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DETERMINATION OF AREAS WITH HIGH LANDSLIDE RISK IN THE PROVINCE OF KILIS (TURKEY) BY MULTI-CRITERIA DECISION MAKING METHOD

Abstract

In countries that show spatial variety over short distances such as Turkey, wrong-unconscious land use practices increase the number and impact area of disasters which cause life and property losses. Landslide is one of these disasters. In this study, we produced base maps for the Province of Kilis using GIS and remote sensing methodologies. Base maps in question were created taking parameters effective in the event of landslide into account. The research results showed that 14% of the Province of Kilis, in the west and northwestern of it in particular, had very high-high landslide risk. In this context, local administrators should consider, during land use planning, these sites where the landslide risk is high-very high. Otherwise, possible landslides may cause losses of life and property. In addition, the foundation of "the Natural Disaster Planning Center of the Province of Kilis" would be a positive step.

Keywords: GIS, Natural Disaster Planning, Landslide Susceptibility Classes, Kilis, Remote Sensing.

KİLİS İLİ'NDE HEYELAN RİSKİ YÜKSEK ALANLARIN ÇOK KRİTERLİ ANALİZ METODU İLE BELİRLENMESİ

Öz

Türkiye gibi kısa mesafelerde mekânsal açıdan çeşitlilik gösteren ülkelerde yanlış ve bilinçsiz arazi kullanım uygulamaları can ve mal kaybına neden olan afetlerin sayısını ve etki alanını artırmaktadır. Bu afetlerden birisi de heyelandır. Herhangi bir alanda heyelan duyarlılık sınıflarını belirlenmesi oldukça önemlidir. Bu çerçevede çalışmamızda CBS (Coğrafi Bilgi Sistemleri) ve uzaktan algılama metodolojileri kullanılarak Kilis İline ait altlık haritalar üretilmiştir. Söz konusu altlık haritalar, heyelan olayında etkili olan parametreler göz önünde bulundurularak oluşturulmuştur. Araştırma sonuçları Kilis İli'nin % 14'lük bir kısmında özellikle batısı ve kuzeybatısında heyelan riskinin çok yüksek ve yüksek olduğunu göstermektedir. Bu çerçevede yerel yöneticilerin arazi kullanım (yerleşim, tarım vb.) planlaması yaparken heyelan riskinin çok yüksek ve yüksek olduğu bu sahaları göz önünde bulundurmaları gerekmektedir. Aksi takdirde yaşanacak heyelanlar, can ve mal kaybına sebep olabilecektir. Bunlar yanında interdisipliner bir perspektife sahip "Kilis İli Doğal Afet Planlama Merkezi" kurulması olumlu bir adım olacaktır.

Anahtar kelimeler: CBS, Doğal Afet Planlaması, Heyelan Duyarlılık Sınıfları, Kilis, Uzaktan Algılama.

1. Introduction

The rapid and unconscious use of natural resources or ignoring the operation of laws and systems of nature lead to an increase in the number and impact area of disasters (Gülersoy, 2008; Esen, 2016). Indeed, residential areas grow rapidly due to the rapid increase in the population. Residential areas move away from their initial location and spread to areas containing various risks due to unplanned and rapid urban growth (Guzzetti, 2005; Değerliyurt, 2014). In a country which shows geological, geomorphologic and climatologic variety over short distances such as Turkey, disasters become inevitable if cities are not planned properly. Indeed, Turkey's history of natural disasters shows a very high risk for disasters which may cause losses of life and property. Landslide is one of these disasters that pose a threat for Turkey. In general, a landslide is the break and displacement of masses formed by rocks, debris mantle or soil with the influence of gravity. Mass movements usually expressed with the term 'landslide' fall under three categories: actual landslides, collapses and land slips (Erinç, 1982; Keefer et al., 1987; Cruden, 1991; Cruden and Varnes, 1996; Ünal, 2000; Huggett, 2011; Lutgens, Tarbuck and Tasa, 2011). Landslide risk analysis aims to determine the expected degree of loss due to a landslide and the expected number of live lost, people injured, damage to property and disruption of economic activity (Varnes, 1984). It is possible to classify factors determining the landslide hazard as intrinsic variables (geology, slope angle and direction, geotechnical properties of soil, vegetation and long-term drainage forms) and extrinsic variables (heavy rainfall, earthquakes) (Varnes, 1984; Dai, Lee, Li and Xu, 2001; Dai, Lee and Ngai, 2002). Landslide is one of the most common natural disasters in the world and in Turkey. According to the recent research, 46% of natural disasters in the world are floods, 26% are hurricanes and 10% are landslides (CRED, 2010; Akıncı, Doğan, Kılıçoğlu and Keçeci, 2010). It is noteworthy that the most common natural

disaster in Turkey is landslide according to the disaster profile of Turkey covering the last 50 years (Şahin and Sipahioğlu, 2007; Gökçe, Özden and Demir, 2008; Akıncı et al., 2010; Dağ and Bulut, 2012; Özşahin and Kaymaz, 2013).

Today, evaluations and map productions aimed at landslide risk analysis are usually performed in the GIS environment. The use of GIS software in studies related to landslide provides great conveniences (AFAD, 2015). In this context, the most preferred method is the generation of susceptibility maps. The qualitative and quantitative landslide susceptibility methods for susceptibility assessments are inventory, bivariate, multivariate, probabilistic frequency ratio, logistics regression, fuzzy logic, such as AHP, probabilistic frequency and artificial neural network analysis (Westen, 1997; Dai et al., 2001; Lee and Min, 2001; Ercanoglu and Gokceoglu, 2004; Lee, 2005; Pradhan, Singh and Buchroithner, 2006; Dahal et al. 2008; Sarkar, Kanungo, Patra and Kumar, 2008a; Sarkar and Anbalagan, 2008b; Dwikorita et al., 2011). At the same time various studies on landslide susceptibility analyses and maps were conducted in the world and in Turkey using Geographic Information Systems and Remote Sensing (Carrara, 1983; Aleotti and Chowdhury, 1999; Guzzetti, Carrara, Cardinali and Reichenbach, 1999; Lee, Chwae and Min, 2002; Dai and Lee, 2002; Westen, Rengers and Soeters, 2003; Lee and Talib, 2005; Ayalew and Yamagishi, 2005; Yesilnacar and Topal, 2005; Guzzetti, Reichenbach, Cardinali, Galli and Ardizzone, 2005; Lee and Sambath, 2006; Akgun, Dag and Bulut, 2007; Nefeslioglu, Gokceoglu and Sonmez, 2008; Yilmaz, 2009; Pradhan, Lee and Buchroithner, 2010; Pradhan, 2010a; Pradhan, 2010b; Pradhan and Lee, 2010; Bai et al., 2010; Yalcin, Reis, Aydınoglu and Yomralıoglu, 2011; Oh and Pradhan, 2011; Mohammady, Pourghasemi and Pradhan, 2012; Pourghasemi, Mohammadya and Pradhan, 2012; Bui, Pradhan, Lofmani Revhaug and Dick, 2012; Özdemir and Altural, 2013; Regmi et al., 2014; Shahabi, Khezri, Ahmad and Hashim, 2014; Gorsevski et al., 2016).

Above mentioned studies aim to detect hazardous and risky sites from maps generated, to mitigate effects of landslides and to make estimations related to potential sites where the same event would reoccur in future. In this context, we produced base maps for the Province of Kilis using GIS and remote sensing methodologies in this study. Base maps in question were created considering parameters effective in the event of landslide. The produced base maps were superposed in GIS environment and the landslide susceptibility map for Kilis was obtained. The landslide susceptibility map produced can actively serve in decision-making mechanisms for many institutions and organizations in the Province of Kilis. In this way, hazards due to landslides will be prevented in the Province of Kilis. At this point, it should be remembered that unplanned, random establishment and development of settlements may cause a natural event to turn into a natural disaster causing losses of life and property.

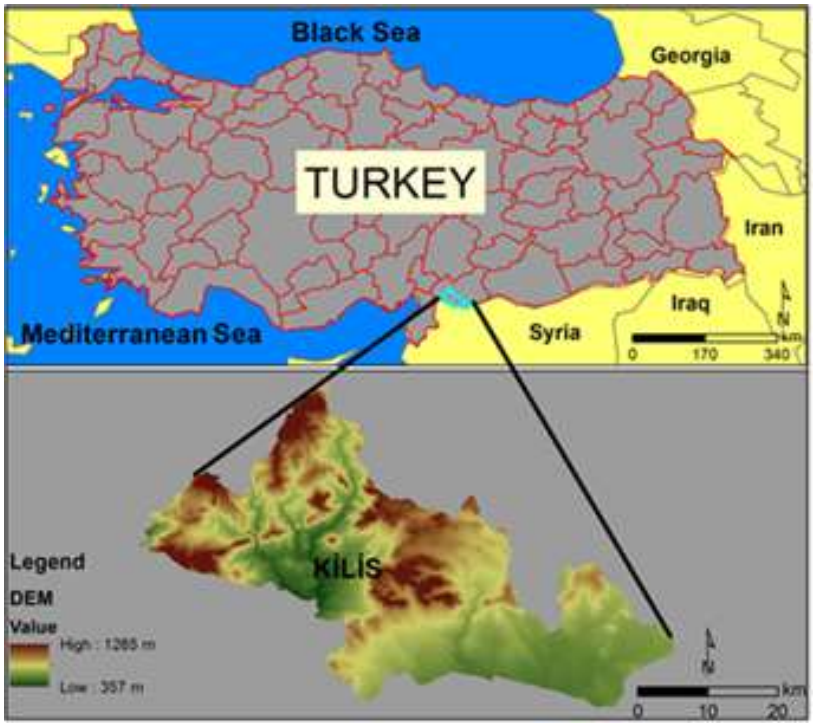


Figure 1. Location map of the Province of Kilis.

2. Location and General Properties of The Study Site

Surrounded by the Mediterranean Region, the Southeastern Anatolia Region and the Syria border in the South, the study site is located on the transition zone among the Mediterranean, steppe and arid climate regions (Figure 1). Therefore climate, vegetation, slope and geological and geomorphologic properties vary over short distances, which affect the level of landslide risk in the study site. Also, the said situation yields different risk values related to landslide occurrence in Kilis, which is not homogeneous in terms of natural environment conditions (Sönmez, Çelik and Seven, 2013).

3. Material and Method

This study followed two steps to produce a landslide susceptibility map. In the first step, a field survey was performed in eastern and western parts of the Province of Kilis. In field surveys, photographs were taken in the areas where landslides occur and their coordinates were obtained with GPS. Also, crown and heel sections of landslide in the area were drawn for accuracy assessment. Drawing crown and heel sections of landslide is important for reliability of the landslide susceptibility map. In other words, the accuracy assessment was obtained by superposing crown and heel sections of landslide with the susceptibility map.

The second step of the study was office work. The first part of the office work consisted of data provision. The data obtained consist of the downloaded satellite images, the 1/25000 scale topographic map obtained from the General Command of Mapping (GCM) and detailed analysis of studies performed previously on the subject. The 1/25000 scale data of the General Command of Mapping related to the Province of Kilis were digitized in the GIS environment. Digitized contour data were applied to spatial analysis. Curvature, DEM, slope, aspect and geomorphology maps were generated as a result of the spatial analysis. Finally, sheets of 1/25000 scale

geological maps were digitized. Each of the digitized geological maps was used as input for the landslide susceptibility map (Figures 2, 3a-b-c-d).

MODIS satellite image of the year 2014 was used to present land cover density of Kilis. *ISO-DATA* method was applied to the satellite image of the year 2014 in uncontrolled classification in order to measure closure condition of land cover. As a result of accuracy analysis of land use, high accuracy ratio with a kappa coefficient of 0.91 was obtained. In the study area, exposed (open) or closure state of the land in terms of vegetation was addressed in two different categories: a) bare vegetation (non-vegetation), b) bushy and forestry areas (vegetation).

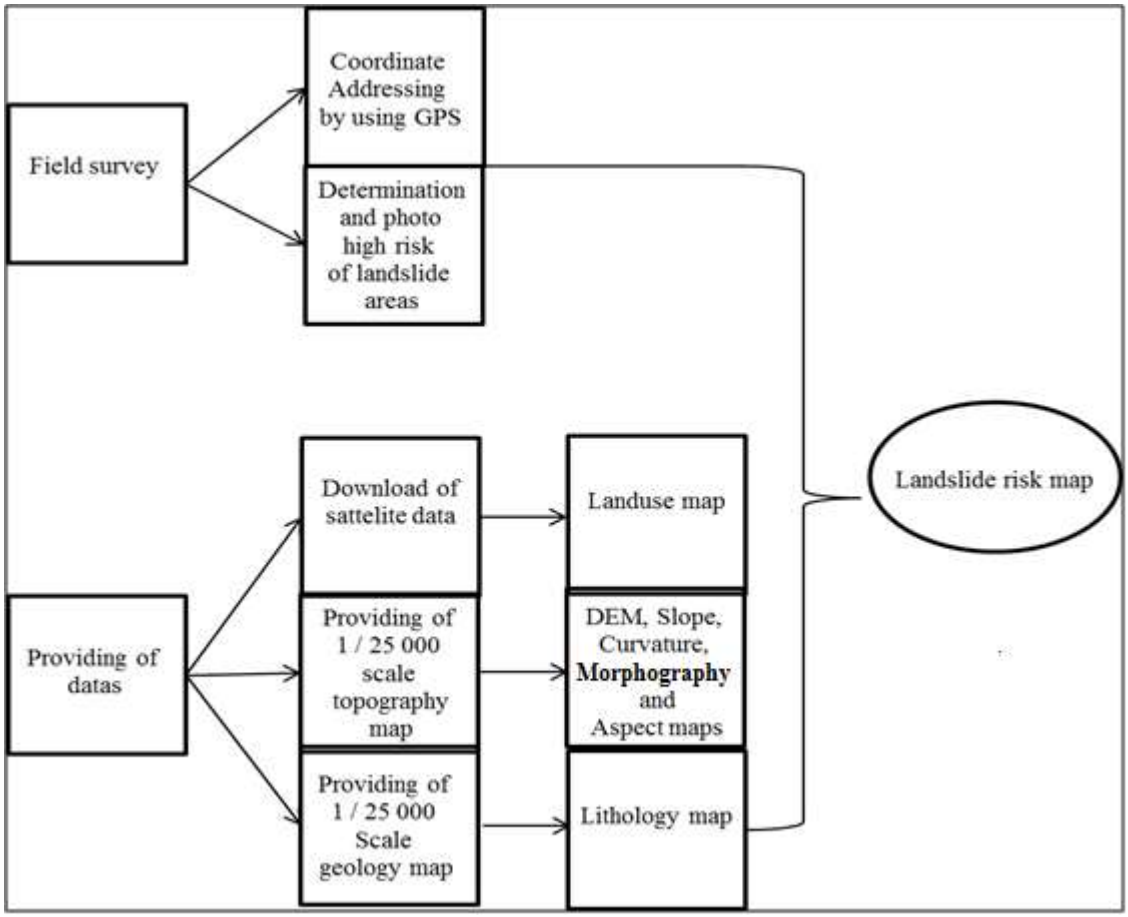


Figure 2. Flow chart of the study.

Landslide risk map of Kilis Province was produced to take the landslide risk into consideration in the works of land use intended for settlement, transportation and agriculture (farming), or of planning. In our study, Multi-Criteria Decision Making Method was used (Guitouni and Martel, 1998; Khadam and Kaluarachch, 2003; Liu and Stewart, 2004; Loken, 2007; Qin, Huang, Chakma, Nie and Lin, 2008; Ambrasaite, Barfod and Salling, 2011; Demirel and Tüzün, 2011; Zhang, Li and Fung, 2012; Velasquez and Hester, 2013; Gülersoy and Çelik, 2015). Landslide risk map created with the said method was produced on GIS platform. In order for this map to be able to produce, parameters of slope, morphography, aspect, lithology, altitude, vegetation density effective over landslide were used. At first, GIS class values of these parameters were assigned according to influence values within themselves, and later, their degrees of influence were determined according to GIS weight values within the erosion risk. In the final analysis,

each one of parameters effective in the landslide was rendered into raster and superposing operation was performed by *Raster Calculator* option (Chart 1; Figures 3a-b-c-d-e-f-g).

Chart 1. GIS classes and weight values of layers used as base for determination of landslide susceptibility classes in the province of Kilis.

Base	Class Value	GIS weight value	Base	Class Value	GIS weight value
Lithology	1	8	Morphography	1	5
	3			3	
	5			5	
Slope	1	7	Vegetation	1	4
	2			5	
	3		Aspect	1	3
	4			3	
Curvature	1	6		5	
	2		DEM	1	2
	3			2	
	4			3	
	5			4	
	6			5	
				6	

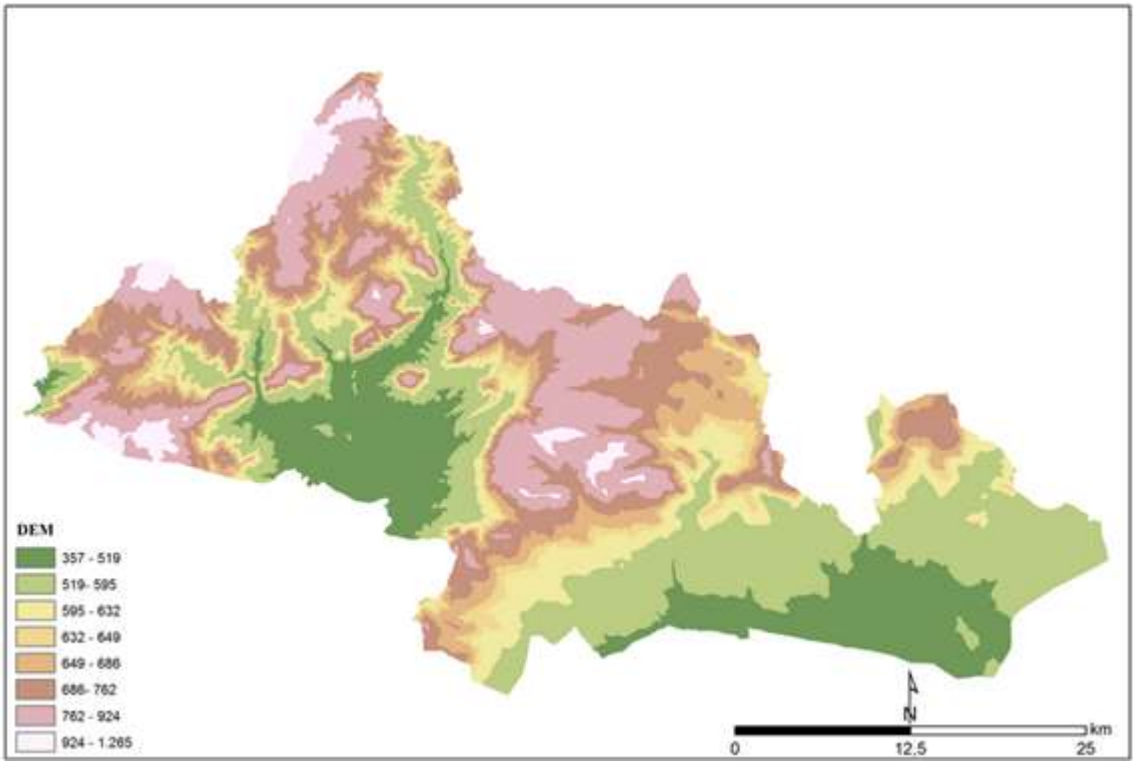


Figure 3a. DEM layer used as base for determination of landslide susceptibility classes in the province of Kilis.

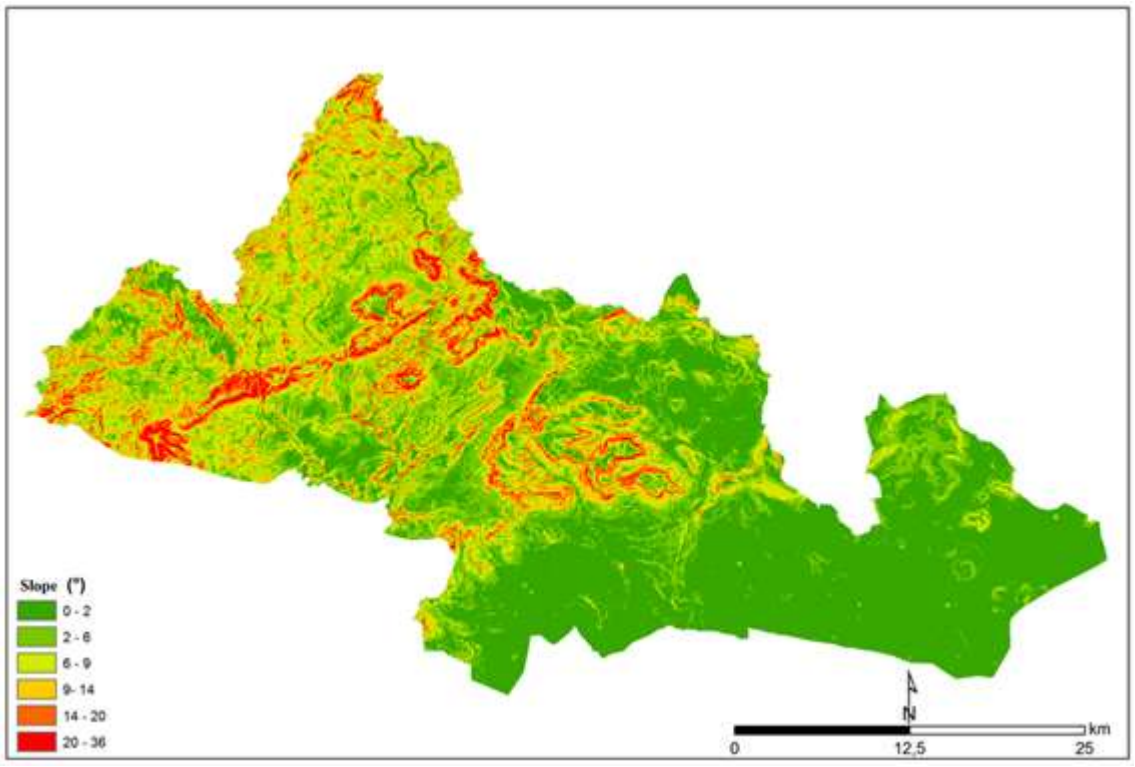


Figure 3b. Slope layer used as base for determination of landslide susceptibility classes in the province of Kilis.

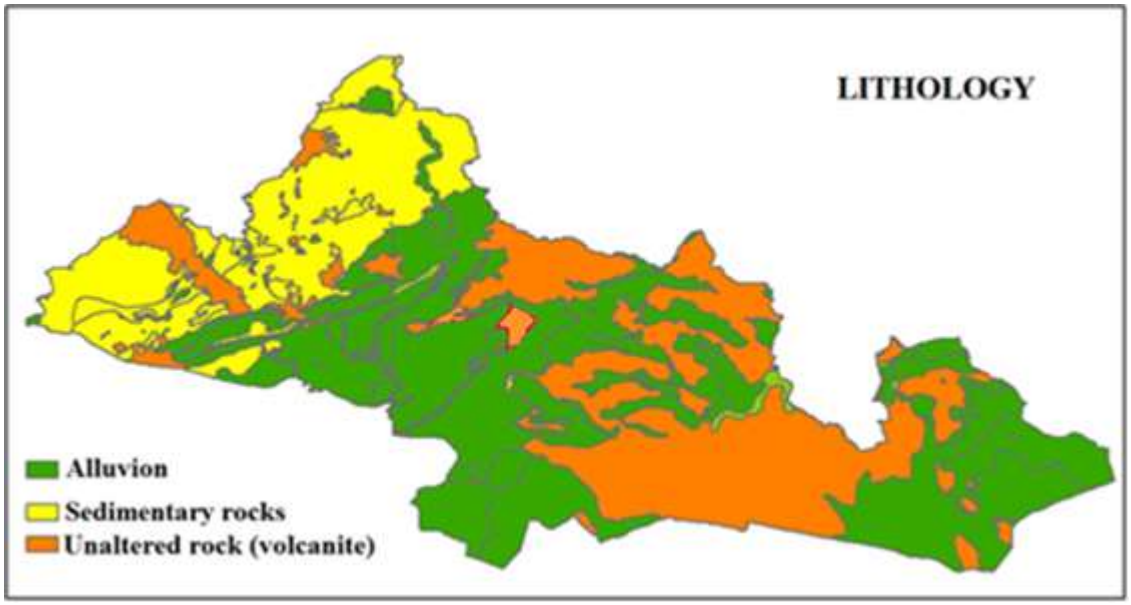


Figure 3c. Lithology layer used as base for determination of landslide susceptibility classes in the province of Kilis.

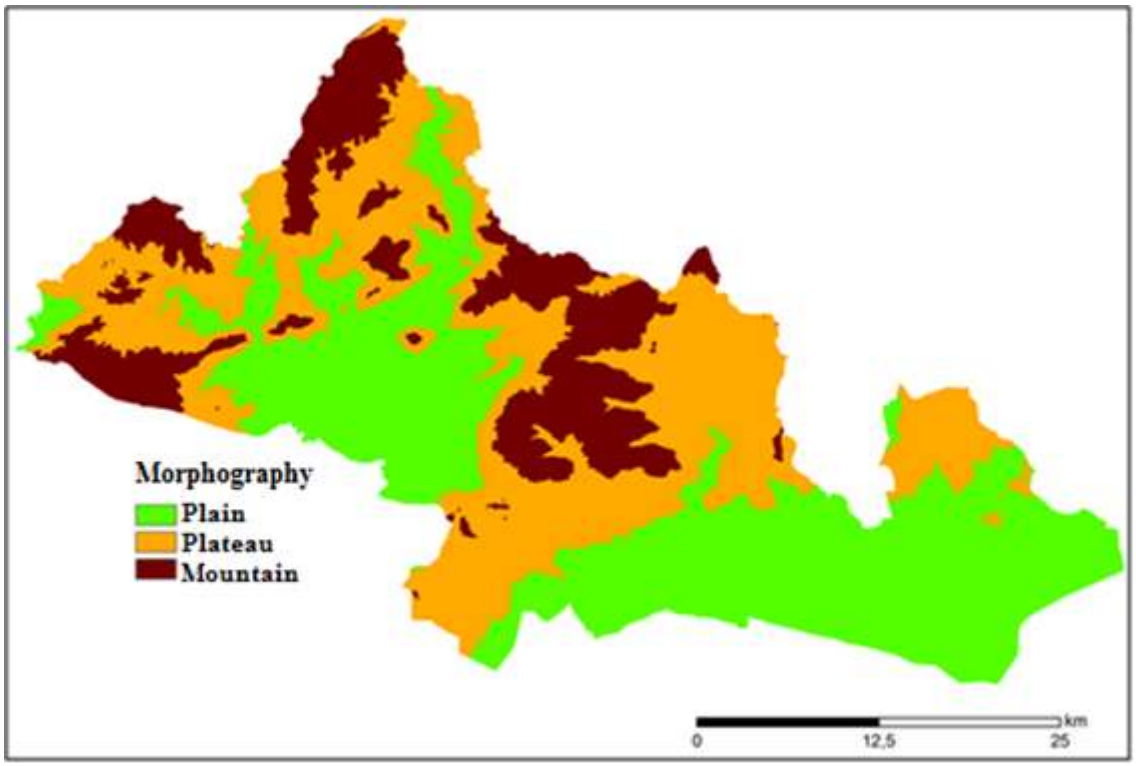


Figure 3d. Morphography layer used as base for determination of landslide susceptibility classes in the province of Kilis.

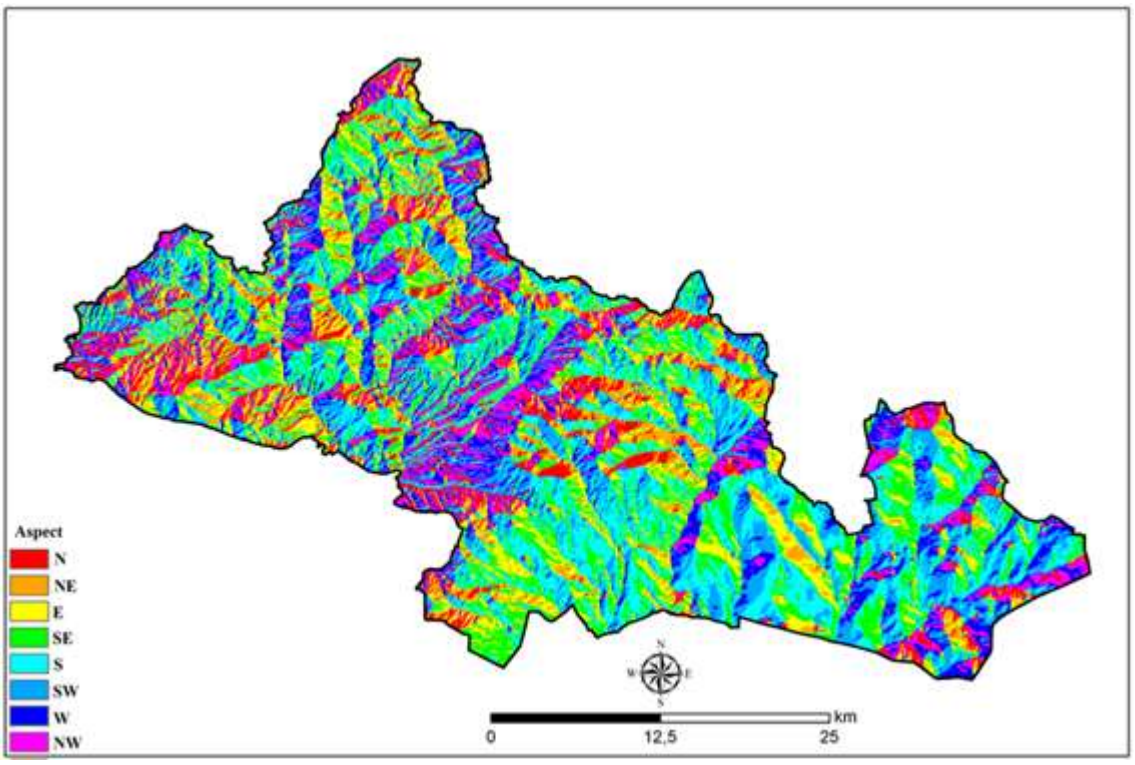


Figure 3e. Aspect layer used as base for determination of landslide susceptibility classes in the province of Kilis.

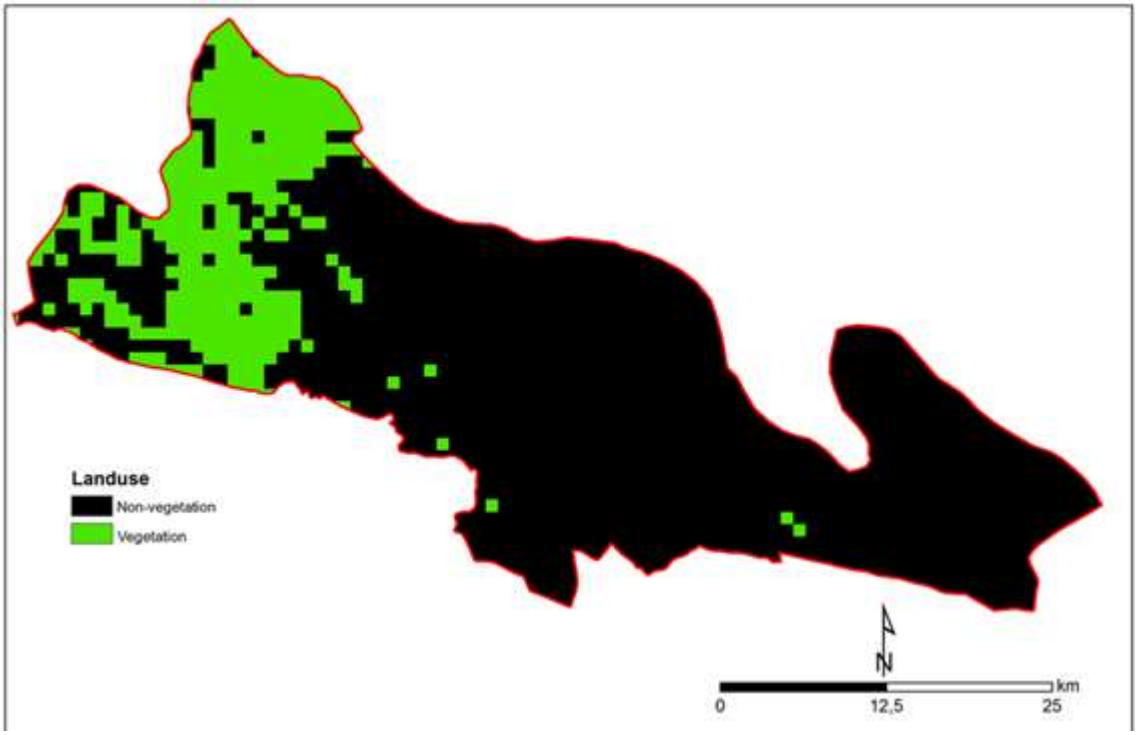


Figure 3f. Land use layer used as base for determination of landslide susceptibility classes in the province of Kilis.

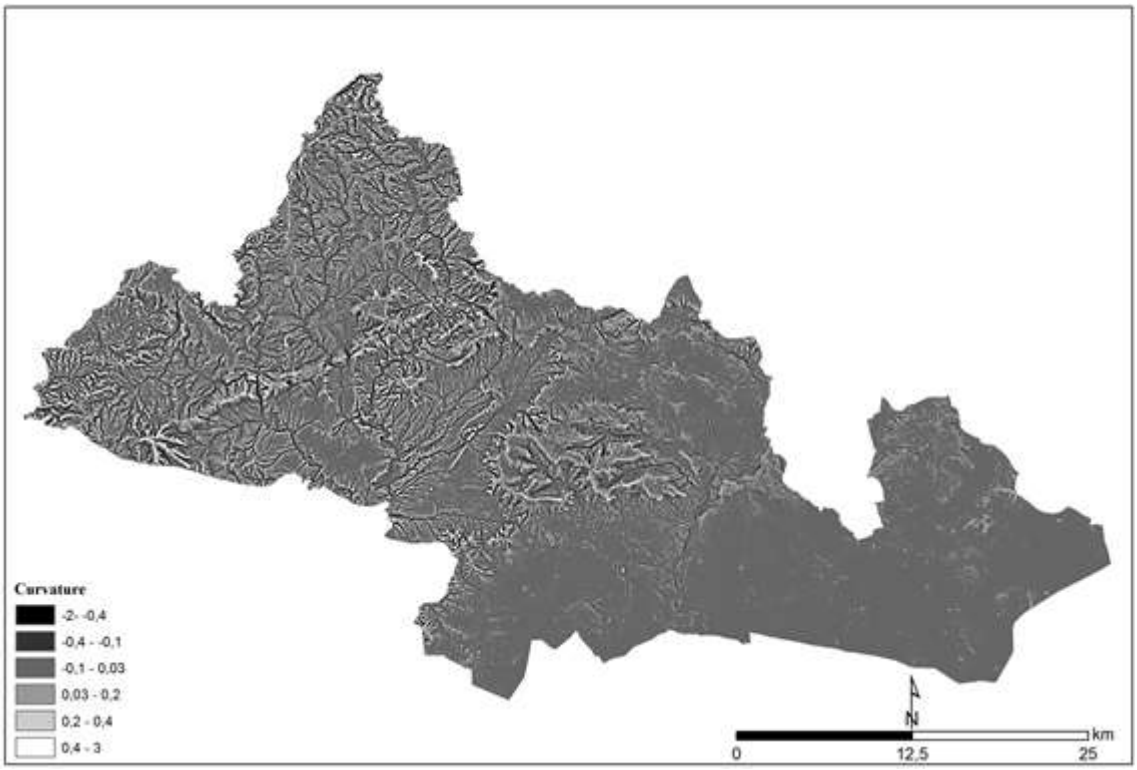


Figure 3g. Curvature layer used as base for determination of landslide susceptibility classes in the province of Kilis.

4. Findings

Crown-heel sections of landslide areas were determined and charted on map with the records of the Mineral Research and Exploration Institute (MREI) and the field survey. Then, the areas detected to have high landslide risk in the field survey and the susceptibility map were superposed with overlay analysis. As a result, it was understood that 90% of the areas detected in the field survey had high landslide susceptibility. Also, it was seen that the susceptibility map and landslides occurred in previous years according to MREI records were consistent. In other words, it was understood that landslides occurred in the past in the area classified as very high-risk in the landslide susceptibility map, which demonstrates the high accuracy of the landslide susceptibility map (Figures 3a-b-c-d-e-f-g, 4, 5, 6 and 7).

The areas with very high landslide risk in the Province of Kilis are generally mountainous areas above 760 m with 20° slope and northern and sometimes southern exposure consisting of volcanite and resistant sedimentary rocks. The rainfall is above 600 mm in the said areas and the vegetation cover is usually naked and sometimes moderately dense.

The areas with high landslide risk in the Province are generally mountainous areas and partially slopes between 690-760 m with 14 to 20° slope and northern and sometimes southern exposure consisting of volcanite and resistant sedimentary rocks. The rainfall is above 500 mm in said areas and the vegetation cover is usually naked and moderately dense.

The areas with moderate landslide risk in the Province are generally slopes between 550-750 m with 9 to 14° slope and southern and sometimes northern exposure consisting of volcanite and resistant sedimentary rocks. The rainfall is between 400-600 mm in the said areas and the vegetation cover is usually naked and moderately dense.



Figure 4. The landslide risk is high in the Northwest of the Province of Kilis. These areas are generally mountainous with an elevation of 760 m, a slope of 20° and northern and sometimes southern exposure consisting of volcanite and resistant sedimentary rocks. The rainfall is above 600 mm in said areas.

The areas with low and very low landslide risk in the Province of Kilis are generally plains with an elevation between 350-550 m, a slope between 0-9° and southern exposure consisting of alluviums. The rainfall is between 400-500 mm in the said areas and the vegetation cover is usually naked in the East of the Province and dense around the central district and in the West of the Province (Figures 1, 2, 3a-b-c-d, 4, 5; Chart 1, 2).

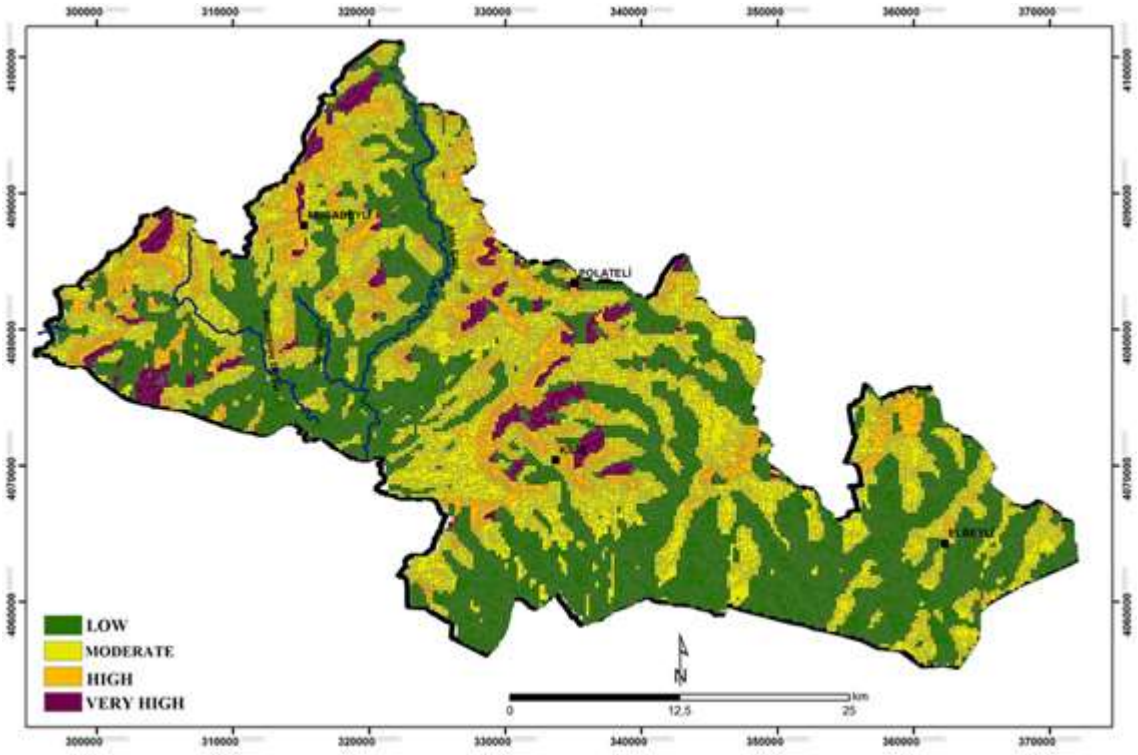


Figure 5. The landslide susceptibility map of the Province of Kilis.

Chart 2. The distribution of landslide risk in the Province of Kilis according to susceptibility classes (%).

Landslide Risk	%	km²
Low	76	1248
Moderate	10	164
High	9	148
Very high	5	82
	100	1642

In summary, it is noteworthy that landslide risk is high especially in the northwestern part of the Province of Kilis. The District of Elbeyli, located in the East of the Province of Kilis, and its immediate vicinity have low landslide susceptibility.

5. Conclusion and Discussion

In conclusion, the areas with high and very high landslide risk in the Province of Kilis are generally mountainous areas and partially slopes with an elevation above 690 m and a slope above 14° and northern and sometimes southern exposure consisting of volcanite and resistant sedimentary rocks. The rainfall is above 500-600 mm in the said areas and the vegetation cover is usually naked and sometimes moderately dense. Previous studies have presented similar results (Iverson, Reid and Lahusen, 1997; Ayalew and Yamagishi, 2004; El Khattabi and Carlier, 2004; Gokceoglu, Sönmez, Nefeslioglu, Duman and Can, 2005; Sidle and Ochiai, 2006; Lee and Pradhan, 2007; Gökçe, Özden and Demir, 2008; Akgun, Dag and Bulut, 2008; Intarawichian, 2008; Khanh, 2009; Pradhan, 2011; Ozdemir and Altural, 2013).

The landslide risk is very-high and high in 14% of the Province of Kilis. Local administrators in the Province should consider these sites where the landslide risk is very high during land use (settlement, farmland, etc.) planning. Indeed, landslides are disasters which may potentially cause losses of life and property. Previous studies have presented similar results for the relationship between landslides and land use (Nagarajan, Roy, Vinod, Mukherjee and Khire, 2000; Dai et al., 2001; Kanungo, Arora, Sarkar and Gupta, 2006; AFAD, 2015). Another point to consider is that the naked fields in the Province (especially the section in the West of Afrin Valley) should be planted with species suitable for the local ecosystem as soon as possible (Çelik and Gülersoy, 2013). On the other hand, the results achieved and the maps produced in this study can help planners and engineers in future development and land-use planning for the Province of Kilis. The foundation of "the Natural Disaster Planning Center of the Province of Kilis" to carry out above mentioned activities would be a positive step.

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