Slope Instability Assessment using a weighted overlay mapping method, A case study of Khorramabad- Doroud railway track, W Iran

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Received: 20 December 2013 / Accepted: 06 September 2014 / Published online: 23 September 2014

Abstract

Every year, a considerable portion of the national budget specifies to reconstruct the properties which have been destroyed during natural disasters in Iran. Recognition of vulnerable sites to natural disasters can reduce the probable damages. The most important point in designing railway tracks is to join stations in the least possible time. So, the railway track is meant to cross lots of valleys, mountains and hilly areas. In order to insure the safety of lives and properties that are going to use the railway track, a supplementary study of landslide and rock fall susceptible areas is vitally important. Six factors of slope angle, morphology, material's fabric (lithology), vegetation cover, hydrological condition and faults and fractures activities, were recognized as major factors in occurrence of a landslides in the Khorramabad - Doroud railway track. Spatial data of these factors were collected from satellite remote sensing imageries, 1:100,000 geological maps and 1:100,000 topographical map sheets and also field investigations. After production of thematic data layers, they were resampled by the cell size of 250 meters. In this GIS based overlay mapping approach, According to the influence to landslides, the Data layers were arranged in a hierarchy order from 1 to 6, where the bigger number, shows higher susceptibility to mass movements. Based on computed Landslide indexes, the area was classified into five different classes of instability including, critical, highly unstable, moderately unstable, moderately stable and stable zone. To facilitate the validation, statistical analyses and field investigations were performed. Results showed a significant relationship between susceptibility classes and recorded mass movements.

Keywords: Slope Instability; Remote Sensing; GIS; Khorramabad-Doroud Railway Track; Landslide Susceptibility.

1–Introduction

Every year, a considerable portion of national budget specifies to reconstruct the properties which have been destroyed during natural disasters in Iran. Recognition of vulnerable sites to natural disasters can reduce the probable damages. During the designing level of civil engineering formations, safety investigations are essentially crucial. The slope instability studies are supposed to highlight the vulnerable areas to landslides and rock falls (Guzzetti *et al.*, 1999; Saha *et al.*, 2002; Saha *et al.*, 2005; Guzzetti *et al.*, 2006). Landslide and rock fall susceptibility assessment studies, provide us with the exact location of areas with unstable slopes (Dai *et al.*, 2001).

Nowadays, Landslides and rock falls have caused huge concern among project planners. In mountainous regions, if the area were affected by a heavy rainfall or an earthquake, a landslide would be highly probable to occur (Chauhan et al., 2010; Arnous,. 2011).

Railways are supposed to transfer people in a fast and secure way. The most important point in designing railway tracks, is to join stations in the least possible time. So, the railway track is meant to cross lots of valleys, mountains and hilly areas. In order to insure the safety of lives and properties who would use the railway track, a supplementary study of landslide and rock fall susceptible areas is vitally important.

Landslide susceptibility (LS) is defined as the probability of occurrence of a landslide in an area. In other word, LS is a degree to check if an area can be affected by further mass movements. In a landslide susceptibility zonation map (LSZ), according to the LS values, an area can be divided in to different zones of landslide probability (Sarkar et al., 2004; Kanungo et al., 2006; Chauhan et al., 2010).

Spatial data are provided in a wide range of methods. In comparison with all the data preparation methods, remote sensing is a fast, cheap and simple approach for spatial data set preparation. This spatial data set includes vegetation, land usage, lithology, structural features and etc. Geographical information systems provide us with preservation and processing of spatial data. During the last few years, the application of GIS systems has been increased dramatically (Arnous,. 2011).

The simultaneous use of GIS and remote sensing can decrease both the period and operation costs of the project. Combination of remote sensing and GIS techniques has become pretty common in a variety of studies (Arnous,. 2011). These techniques provide us with the exact location of favorite places. These favorite places include the location of mineral resources, the location of a particular kind of a species e.g. a plant, the best places for construction of special. Landslide susceptibility and hazard studies are meant to provide civil engineers with the location of prone areas of landslides. So, landslide susceptibility zonation is the first step of slope stability operations. These studies have a considerable importance in designing of roads and railways.

Many RS and GIS studies have been handled in order to recognize the landslide susceptible areas, in the last few years (such as Kouli et al., 2013; Kundu et al., 2013; Liu et al., 2013; Das et al., 2012; Gokceoglu., 2012; Guillard et al., 2012; Hasekioğulları et al., 2012; Oh et al., 2012; Pourghasemi et al., 2012; Van Den Eeckhaut et al., 2012; Xu et al., 2012; Arnous., 2011; Arnous et al., 2011; Avtar et al., 2011; Chauhan et al., 2010; Pradhan et al,. 2010; Rossi et al., 2010; Vahidnia et al., 2010; Fell et al., 2008; Galli et al., 2008; Melchiorre et al., 2008; Yalcin., 2008; Sato et al., 2007; Guzzetti et al., 2006; Kanungo et al., 2006; Komac., 2006; Lee et al., 2006; Lunetta et al., 2006; Van Westen et al., 2006).

Slope stability is controlled by several elements such as lithological, environmental, morphological and climate conditions. In a gradient terrain, shear stress can be motivated and increased as the result of mining activities, constructional activities, penetration of water ingredients, earthquake and etc. Consequently the terrain would be encountered with an unbalanced condition (Guzzetti et al., 2006).

Many factors are involved to cause a slope rupture (Sarkar et al., 2004). These factors include either the factors which decrease the shear strength of material, or factors which increase the shear stress of the material (Lee., 2005). Human activities like deforestation and changing the usage of lands (for agricultural and constructional proposes) can create an unstable condition for the imbedded soil. The penetration of water in the soil's texture is another influential factor which increases shear stress. Mining and constructional activities are other motivating factors for slope instability. According to the available information, six factors of 1- slope angle, 2- morphology, 3- material's fabric (lithology), 4- vegetation cover, 5- hydrological condition and 6- faults and fractures activities, were recognized as major factors in occurrence of a landslide.

During last decade, in the study area, landslides have caused enormous damages to civil engineering formations. Khorramabad – Doroud railway track, crosses from a highly hilly area, and is located between latitudes 33°29'6"N and 34°30'8"N and longitudes 48°20'31"E and 49°4'35"E. The location of the under study area is shown in Figure 1. Several earthquakes have affected the area, and many life and property losses (from the occurrences of landslides and earthquakes) have been reported.

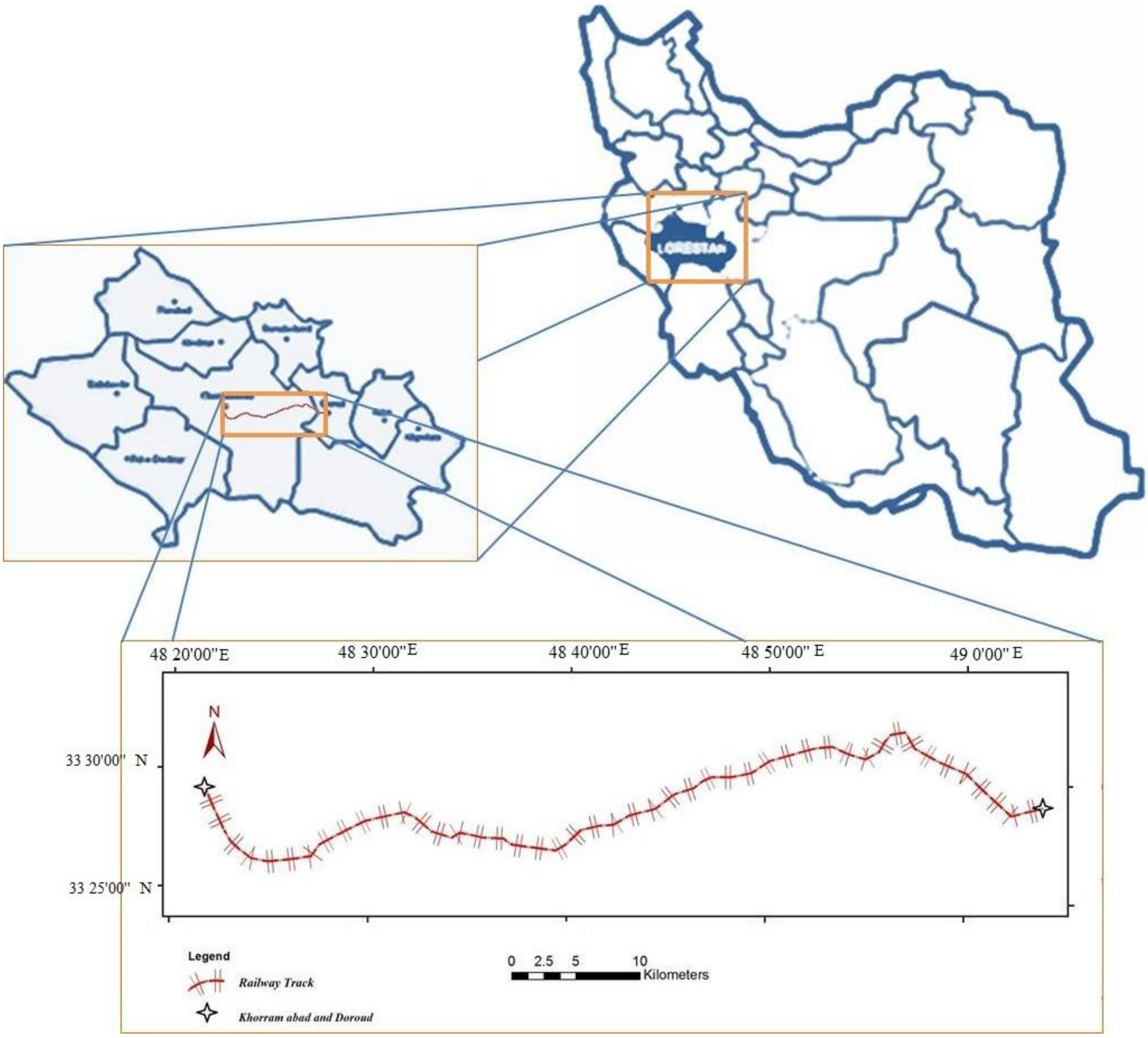

Figure 1) The location of study area.

The climate of the area is generally sub-humid. During the winter, the precipitation rate increases and lots of snow falls have been reported in the area. The average precipitation rate in the region reaches to 530 millimeters. Temperatures vary widely during the cold and hot seasons in the area. During the summer, the temperature ranges from a minimum of 12° C to a maximum of 42° C, while during the winter the temperature varies from a minimum of -8° C to a maximum of 16° C.

The objective of this study was to introduce the landslide prone areas of the Khorramabad–Doroud railway track, to assist the project planners, with detection of unstable slopes.

2- Geological and Tectonic characteristics of the area

The area under investigation belongs to the Zagros zone tectonically (Berberian et al., 1981). Several lithological units present in the area. Their ages differs from Jurassic to quaternary. The area's geological map can be observed in Figure 2.

The oldest rocks of the area are Jurassic Marl and Limestone. Cretaceous presents in the area with three formations. Thin bedded limestones of lower cretaceous and marly blue limestone of upper cretaceous are observable in the first ten kilometers of Khorramabad–Doroud railway track. Amiran formation which has been covered a remarkable part of the area belongs to the upper cretaceous and consists of Shale, Sandstone and Conglomerate. This formation can be observed in kilometers 14 to 17 of Khorramabad–Doroud railway track.

Kashkan formation's rocks do not exist in the railway path, but is in the adjacency to railway path. Kashkan formation belongs to the Eocene and is consisted of Sandstone, conglomerate and red marl. White massive limestone of Asmari formation is widespread in the area as well as in the 18th kilometer of Khorramabd–Doroud railway track. Asmari formation belongs to the Oligocene. Also a considerable part of the area is covered by red marls of Gachsaran formation which is known as Miocene part of the area.

Pliocene rocks of the area are red marl and conglomerates of Aghajari formation. Moreover the conglomerates of Bakhtiari formation which have covered a huge part of the under study are belong to the Pliocene.

The most vulnerable to landslide portion of the area has been covered by Quaternary deposits as well as alluvial fans. These parts are the youngest part of the area.

The under investigation area has been affected by several fault's activities. High Zagros trust fault and Doroud faults are two main faults of the area under study. While several minor faults and fractures exist in the area.

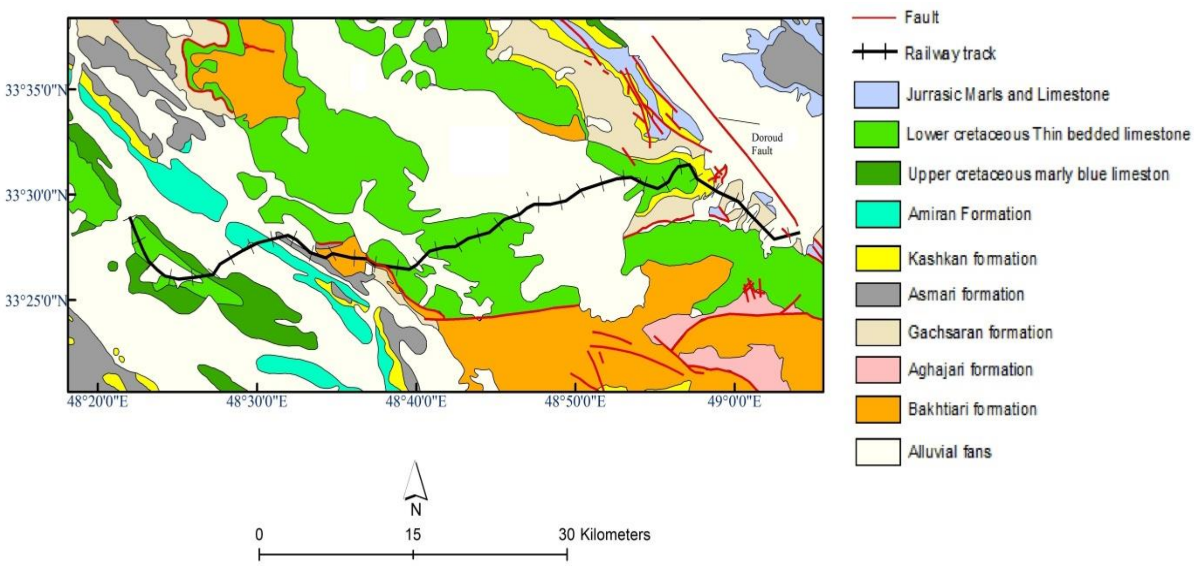

Figure 2) geological map of the area under study.

3- Materials and Methods

According to the several GIS- based landslide studies that have been conducted in last few years, and during a comprehensive examination of the study area, it was resulted that six key factors were responsible for occurrence of landslides. These factors include Slope angle, related relief, Lithology, Vegetation, adjacency to drainage network and structural features.

Spatial data of these factors were collected from satellite remote sensing images (Landsat 7, ETM$^+$, 2006), Geological survey of Iran (GSI) 1:100,000 geological maps and national cartography center of Iran 1:100,000 topographical map sheets and also field investigations. Table 1 provides the details of these data with their application in this study. The flow diagram of this study has been demonstrated in Figure 3.

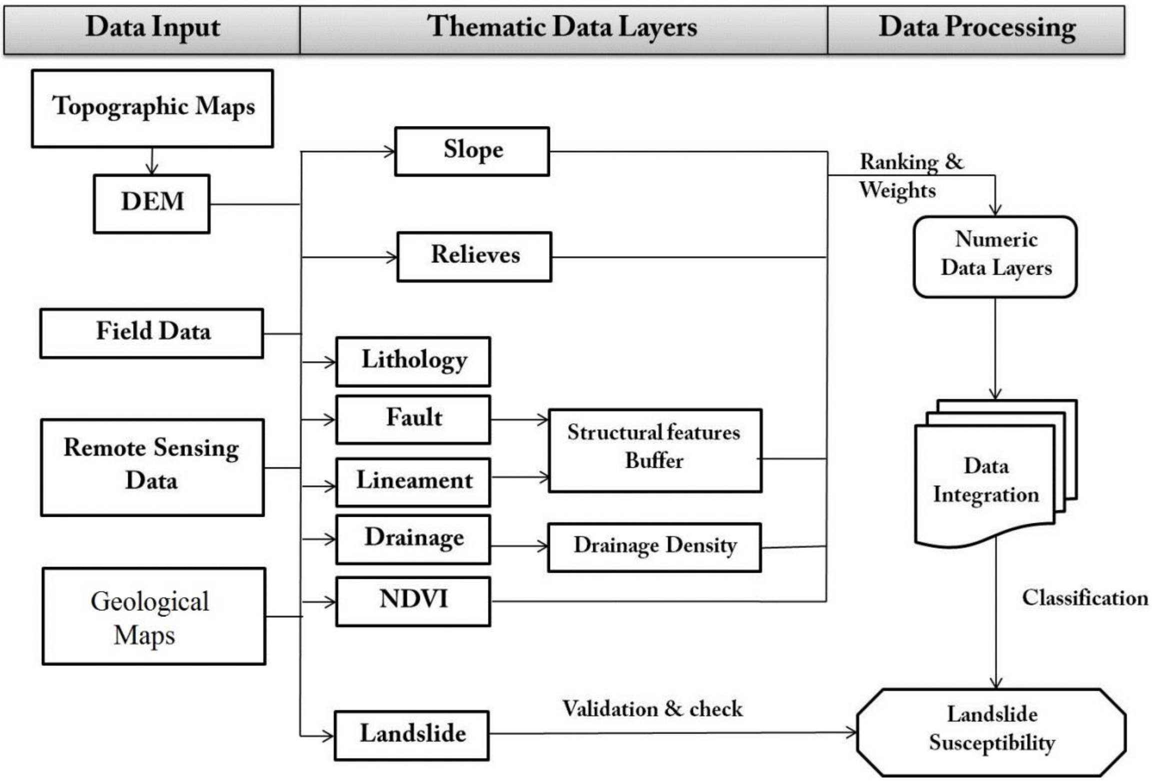

Figure 3) The flow diagram of study

Preprocessing of satellite data was firstly carried out in order to correct the radiometric and numeral errors of these data. The 1:100,000 topographical map sheets were used for numeral correction of ETM^+ data. For extracting the information of satellite data, both visual and digital interpretation methods were used. For highlighting the features of the study area, false color composite images were prepared and several filters such as directional and non-directional filters were passed through the satellite images. The fractures and lineaments were detected using edge enhancement filters.

Geological maps of the study area were digitized, and then lithological data layer was extracted from it. Also the approximate location of faults was firstly identified by digitized geological map of the area, and then supplementary remote sensing studies were carried out for assigning the exact location of faults.

Drainage network data (i.e. spatial distribution of streams) canals and rivers were qualified by both remote sensing data, and digitized topographic maps of the area.

The most important part in validating of a LSZ map is to assess the location of recorded mass movements. Using satellite data, topographic data and also field surveying the landslide inventory map of the study area was prepared.

A typical integration method requires all the data layers in the same extent and cell size. The cell size of the data layer is the smallest unit of the area that can be assumed as an isotropic part. According to the scope of the project and its sensitivity, a cell size of 250m was specified for each data layer. In this study, according to the expert's judgments these factors were ranked and then infused.

The base of classification of thematic data layers was correlation with recorded mass movements (landslide inventory map). For this purpose, recorded landslides were divided by two classes. In the first class, 40 per cent of landslides were randomly separated for training of GIS based integration system. And, 60 per cent of landslides were randomly selected for testing and validation of output data.

Table 1) The data type, their sources and their application in the study

Data types	Description			Specific use
	Satellite/Sensor	Spatial resolutions	Year of acquisition	
Remote sensing data	Landsat/ETM^{+}	30m,15m	2006	NDVI, Structural features
Topographical Map	Scale: 1:100,000(2006)			Slope, Relieves
Geological Map	Scale: 1:100,000			Lithology, Structural features
Field data	GPS surveys			Landslide distribution

4- Digital Elevation Model (DEM)

Surface topography is responsible for controlling the source and the direction of flows. Two topographical feature of slope angle and related relief were derived from DEM. DEM shows the spatial variation of elevation over an area. Topographic map sheets of Khorramabad at 1:100,000 scales (2006) were employed for generation of the DEM. Contours at 50m intervals were considered for generating the DEM. Figure 4 demonstrates the 3D preview of under study area which has been extracted from DEM.

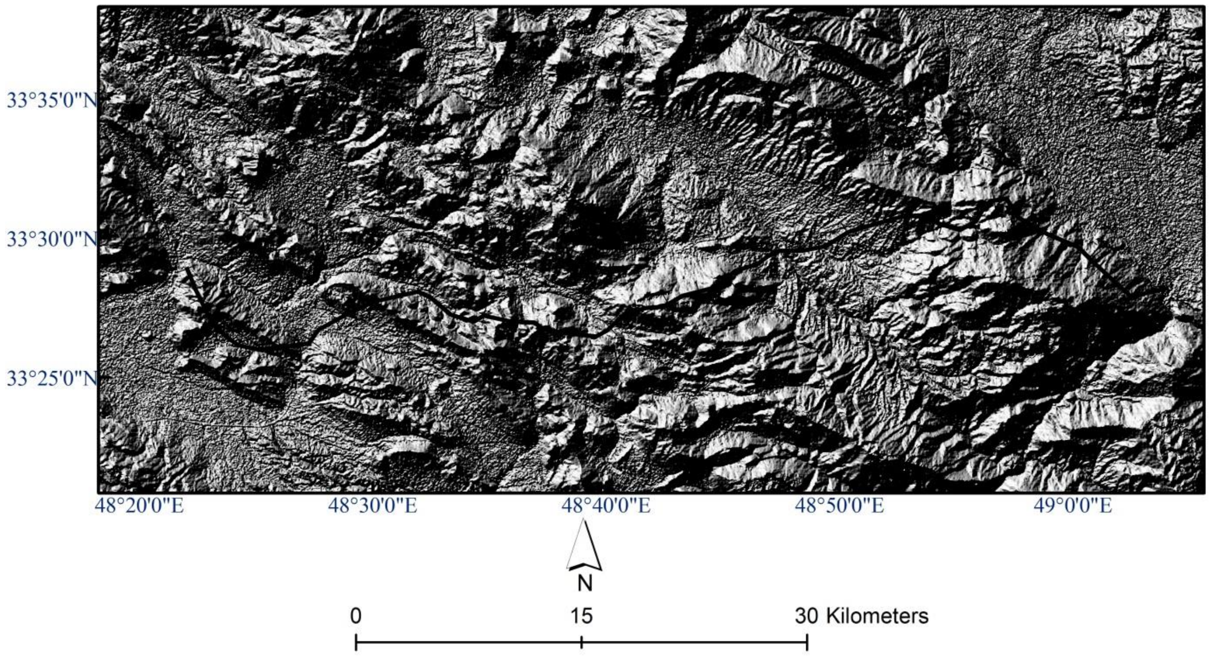

Figure 4) 3D view of the area.

Slope is known as the main cause of land sliding. The larger the slope angle, the more probable to landslide. Spatial distribution of slope categories can be obtained from DEM. It was observed that landslides like to occur in slopes with more than 35° and often do not occur in flat areas. Also, a number of ancient landslides in the area have occurred in slope degrees of 15–35°. Therefore, three slope categories of (a) 0–15°, (b) 15–35° and (c) ≥35°, were considered and represented in the form of slope data layer. The slope thematic data layer has been demonstrated in Figure 5.

Related relief is another important causative factor which is responsible for Rock fall and landslide occurring. Related relief is the difference of maximum and minimum elevation within an area. A 5×5 matrix filter was defined for a computer program, which calculated the difference of maximum and minimum values within a 5×5 neighborhood. This filter was moved across the DEM whit a cell size of 250m. The relative relief calculated value for a 5×5 neighborhood with the cell size of 250m was allotted to the central pixel. According to these calculated values, the area was classified into five categories of (a) <50 m, (b) 50-100 m and (c) >100m. The base for this classification was the frequency of recorded mass movements. Figure 6 represents the related relief thematic data layer (Chauhan et al., 2010).

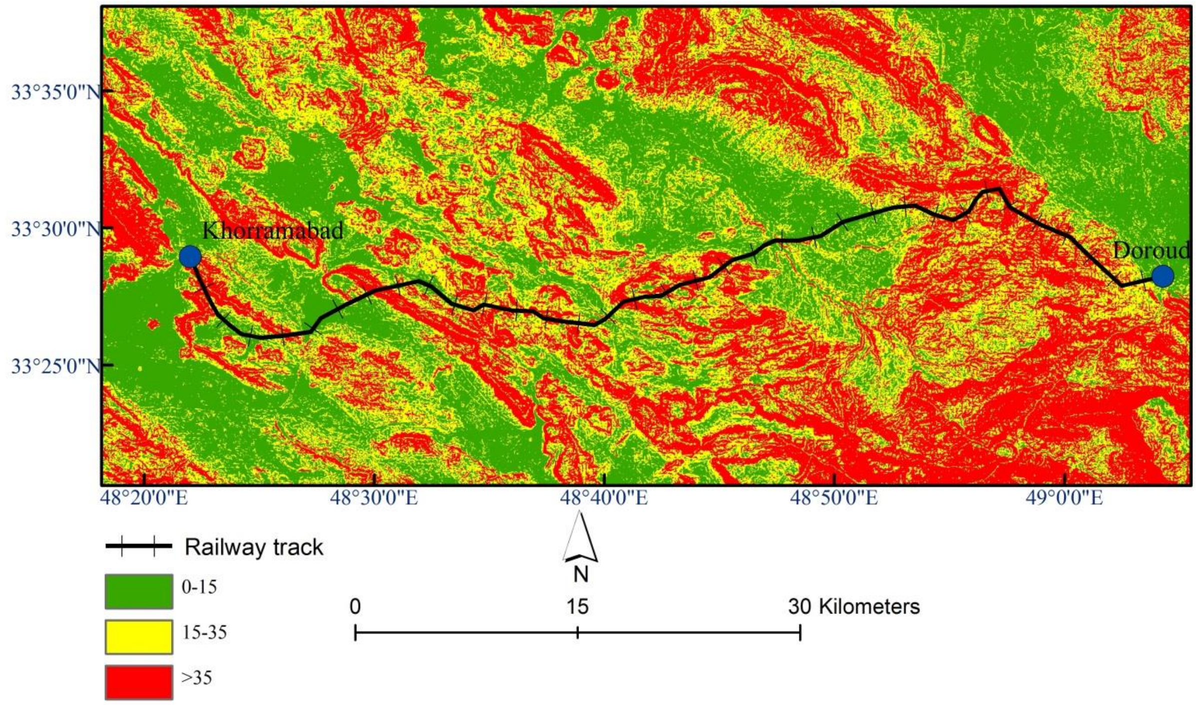

Figure 5) Slope map of the area.

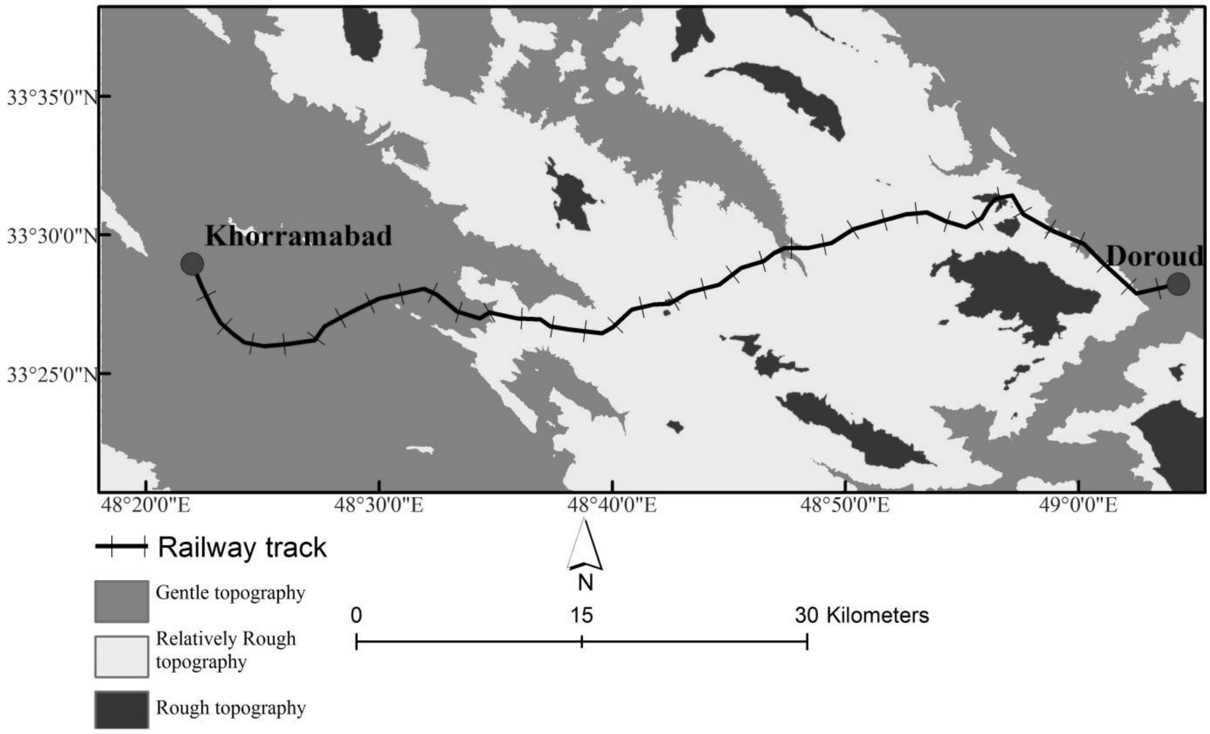

Figure 6) The Related relief map of the area.

5- Lithology

The shear strength of a material depends on the texture and fabric of that material. Different formations possess different shear strengths and as a result they have various mechanical behaviors in occurrence of rock falls and landslides (Carrara *et al.*, 1999; Chung *et al.*, 1999; Guzzetti *et al.*, 1999). The stronger rocks give more resistance to the driving forces as compared to the weaker rocks, and hence are less prone to landslides. The lithological units were extracted from 1:100,000 geological maps of digitized maps. The lithological map of the studied area is shown in Figure 2. The instability features were allotted to each category of lithological maps is presented in table 2. These attributes were allotted to each lithological unit according to the mono axial and three axial strength experimental analyses which had carried out before in the area.

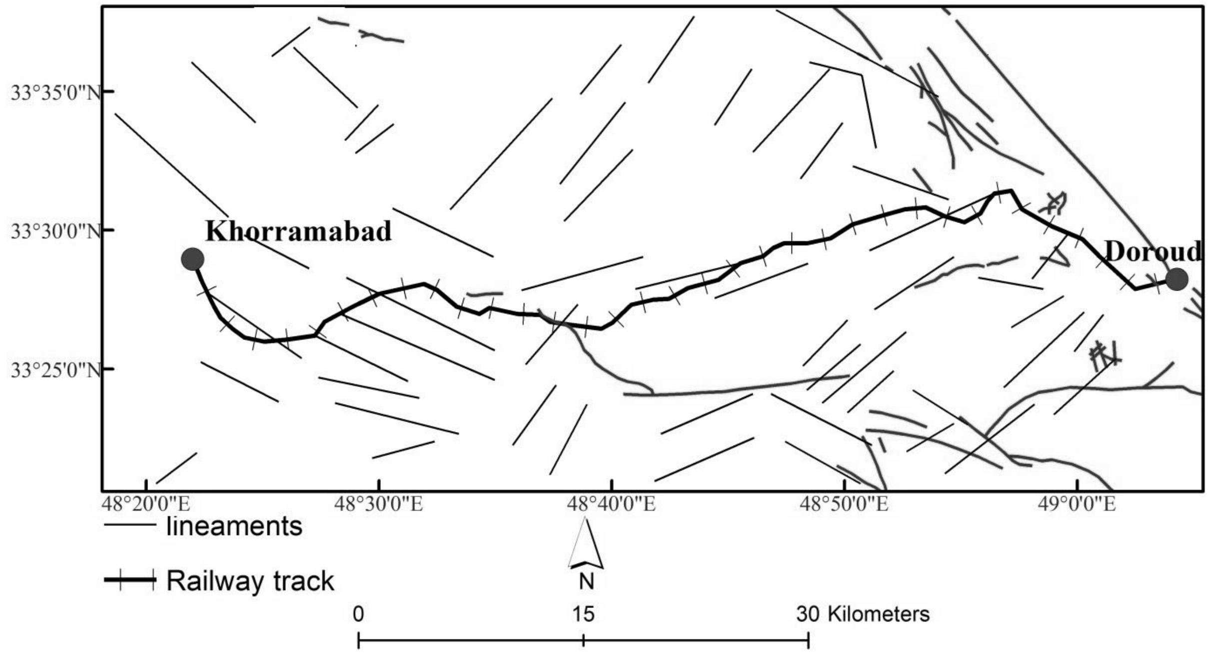

Figure 7) The structural features map of the area

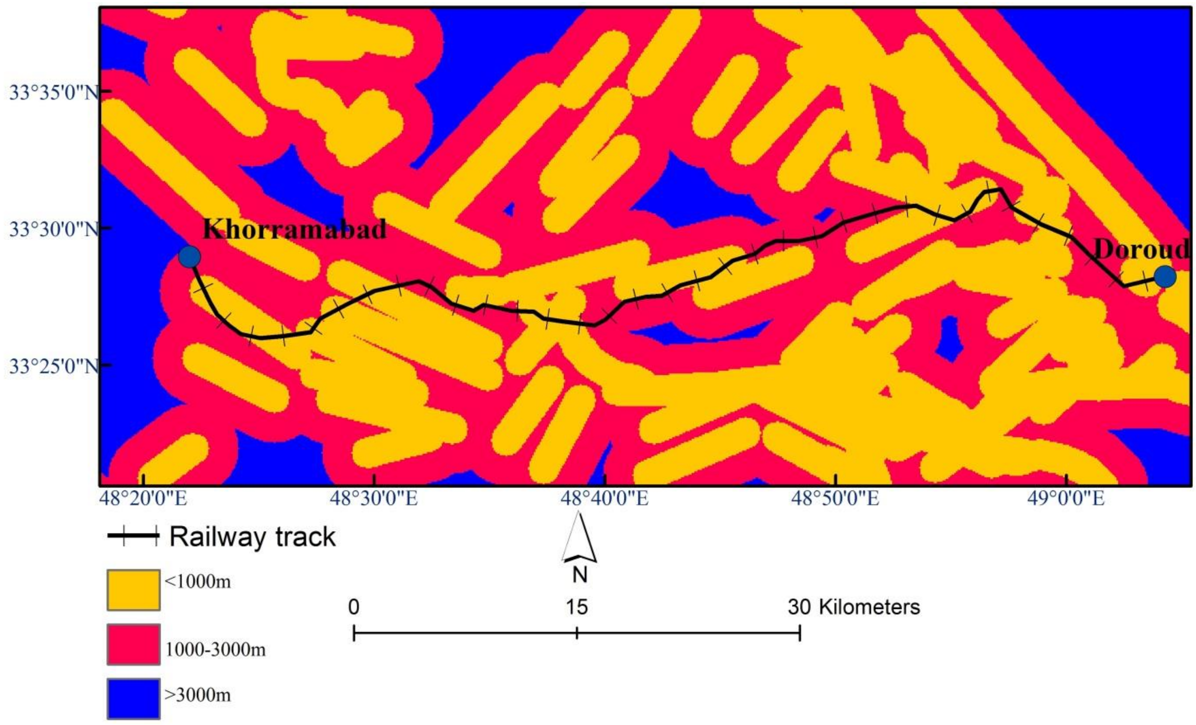

Figure 8) The buffer map of structural features.

6- Structural features

Lineaments are the structural features which describe the zone of weakness, fractures along which landslide susceptibility is higher. It has generally been observed that the probability of landslide occurrence increases at places adjacent to faults and lineaments, which not only affect the surface material structures but also make contribution to terrain permeability causing slope instability; moreover the closer places to the faults have experienced higher seismic acceleration intensity (Chauhan *et al.*, 2010). Initially more than 30 lineaments were recognized through either geological map of the area (minor and main faults) or ETM^+ enhanced imageries (Other lineaments). Abrupt relief change, sharp tonal contrast and straight drainage courses were some key features of interpretation of satellite imageries, in order to identify lineaments. The structural features data layer which includes faults, fractures, and trust zones is demonstrated in Figure 7. The structural features buffer map was created with three different categories of a: 0-1000m, b: 1000-3000m and c: more than 3000m. The base of this classification was the frequency of landslides and epicenters of earthquakes. This thematic data layer is shown in Figure 8.

Table 2) The Thematic data layers' rank and weighting.

Theme	Weight(w_i)	Features	Rank (r_i)
Slope angle	6	<15° 15-35 >35°	Null 5 10
Drainage density	5	High Moderate Low	10 5 Null
Adjacency to Structural features	4	<1000m 1000-3000m >3000m	10 5 Null
Lithology	3	Jurrasic Marls and Limestone	1
		Lower cretaceous Thin bedded limestone, Upper cretaceous marly blue limestone, Amiran Formation	2
		Kashkan formation, Asmari formation	3
		Gachsaran formation, Aghajari formation	4
		Bakhtiari formation	5
		Quaternary deposit, Quaternary alluvial fans	10
Morphology (Related Relief)	2	Rough topography	10
		Relatively rough topography	5
		Gentle topography	Null
NDVI (Vegetation)	1	Barren Dense Moderate Low	10 Null 3 5

7- Drainage network

The drainage network in hilly areas often creates valleys. These valleys are vulnerable places for a mass movement of embedded steep slopes. While the water passes through an area, it washes surface coarse material. Beside the presence of the lateral pressure, the water desires to penetrate in fine-grained material. These penetrations might cause the entire material to collapse, as the result of the following process. The water presence has a reverse relationship with shear strength of a material, since as the percentage of water increases, the shear strength of the material have a tendency to fall by half with an exponential behavior. According of this fact, the higher accumulation of drainage canals will result in the more water penetration, and consequently the fewer shear strength of the formation.

Drainage density is defined as the total length of drainage network in a basin or area divided by to total surface of basin or area. As mentioned above the areas with higher drainage density are more exposed to mass movements (Chauhan *et al.*, 2010). According to the calculated drainage density values, the area was classified in to three different parts of a: high, b: moderate and c: low drainage density. Figure 9 presents the thematic data layer of drainage density.

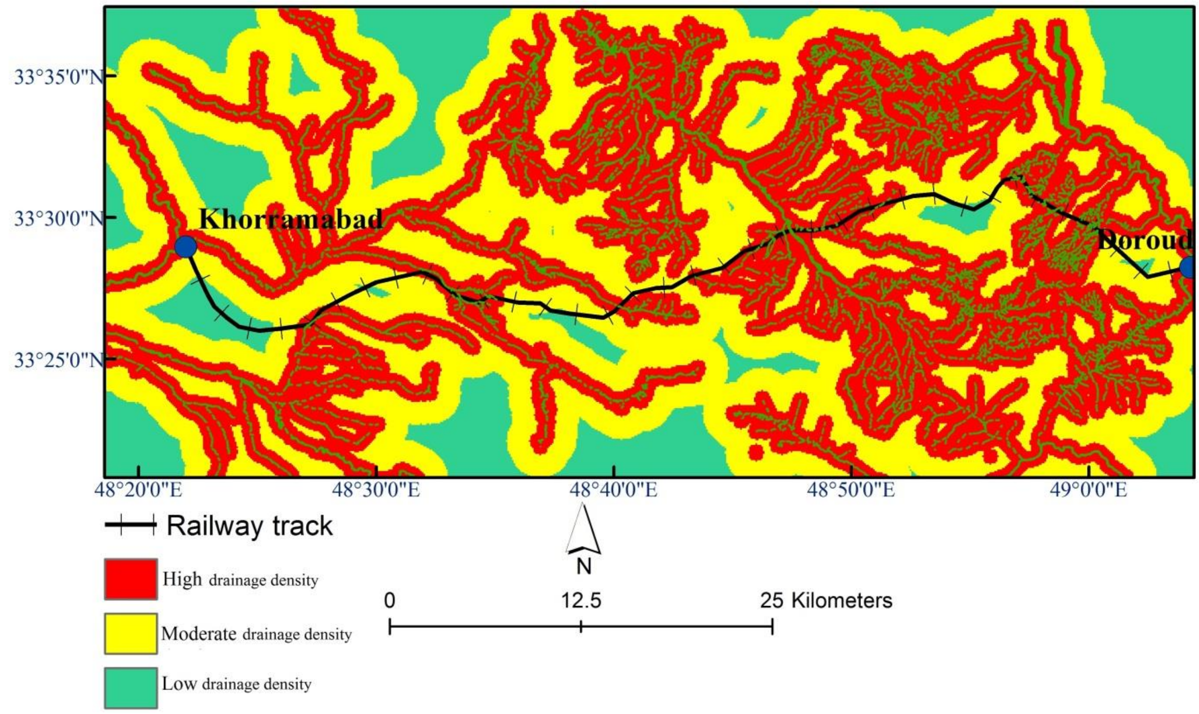

Figure 9) Drainage density map of the area.

7- Vegetation

Vegetation cover plays an important role in controlling erosional and movement activities. It has generally been observed than within deforested areas, the erosional activities have been expanding due to uncovered and exposed soil. One direct result of erosion would be increase in the amount of landslides. So, poor vegetation cover areas are more vulnerable to landslides and vice versa (Ali et al., 2008).

Satellite imageries have provided us with a wide range of applications. One of these applications is identifying the vegetation density. It means that, it is not far-fetch to specify the species of plants in their location.

The Normalized Difference Vegetation Index (NDVI) is a nonlinear transformation of visible and near Infrared bands, which is defined as equation 1:

(NDVI= (Near infrared value – visible value) / (Near infrared value + visible value) *(1*

NDVI is ranged between -1 and +1, where the bigger values are expected to have denser vegetation. While barren areas are generally provided with lower than 0 values (Avtar et al., 2011). In this study visible band was the band 3 of ETM^+ Landsat imageries, and near infrared band was band 4 of it. According to the obtained NDVI values the area was classified in to four zones of a: dense, b: moderate, c: poor vegetation and d: barren areas. The vegetation thematic data layer can be seen in Figure 10.

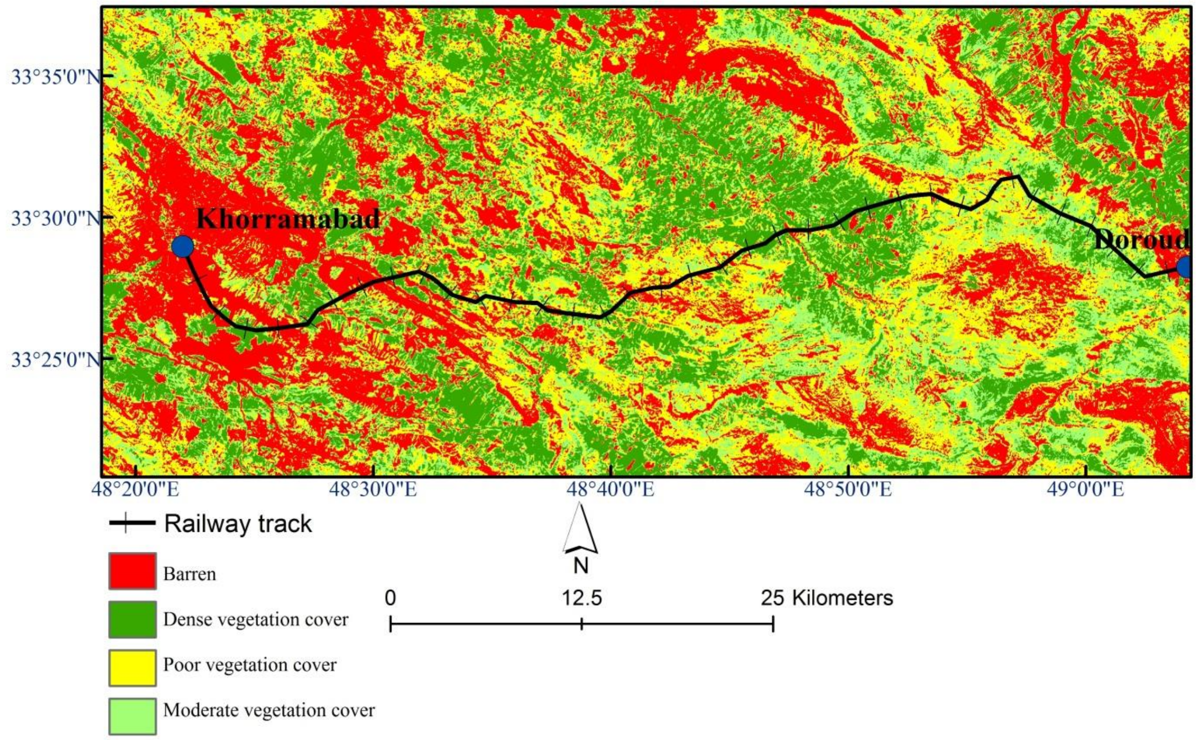

Figure 10) The vegetation cover map of the area.

8- Landslide Inventory map

Landslides were firstly identified by satellite data interpretation. Then field surveying was carried out in order to prove whether these mass movements were recorded correctly (Van Westen *et al.*, 2003). These records were used for checking the accuracy of landslide susceptibility zonation map i.e. the higher susceptible zones are expected to possess more recorded landslides. The landslide distribution data layer can be observed in Figure 11.

9- GIS based Overlay Mapping Method

Lots of authors have used the direct ranking systems for the integration of spatial data (Arnous et al., 2011). This method is the most innovative method of multi criteria decision making systems, besides there is no an exact approach for integration of data set.

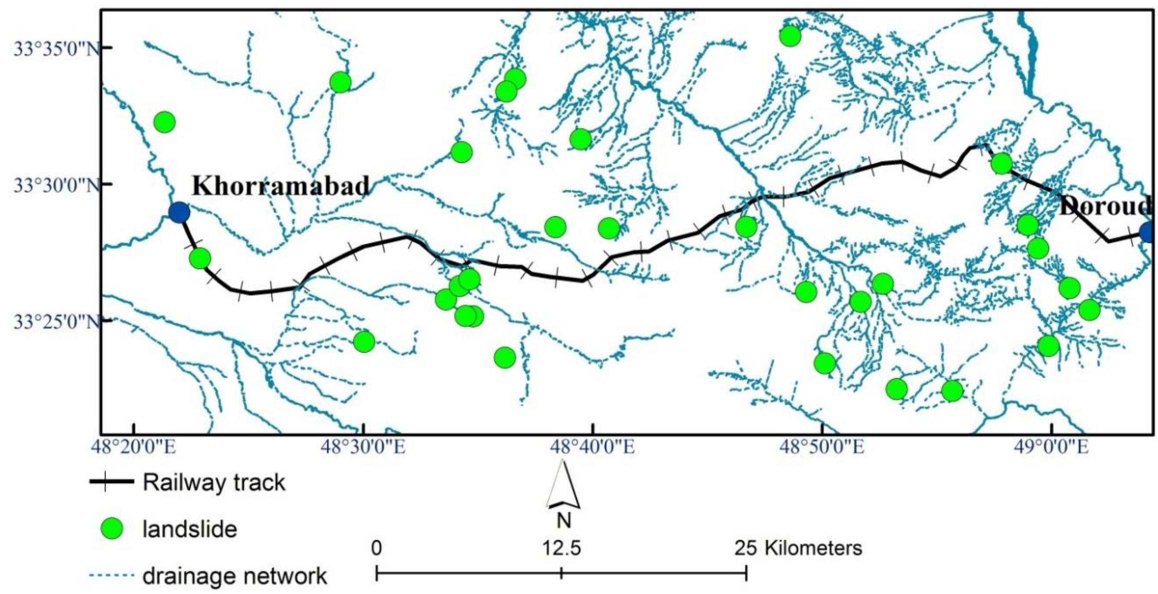

Figure 11) the location of landslides in the study area.

The advantages of overlay mapping system are as follow. Each factor would be ranked according to its importance. The alternation of casual factor's weight is easy. Moreover the method and its calculations are simple. There are also some disadvantages as there are no exact method for the ranking of factors and sub-factors (Arnous et al., 2011).

After production of thematic data layers, respecting to the scope of this study, they were resampled by the cell size of 250 meters. Then according to their influence to landslide they were arranged in a hierarchy order from 1 to 6, where the bigger number, shows an area with higher vulnerability to mass movements. In this study the slope angle was considered as the most crucial factor in occurrence of a landslide in the area, and accordingly the biggest integer rate (6) was allotted to this factor. The sub-factors which are categorizes of each factor, were also arranged in order, according to their influence to mass- movements. The weight of each causative factor and the rate of each class are shown in table 2. Landslide index values were computed by the equation 2:

$$LSI = \sum_{i=1}^{6} w_i \times R\acute{\imath} \qquad (2$$

Where the wi is the weight of each casual causative factor and the ri is the rate of each sub- factor and LSI is the landslide susceptibility value, which was calculated for each pixel.

Table 2) The Thematic data layers' rank and weighting.

The higher the LSI, the greater the susceptibility and vulnerability to ground mass movements. The landslide Susceptibility index obtained ranged from 6 to 162, as it is presented in table 3. These values could be classified into several susceptibility zones depending on the engineering judgments. One of the most common used approaches for categorization of such values is to highlight abrupt and instantaneous changes in the values. In this method of classification, class breaks were identified that best group similar values and that maximize the differences between classes. The features were divided into classes whose boundaries were set where there were relatively big differences in the data values. This classification is based on the Jenks' Natural Breaks algorithm. This is done by seeking to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other groups. In other words, the method seeks to reduce the variance within classes and maximize the variance between classes (Jenk., 1976). Hence respecting to the natural breaks of LSI values, the area was classified into five different classes of instability including, critical, highly unstable, moderately unstable, moderately stable and stable zones (Carrara et al., 1999; Arnous et al., 2011). The Figure 12 illustrates the frequency of each class cells and table 4 shows percentage of surrounded area of each class in the map. The Landslide Susceptibility obtained map is presented in Figure 13.

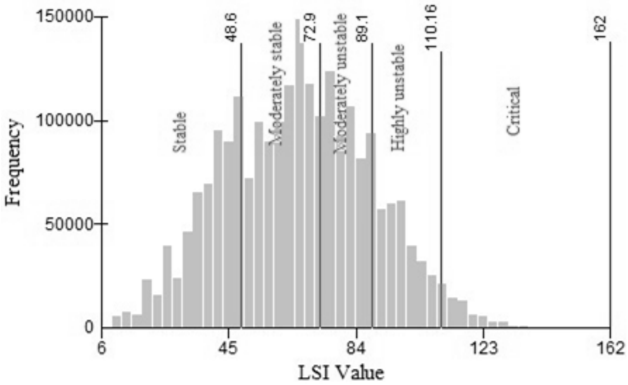

Figure 12) Susceptibility classes of LSZ map.

Table 3) Statistics of LSI values.

Frequency of Pixels	Min	Max	Mean	Standard deviation
2277357	6	162	67	23

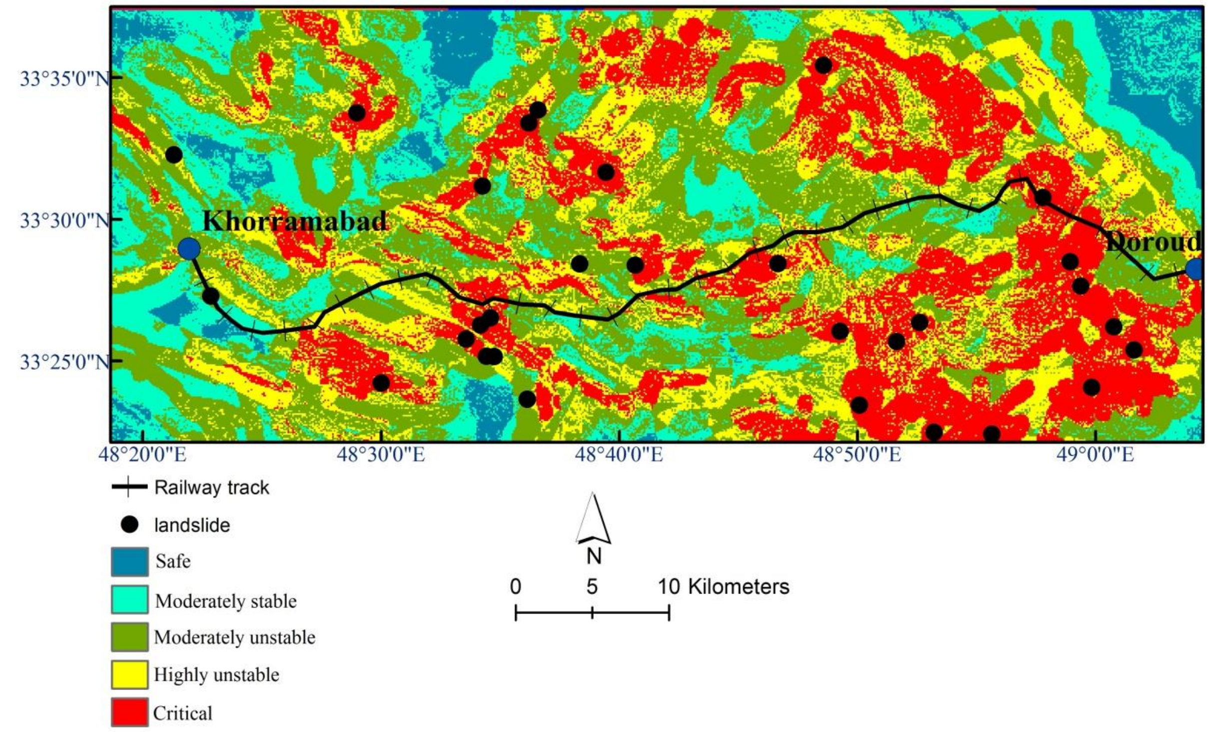

Figure 13) Landslide Susceptibility Zonation of the area under investigation.

Table 4) percentage of surrounded area of each class in LSZ map

Landslide Susceptibility Classes	critical	highly unstable	Moderately unstable	moderately stable	stable
Percentage of surrounded area	2.5	14.3	24.5	35.6	23.2

10- Discussion

The Landslide susceptibility obtained map, was checked in the field. It was observed that critical and highly unstable classes were exposed to the slope instability, landslides and erosion.

To facilitate the validation, statistical analyses were performed. The obtained LSI map was evaluated regarding to the distribution of recorded landslides in the area (Chauhan et al., 2010). Sixty percentages of landslides were randomly selected for testing the accuracy of LSZ map. Landslide density is the surface of recorded mass movements divided by the surface of area. The computed landslide density values for each pixel are presented in table 5.

Table 5) landslide density for each class

Landslide Susceptibility	area (Km^2)	surface of recorded Mass movements (Km^2)	Landslide density×100
Critical	60.4	6.4	10.6
Highly unstable	342.8	5.8	1.69
Moderately unstable	589.5	3.7	0.63
Moderately stable	856.2	1.9	0.22
Safe	558.4	0.8	0.14

Usually, an ideal LSZ map should have the highest landslide density for very high susceptible zones (critical) as compared to other zones, and there ought to be a decreasing trend of landslide density values successively from critical to very low susceptible zone (safe). It may be observed that the landslide density for critical zone of LSZ maps is higher than that obtained for other susceptibility zones. The Landslide densities for safe, moderately stable, moderately unstable, highly unstable and critical zones are 0.014, 0.022, 0.063, 0.169 and 1.06. This demonstrates a gradual increase in landslide density amounts from the lower to the higher LSI values (Sarkar et al., 2004).

Further, to see the effectiveness of the susceptibility map, a statistical significance chi-square test was performed. For the null hypothesis, it was assumed that the number of land-slide cells present in the susceptibility classes was purely due to chance. The observed cells with and without landslides for each of the five classes were determined from the map, and the expected cells for the same were estimated from the observed values (Table 6). The chi-square value computed for the above data is 7.16 with a probability of 0.05. The standard chi-square value with four degrees of freedom at the 0.05 significance level is 9.49. Thus, the null hypothesis could be rejected and the susceptibility map could be considered as statistically significant (Sarkar et al., 2004).

Table 6) observed and expected values for the chi-square test

	Observed					**Expected**				
	Safe	Moderately Stable	Moderately Unstable	Highly Unstable	Critical	Safe	Moderately Stable	Moderately Unstable	Highly Unstable	Critical
Pixels with landslide	970	2467	2852	4108	4437	740.023	1782.831	3514.6	3467.2	6059.91
Pixels without landslide	527618	807911	555025	320237	52732	527847.9	808595.16	554362.3	320877.8	51109.08
Total Pixels	528588	810378	557877	324345	57169	528588	810378	557877	324345	57169

The characterizations of each class are given as below:

Critical zone is a very unstable zone where landslides are likely to occur. The area is degraded to such a state that it is practically impossible to evolve economically and socially acceptable remedial measures which can positively prevent recurrence of the hazard. The area has to be entirely avoided for railway track or other development purposes and preferably left to allow regeneration of natural vegetation and attainment of natural stability in time through the physical processes active in the area (Varnes., 1984).

Highly Unstable Zones are prone to land sliding. Terrain setting is comparable to the critical zone and in many cases the landslides initiated in the critical zone will affect this zone also. The area needs urgent attention in the form of migratory measures like regeneration of natural vegetation, reforestation, drainage correction, restriction of seasonal tilling activity and contour bonding to ensure proper drainage etc. Unless immediate action plans are implemented this zone will soon deteriorate to the critical zone (Varnes., 1984).

Moderately Unstable zones are areas which are stable in the present condition but future land use activity must be planned to maintain its present status. However, if natural drainage is disrupted landslides could be triggered (Varnes., 1984).

For all practical purposes Moderately Stable Zones are safe from mass movements by virtue of its present geo environmental set up. However, many slopes falling within this zone could be destabilized by uncontrolled erosion, improper land use practices and development activities (Varnes., 1984).

Stable zones where no restrictions are warranted as reasonable human activity of any form do not possibly threaten the balance (Varnes., 1984).

There are some suggestions for reducing landslide risks as introduced by Die et al. (2002). The first approach would be the modification of slope geometry. This method is based on either removing unstable material or adding supplementary material in order to flatten the slope gradient. Despite of its benefits, this method might adversely affect the area, since the morphology of a slope is too complicated and is not well-known. Another negative aspect of the method is the high cost.

Another approach for stabilizing the slopes would be controlling of the water pressure. Surface water often penetrates in the imbedded soil's texture, which leads to reducing the shear strength of the imbedded material. Designing the underground drainage networks and pumping wells would be effective in decreasing the volume of surface water. The underground drainage system should have the capacity to decrease pore water pressure at the failure surface (Die et al., 2002).

Placing retaining structures can also lead to reinforce the slope's material. These structures include gabion walls, passive piles and etc. Type and size of these structures is the function of the geometry of the area, dimension of the area, the type of the landslide which is likely to develop and foundation conditions (Die et al., 2002).

The landslide susceptibility maps help in decision making, while implementing the railway project. It is always better to avoid the critical and highly unstable zones but, if not possible, corrective measures must be worked out to minimize the probability of landslide occurrences (Sarkar et al., 2004).

10- Conclusion

The initial design of civil engineering formations highly requires safety investigations. Landslide and rock fall hazard assessments are one step of site selections. In this paper an integrated remote sensing and GIS approach was used in order to assess slope instability potential in the Khorramabad - Doroud railway track, which is known as a landslide prone area. A lot of field and office works were carried out to prepare the data layers. The various thematic layers were resampled by the cell size of 250m. Then, they were arranged in hierarchical order of importance and a weighting number given to each layer in a scale of 1 to 6. Then, the data layers were infused according to their weighting order. A LSZ map was produced which divided the area in five different zones of landslide susceptibility. For validation of results, field observations and statistical analyses were carried out. Validation's highly approved the accuracy of results.

Acknowledgments:

The authors would like to thank Dr. M.H. Vahidnia, Dr. M. Kurdi, Dr. C. Irigaray, and Dr. F. Hosseinali for their appreciate comments which help us to improve manuscript.

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