was validated at high confidence level.

3. RESULTS AND DISCUSSION

Landslides are important processes on hill slopes and a devastating extreme event in many parts of the world [33, 34]. It has wide-range of impacts on people and economy of the mountainous community. The impact of landslide is hard to assess as it is some time occurs in association with other hazards, which act as landslide triggering factors. Frequency Ratio Model has already been tested by many researchers for LS analysis in different part of the world [26, 35-37]. Landslide is a natural process and cannot be eliminated but the risk can be minimized. In this paper the FRM was applied for susceptibility zonation, which indicates the areas prone to landslides by integrating the triggering factors of landslides with the inventory of spatial distribution of past landslides. LSZ has been extensively applied in the past two decades and it has helped in reducing landslides [37].

3.1. Inventory of Landslides in Shahpur Valley

The landslide inventory map shows spatial distribution of landslides (Fig. 3), which is the preliminary step for a reliable predictive LSZ. It is hard to visit and map every landslide on the ground due to time and resource constraint. It is therefore, in this study all the activated landslides were demarcated, interpreted and plotted (Fig. 3) on multi-spectral SPOT satellite image of April 2013 with a spatial resolution of 2.5 m. Removing uncertainty in image interpretation and periodic field visits were conducted for ground-truthing and maximum precision. These landslides were then rasterized with pixels of 10x10 m to calculate the number of pixels holding the activated landslides in different classes of each factor map for calculation of landslide frequency ratio.

3.2. Surface Geology and Frequency Ratio

The geology and tectonics of the HKKH region is marked by the collision of Indian plate with the Eurasian plate [38]. This collision occurred due to the northward subduction of Tethys ocean floor under the Eurasian plate, which initiated in the Cretaceous to Mio-Pliocene and still continue at a rate of 4.5 mm/year [38]. The Indus suture zone marks the boundary of collision between the Eurasian and Indian plate.

In Shahpur valley, LS has a close relationship with surface geology, its formation and rock type. It is fact that lithological formation and tectonics significantly influence the slope instability, as it has profound impact on the strength and permeability of rocks and soil. In Shahpur valley, the surface geology and tectonics of this region mapped after Baig (1990) where the dominant formations includes Alluvium, Alpurai Group, Besham Group, Darwaza Sar Potassic Granite Gneiss (DSPGG), Greenschist Melange, Jabrai Granite Gneiss, Jijal Ultramafic, Karora Group and Manglaur formation (Fig. 4a). Most of these lithological zones were complex of different rock types. Analyzing the relationship of past landslides distribution and lithological units through FRM, it was found that Darwaza Sar Potassic Granite Gneiss (DSPGG) and alluvium has highest tendency towards LS followed by Greenschist Melange (Table 1).

3.3. Proximity to Thrust/Fault and Frequency Ratio

Several authors have pointed out the strong relationship of thrust and fault lines with landslide occurrences [39, 40]. Proximity to fault line has become standard practice for assessing LS [41]. It is clear from the literature that slope failure increases in proximity to tectonic structures. Fault lines are usually associated with fractured zones. Presence of thrust and fault zones at high degree slope presents favorable conditions for landslide occurrence.

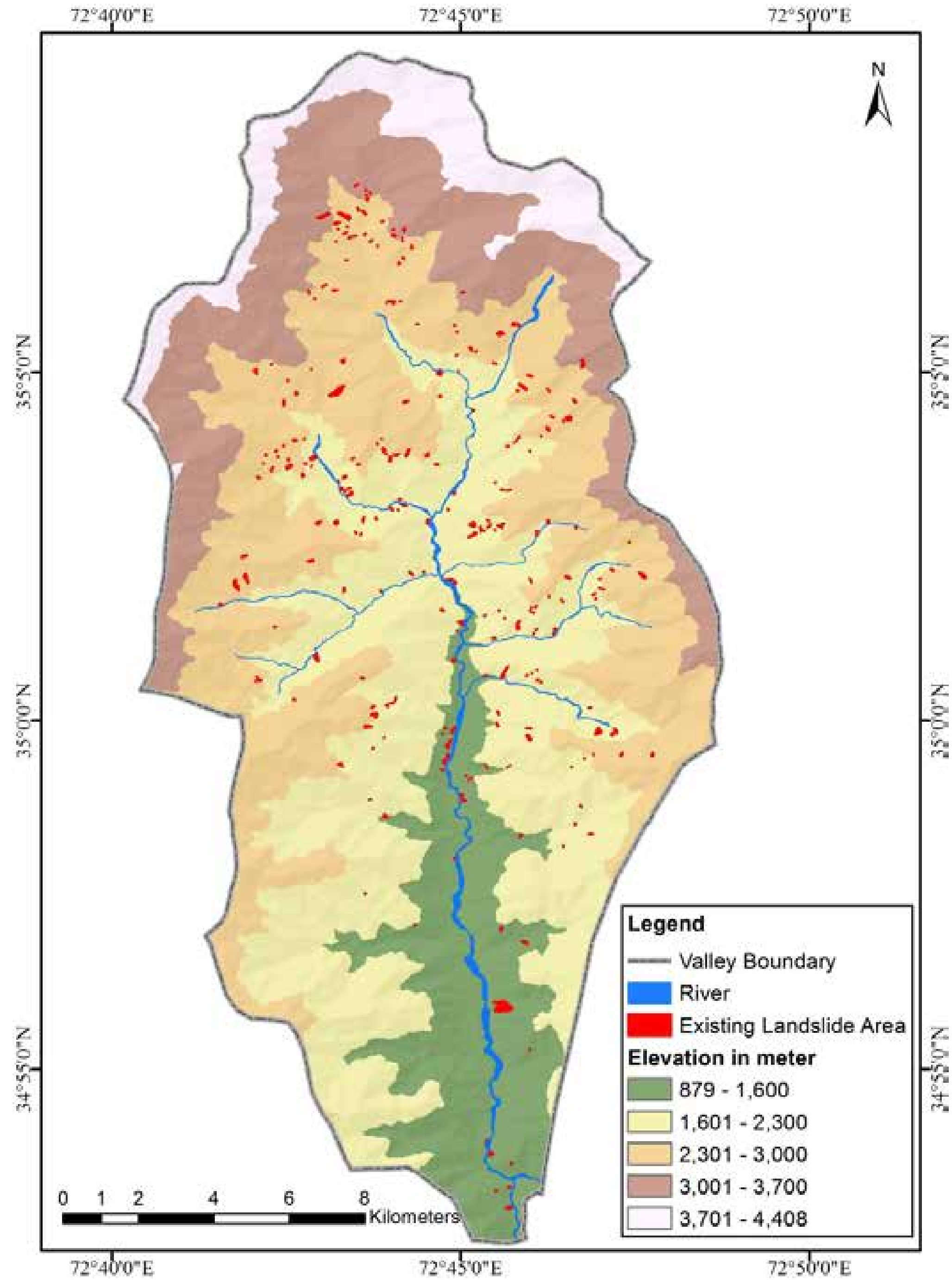

Fig. 3. Shahpur valley, spatial distribution of activated landslides.

In Shahpur valley, there is a complex tectonic setup and considered as one of the determining factor in slope failure processes. The thrust and fault line map has been produced from geological map of Besham area after Baig [29]. The Main Mantle Thrust (MMT) and Makhad Thrust (MT) were found passing through the study area (Fig. 4b). Puran fault, Alpurai fault, Chakesar fault and Karshut fault lines also passes through Shahpur valley and it has profound impacts on slope failure. Applying spatial techniques, on the thrust and fault lines Euclidean distance of 500, 1000, 1500 and more than 1500 meter were generated from thrust and fault line in GIS environment. In this process an attempt has been made to explore the impact of proximity to thrust and fault line on landsliding. It was found from the analysis that these tectonic structures have significant impact on landslide

Table 1. Shahpur valley, frequency ratio values of the landslide conditioning parameters.

Class	$N_{pix (Si)}$	%age of $N_{pix (Si)}$	$N_{pix (Ni)}$	%age of $N_{pix (Ni)}$	Frequency Ratio
Surface Geology					
Alluvium	1500	18.53	290137	11.20	1.66
Greenschist Melange	806	9.96	165892	6.40	1.56
Jabrai Granite Gneiss	903	11.16	497979	19.22	0.58
Alpuraicalc-mica-garnet schist	990	12.23	235014	9.07	1.35
Karora Group	967	11.95	501955	19.37	0.62
Besham Group	1437	17.76	441986	17.06	1.04
Manglaur Formation	1219	15.06	378895	14.62	1.03
Darwaza Sar Potassic Granite Gneiss	271	3.35	43693	1.69	1.99
Jijal Ultramafics	0	0.00	35939	1.39	0.00
Fault Line Buffer (m)					
0 – 250	4018	444.96	897661	180.26	2.47
251 – 500	2325	257.48	796194	159.89	1.61
501 – 1000	760	84.16	591759	118.83	0.71
> 1000	990	109.63	1894091	380.36	0.29
Slope Gradient					
0-5^{0}	91	1.12	67672	2.61	0.43
6-15^{0}	514	6.35	261202	10.09	0.63
16-30^{0}	2138	26.42	668428	25.81	1.02
31-45^{0}	4847	59.89	1365626	52.73	1.14
> 46^{0}	503	6.22	226881	8.76	0.71
Slope Aspect					
Flat	1	0.01	1003	0.04	0.32
North	503	6.22	214528	8.28	0.75
Northeast	531	6.56	284345	10.98	0.60
East	1444	17.84	387747	14.97	1.19
Southeast	881	10.89	395235	15.26	0.71
South	1775	21.93	366716	14.16	1.55
Southwest	1135	14.02	356711	13.77	1.02
West	819	10.12	317177	12.25	0.83
Northwest	1004	12.41	266347	10.28	1.21
Land Cover					
Range Land	2762	34.13	846981	32.71	1.04
Forest	2621	32.39	1035399	39.98	0.81
Glacier and Snow	108	1.33	111001	4.29	0.31
Agriculture Land	2100	25.95	416605	16.09	1.61
Settlement	48	0.59	37492	1.45	0.41
Barren Land	87	1.08	87813	3.39	0.32
Water bodies	367	4.53	54210	2.09	2.17
Road Buffer (m)					
0-100	769	9.50	134060	3.21	2.96
101-200	541	6.68	110469	2.64	2.53
201-300	591	7.30	100728	2.41	3.03
301-400	141	1.74	94590	2.26	0.77
> 400	6051	74.77	3739858	89.48	0.84
Stream Buffer (m)					
0-100	1918	23.70	294929	7.06	3.36
101-200	1555	19.21	266588	6.38	3.01
201-300	1021	12.62	257173	6.15	2.05
301-400	799	9.87	250374	5.99	1.65
401-500	395	4.88	241482	5.78	0.84
>500	2405	29.72	2869159	68.65	0.43

occurrence. The investigation further indicates that number of landslides is high near the thrust/ fault line and it decreases as one move away from the thrust and fault lines (Table 1).

3.4. Slope Gradient and Frequency Ratio

Physiography has greater impact on the human activity of local population and distribution of natural resources. The behavior of landslide has close association with the slope gradient [42] and recognized as a controlling factor in slope failure [7]. Slope gradient is directly proportional to slope instability and landslide density increases with increase in slope gradient [43]. It is, therefore, the frequency and landslide occurrence increases with increasing slope gradient. During the field survey, it was found that there is high concentration of landslide occurrence along the streams and roads, where abrupt change in slope gradient and lateral cutting is dominant factors.

In Shahpur valley, slope gradient map was produced from AsterGDEM 30 m resolution in GIS (Fig. 4c). The resultant map has been classified in different groups based on degree of slopes. The analysis reveals that with increasing slope gradient, the rate of landslide occurrences enhances and thus up to 45 degree slope there is a gradual increase in the value of frequency ratio as shown in Table 1.

3.5. Slope Aspect and Frequency Ratio

In the study region, slope aspect has been generated from ASTER GDEM 30m resolution in GIS environment. Slope aspect is an important factor which influences landslide occurrences and has been used by many researcher in LS mapping [44]. Literature reveals that slope aspect does not have direct impacts on landslide activation, but it indirectly stimulates landslide initiation. It is mainly depend upon the duration and intensity of sunlight on slopes, amount of precipitation receives and moisture retaining capacity, where all the factors have strong correlation with vegetation cover and landslide [3]. Similarly, rain-induced landslide is common phenomena in the HKKH region [43]. In Shahpur valley, the slope aspect has been displayed as flat, northward, northeast, east, southeast, south, southwest, west and northwest facing slopes (Fig. 4d). In the Hindu Kush region, the south facing slopes have high sunlight exposition and receive ample precipitation from monsoon in summer. It is therefore, the south facing slopes have high frequency ratio and thus have high tendency to landslide occurrence (Table 1).

3.6. Land Use/ Land Cover (LULC) and Frequency Ratio

LULC has an immense impact on slope stability [43] and it is vegetation cover that reduces the potentials of soil erosion and thus minimizes the chances of slope failure. The roots bind the soil and keep the slope stable [12]. However, the barren slopes have more exposure to geomorphic agents and led to erosion and slope instability. The LULC of Shahpur valley is extracted from multispectral satellite image of SPOT of April 2013 having 2.5m spatial resolution. In Shahpur valley, the major land cover were forest, agricultural land, rangeland, settlements, glacier/snow and water bodies (Fig. 5a).

In Shahpur valley, while analyzing the impact of land use/land cover on LS, it was found that waterbodies has the highest score of frequency ratio followed by agricultural land and rangeland (Table 1). The area covered by rivers and streams has been kept in class waterbodies. It has a profound impact on landsliding due to its lateral erosion, which in turn make the slope susceptible. In Shahpur valley, agricultural activities are mostly carried out on terraces of mountain slopes. The third highest frequency ratio exists in rangeland category (Table 1) due to consistent overgrazing and deforestation.

3.7. Proximity to Road and Frequency Ratio

The construction of roads involve mostly improper excavation and cutting of slopes which disturb the slope and increases the slope instability. Landslide expert consider roads as a major contributor in deforestation process [45] and in turn expedite the process of weathering and mass wasting. In Shahpur valley, proximity to road has been used as a determining parameter for slope instability. On road network data, multiple ring buffers of 0-100, 101-200, 201-300 and 301-400 m were applied to find out the impact of road proximity to landslide

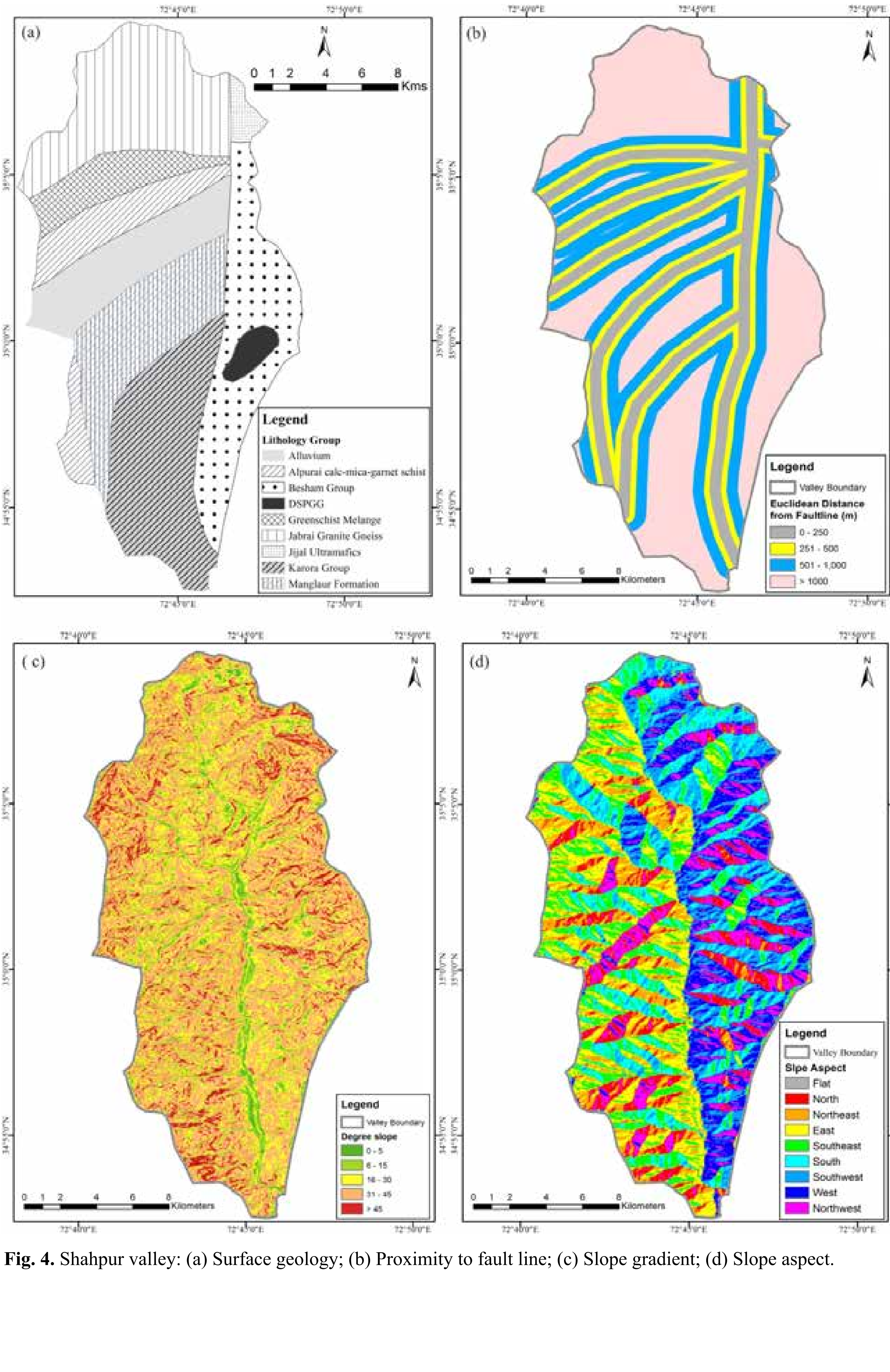

Fig. 4. Shahpur valley: (a) Surface geology; (b) Proximity to fault line; (c) Slope gradient; (d) Slope aspect.

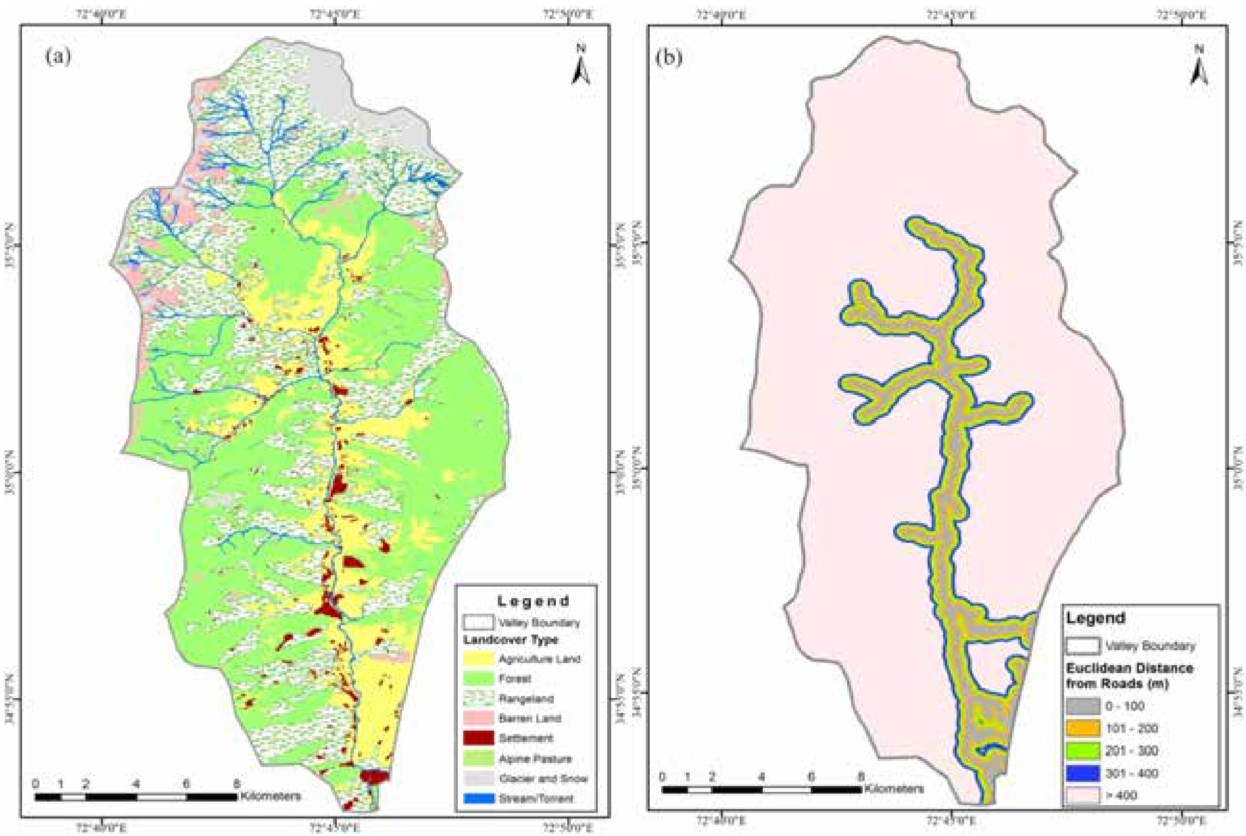

Fig. 5. Shahpur valley: (a) Land use/ land cover; (b) Proximity to road.

occurrences (Fig. 5b; Table 1). The analysis revealed that LS and road proximity has a close relationship. Landslide frequency ratio was found higher near the road up to 300 m and beyond 300 m there is decrease in frequency ratio score (Table 1). This means that slope near the road are more susceptible to landslide hazard and more stable as one move away from roads.

3.8. Proximity to River/Stream and Frequency Ratio

In order to analyze the impact of river/stream on landslide hazard, a statistical model frequency ratio was applied. Euclidean distance from river/ streams was taken as 0-100, 101-200, 201-300, 301-400, 401-500 and plus 500 m to analyze the impact of river/streams on landslide hazard (Fig. 6). While analyzing the relationship of distance from the stream and landslide occurrences, it was found that near the streams the frequency ratio was found higher indicating high LS. The highest frequency was found in the region of 100 m distance (3.36) followed by 100 to 200 m distance having 3.01 frequency ratio (Table 1). The analysis revealed that in class less than 401 m, the frequency ratio is greater than 1 indicating that the region has high susceptibility to landslide occurrences. Whereas the region with over 400 m distance from river/ stream, the frequency ratio is < 1 signify that the susceptibility of landslide occurrence is low (Table 1).

3.9. FRM and Landslide Susceptibility Zonation

Landslide hazard is the most common threat to the lives and property of the people of Shahpur valley. Hence, it is important to identify and map landslide prone areas for safer community. LSZ is one of the pre-requisite for developmental planning in mountainous areas and it is the process that divides the area into different classes according to their level of susceptibility based on certain parameters. All the thematic layers were integrated in GIS environment to generate the LSZ map of Shahpur valley. To minimize subjectivity, quantitative approach was applied for preparation of thematic maps. The objective of this approach was to

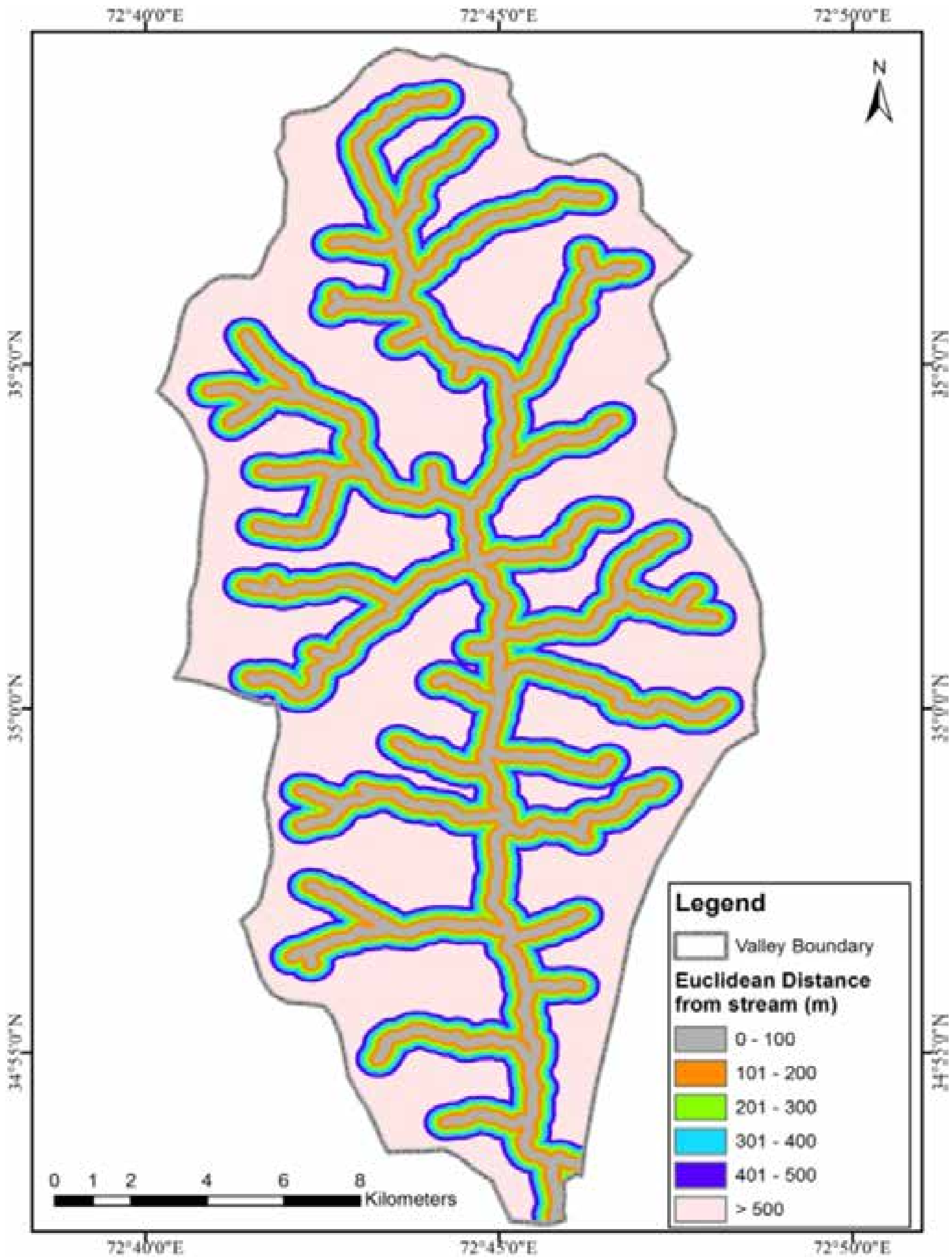

Fig. 6. Shahpur valley, proximity to river/ stream.

quantifying the relative importance of each sub-factor theme in an integrated factor map. The LSI was calculated by a summation of each factor map using frequency ratio value (Eq. 2):

$$LSI = \sum Fr \quad \text{Eq. 2}$$

While using the LSI, all the values range from 2.99 to 15.14. Higher the value of LSI, greater would be the likelihood of landslide occurrences and vice versa. Based on LSI value, the Shahpur valley was divided into five zones of very low, low, moderate, high and very high susceptibility regions (Fig. 7). The analysis revealed that out of total study area, 2.7% area falls in very high landslide susceptible zone and 9.9% in high LSZ. It clearly indicates that approximately 13% of Shahpur valley lies in highly susceptible zone and may cause enormous damages in future if proper mitigation strategies were not taken in-time. In Shahpur valley, the past landslide events at high confidence level follow the

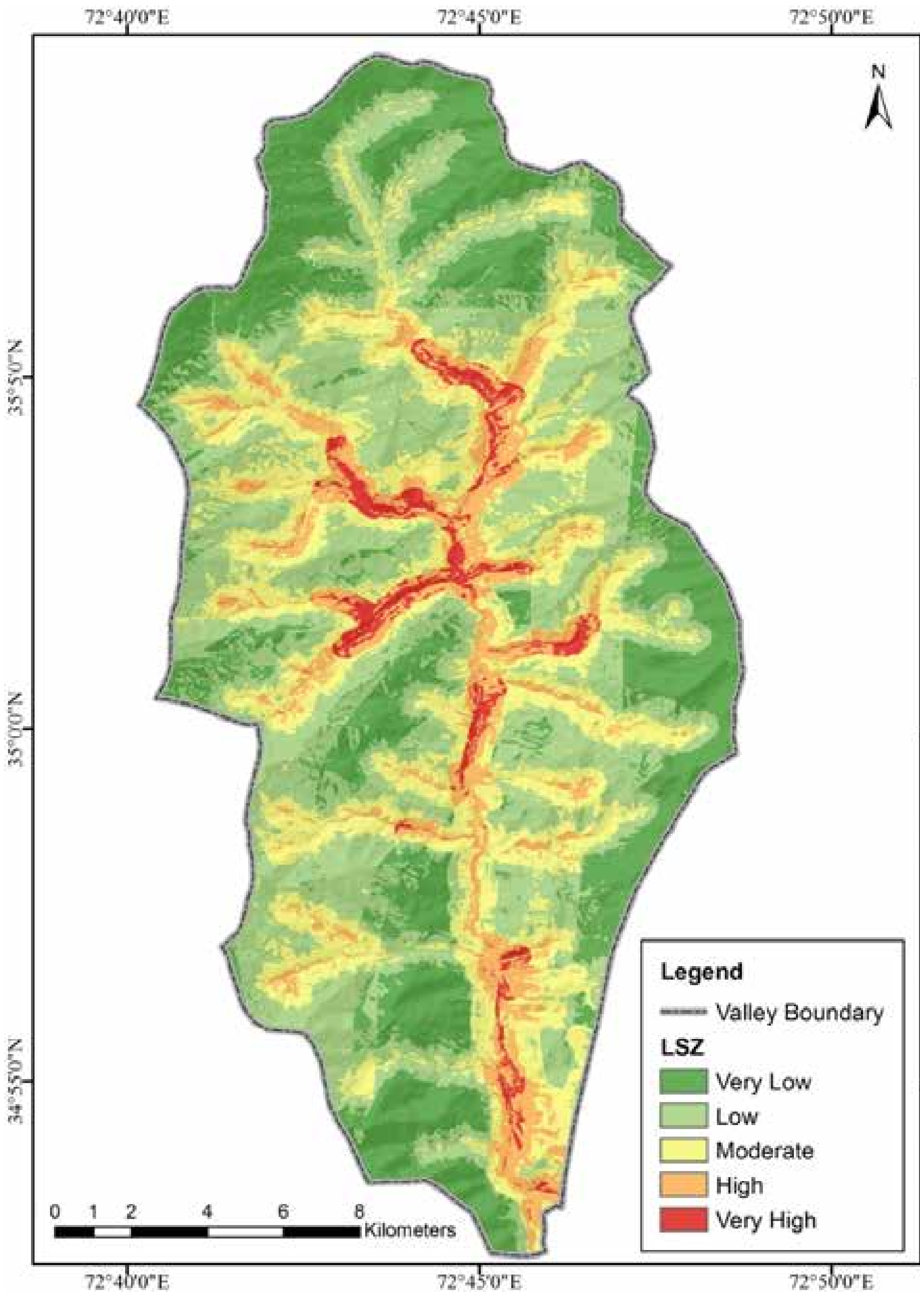

Fig. 7. Shahpur valley, landslide susceptibility zones.

predicted LS zones (Fig. 7). The analysis further verifies that in 2010, a heavy landslide event *Olandar* has incurred 60 deaths, also falls in very high susceptibility zone.

3.10. Validation of Landslide Susceptibility Zonation

In Shahpur valley, the LSZ was produced using FRM and the same was validated by comparing it with already activated landslide map. The success rate curve was calculated to evaluate the accuracy of FRM for selected contributing factors to landslide occurrences. For success rate curve calculation, the LSI values is divided into 100 equal classes sorted in descending order ranging from highly susceptible to very low susceptible classes. This was also overlaid with the existing landslide area layer and the area under already activated landslides falling in each susceptible class was calculated through spatial statistical tool in ArcGIS. The cumulative percentage was calculated and success rate curve

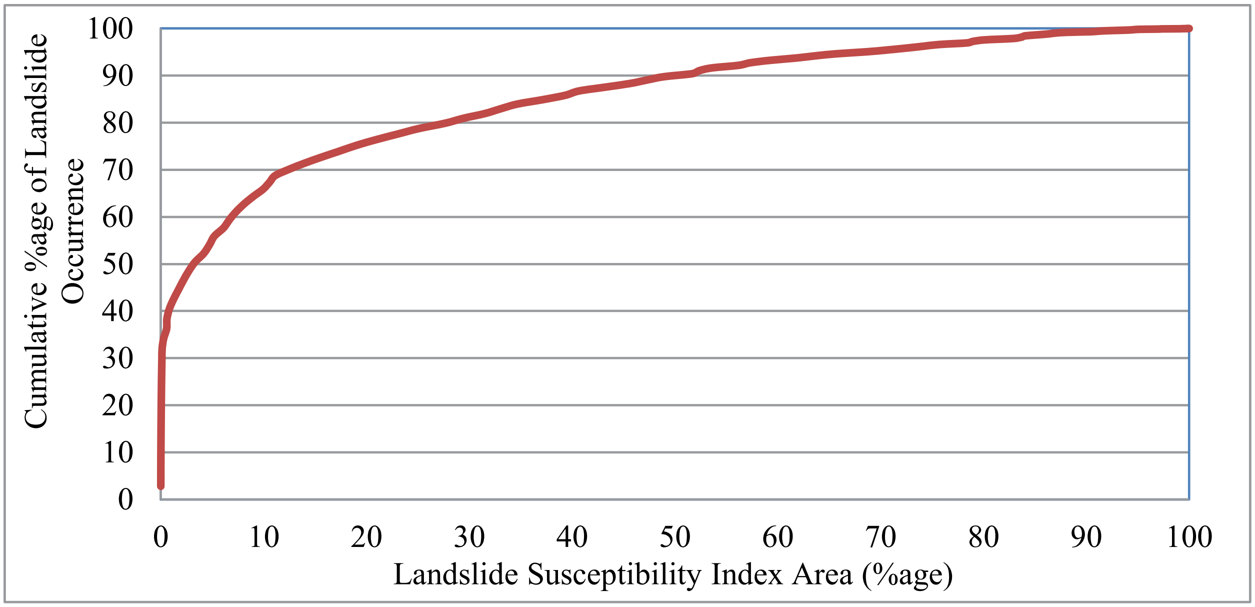

Fig. 8. Shahpur valley, landslide susceptibility success rate curve.

was built by plotting LSI on the x-axis and the cumulative percentage of landslides occurrence on the y-axis (Fig. 8). The success rate curve has steep curve which indicates significant result of FRM and productive results of landslide susceptibility zonation map. The final LSZ map was validated through success rate curve and the prediction accuracy was found as 91.11%. In Shahpur valley, the success rate curve validates satisfactory results of FRM (Fig. 8).

4. CONCLUSIONS

In Shahpur valley, Frequency Ratio Model was applied using susceptibility factors for identification and development of landslide susceptible zonation map. Initially, the detailed inventory of past landslide events was identified and plotted on multi-spectral SPOT satellite image of April 2013. In order to apply FRM in GIS environment, standard parameters of geology, thrust/fault line, land use/ land cover, slope aspect, slope gradient, proximity to river and roads were selected for susceptibility analysis. The analysis revealed that considering geology, Darwaza Sar Potassic Granite Gneiss, Alluvium and Greenschist Melange have the highest frequency ratio and thus highly susceptible to landslide occurrence.

While analyzing the impact of tectonic structure, it was also found that frequency ratio was also found high near the fault lines. Similarly, the impact of slope gradient on landslide susceptibility was found maximum at slope that ranges from 31 to 45 degree. Likewise, it was found that south and east facing slopes have high frequency ratio and thus have high susceptibility of landslides. It is because of its high sunlight exposure and the same it also receives plenty of precipitation. In addition to this, the impact of river bank erosion also joins hand in escalating the landslide susceptibility. In order to get landslide susceptible zonation map, frequency ratio of all the sub-classes of the selected factors were sum-up through weighted overly technique in GIS environment and the resultant LSI was calculated. The final LSZ map was validated through success rate curve and the prediction accuracy was found 91.11%.

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