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Landslide-Triggering Factors in Korucak Subbasin, North Anatolian, Turkey

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Abstract

Korucak Creek Basin is located within upper course of the Yeşilırmak River Basin and southern Middle Karadeniz (Black Sea) section which is known to have the potential of landslide and flood risk. The purpose of identification of landslide-triggering factors is to highlight the regional distribution of potentially unstable slopes and to guide decision makers for regional planning purposes. We assessed morphometric parameters for landslide-triggering factors of Korucak Creek Basin using GIS (Geographical Information System). These parameters are Stream Power Index (SPI) and Compound Topographic Index (CTI). Moreover, slope and elevation values of the basin were classified and superposed over the geologic map. Landslide locations were identified from topographic maps and verified with field observation. The total catchment area of the basin is about 55 km2. More than half of the total basin is covered by metamorphic rock types such as schist, which has high permeability and weakness against erosion and is one of the main causes of the landslides. The results show that the main triggering factors are slope and lithology. Thus, northern and western of the Korucak subbasin are under the highest-risk landslide areas.

Keywords: landslide, natural hazard, schist, risk evaluation, Tokat.

1. Introduction

Landslide is slope instability processes, which are the product of local geomorphic, hydrologic, and geologic conditions; the modification of these conditions by geodynamic processes, vegetation, land use practices, and human activities; the frequency and intensity of rainfall and seismicity (Souters and Van Westen, 1996). Landslides are one

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of the important natural hazards occurring in the Black Sea Region because of a great deal of rain, rugged terrain and clayey main rocks. In the region, the damage caused by landslides is greater than caused by earthquakes in the long term (Dağ and Bulut, 2012). In addition, landslides are generally more manageable and predictable than earthquakes (Brabb, 1991).
Our study area is one of the basins situated within Upper Yeşilırmak River which is located in northern Turkey and flows past Tokat and Amasya provinces, and reaches the Black Sea at Samsun Province. Studies on landslide were carried out by researcher (Ercanoğlu and Gökçeoğlu, 2004; Gökçeoğlu et al., 2005; Ercanoğlu, 2005; Can et al., 2005; Yılmaz and Yıldırım, 2006; Ulusay et al., 2007; Yalçın and Bulut, 2007; Nefeslioğlu et al., 2008; Yılmaz, 2009; Zabçı et al., 2011; Hasekioğulları and Ercanoğlu, 2012; Demir et al., 2013) take into account the above-mentioned processes in the region and immediate surroundings of the study area. The landslide susceptibility maps of the landslide area were prepared for land use planning needed by governor in most of these studies. A landslide susceptibility map depicts areas likely to have landslides in the future by correlating some of the principal factors that contribute to landslides with the past distribution of slope failures (Brabb, 1984). Several attempts have been made to understand the temporal-spatial distribution of landslides and thus minimize possible impacts by means of predictive risk models (Yılmaz, 2009). There are great deals of techniques developed using various parameters to assess landslide susceptibility. Although a consensus on some parameters, such as slope, lithology, land use potential and vegetation cover has been established among the applicants, there is no agreement on many of the factors, particularly slope orientation, shape of slope, elevation (Gökçeoğlu and Ercanoğlu, 2001). Regardless of the techniques, the common purpose of these studies takes various measures to reduce damage and country becoming more resistant to disasters. This study aimed to determining the potential triggering and controlling factors for landslide events and estimation of the conditional probability of the occurrence of future landslides in the Korucak Creek Basin, using widely accepted index known SPI, CTI, and evaluate slope, elevation, number of the first order of streams and hiypsometric integral.

2. Description of the study area

Korucak stream is a subbasin of the Yeşilırmak River and covers an area of 55 km^2, on a standard topographic map (STM) to a 1:25,000 scale in the Tokat H37-a3, b4, b1 section of the map, and between 40º23'49'' and 40º19'06'' latitude, and 36º40'19'' and 36º49'33'' longitude. The study area is situated between Almus Dam and Döllük village near the Tokat Province (Fig. 1).

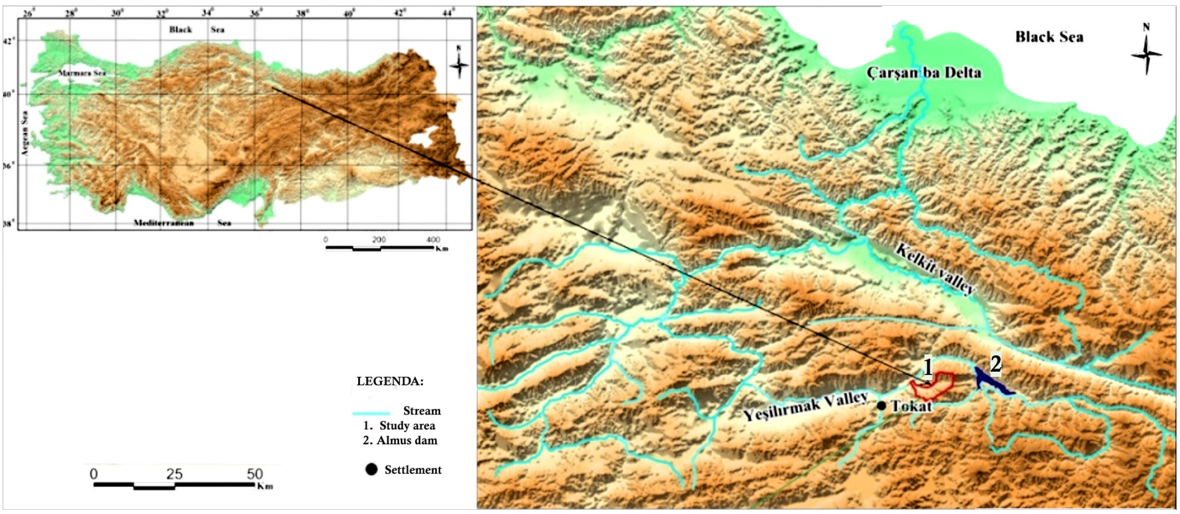

Fig. 1. Location of the study area.

Ophiolitic melange, conglomerate, sandstone, mudstone, diabase, schist and marble are observed in the highland of the Korucak subbasin. Ophiolitic melange bears various-aged limestone with blocks and pebbles of ophiolite (Sümengen, 2013), and named as Artova ophiolitic complex by Özcan et al. (1980). Haydaroğlu formation consists of unit which is intercalated with gravel, andesitic-basaltic lava, tuff, agglomerate, volcanic breccia, sandstone, shale and mudstone with *Nummulites* (Yılmaz, 1982), and is observed southern and northern the subbasin. Almus formation composes of sandstone, mudstone and detritic limestone (Seymen, 1975) and is observed between Bakımlı village and Almus Dam, and the north slope of the subbasin. The formation lies on the Eocene and the older units with an angular unconformity (Sümengen, 2013). The primary relationships along rocks was degenerated by tectonic events during Miocene and in the region (Seymen, 1975), and has been overlapped by Tokat metamorphites, ophiolitic melange and Haydaroğlu formation (Sümengen, 2013). Tokat metamorphics consist of schist, marble, metabasite and crystallized limestones (Özcan and Aksay, 1996). This unit is observed widely in the subbasin and has been incised by Korucak stream and its tributaries.

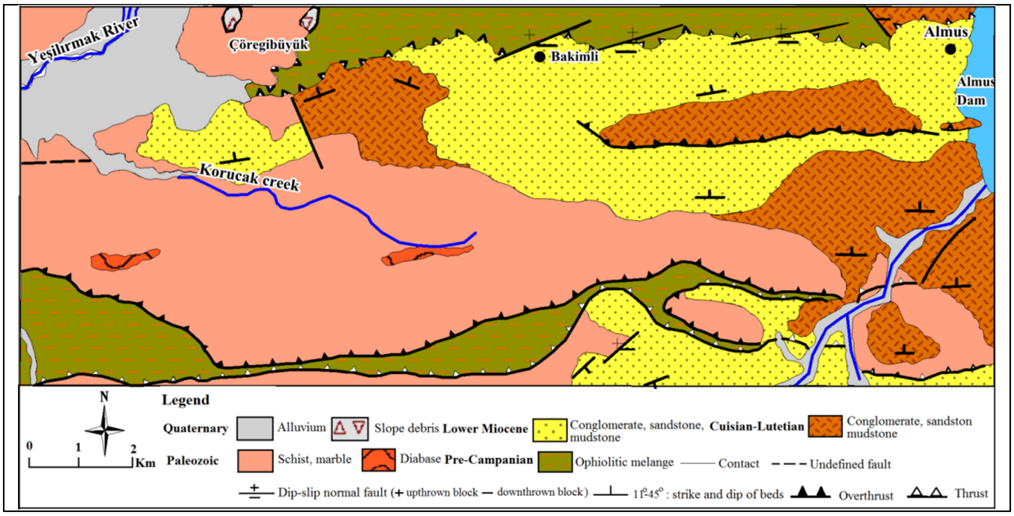

Fig. 2. Geology map of the study area (Sümengen, 2013).

Diabase blocks are observed in the middle and west parts of the Korucak stream. These blocks are found in serpentines (Sümengen, 2013). Eocene, Miocene and Pliocene aged overthrust and thrust faults (Sümengen, 2013; Yılmaz, 1984; Yılmaz et al., 1993) are observed in the study area and its surrounding. These faults are cut by the small strike-slip faults place to place.

West-East trending thrust faults affected ophiolitic melange, metamorphics, and formations with conglomerate, sandstone and mudstone (Özcan and Aksay, 1996). These faults are found in the North Anatolian Fault Zone, which is one of the best-known dextral strike-slip faults in the world because of its remarkable seismic activity, extremely well developed surface expression and importance for the tectonics of eastern Mediterranean region (Bayrak et al., 2011), and a result of movements of this fault.

The Korucak subbasin is found in NNE-SSW trending tectonic depression, which settled in W-E, trending mountainous area. Korucak stream and its tributaries caused erosion of the area, and thus the area has become the high plateau. The high area with metamorphic rocks has been sliced along faultlines. The low slopes are found between the highland and the bottom of the valley, and slope debris are observed on them.

In the study area, landform generations were of two main types: 1- the Lower-Middle Miocene dated erosional-depositional surfaces, which are found at 1700-1400 m (DI) and 1400-1200 m (DII), and compose of metamorphic and ophiolitic units. The Pliocene surfaces (DIII) are found between 1300-900 m around valleys, and these valleys have been cutting these surfaces. In the lower level, shoulders of the Lowest Pleistocene surfaces (DIV) are also seen. These surfaces are covered by a thin and red coloured soil, and cut by relatively deep valleys, 2- Pleistocene fluvial depositional surfaces (SY and SA) are found in variety levels (800-630 m) along the Yeşilırmak valley and lower course of the Korucak stream (Erol, 1980; Altın, 2015) (Fig. 3).

3. Materials and methods

In this study, Tokat H36-37 sheets are used as basic data and 1:100 000 scaled geologic maps published by MTA

(2013). Digital Elevation Model (DEM) was derived 1:25,000 scaled topographic maps. Flow direction, flow accumulation, aspect and slope were obtained using DEM data.

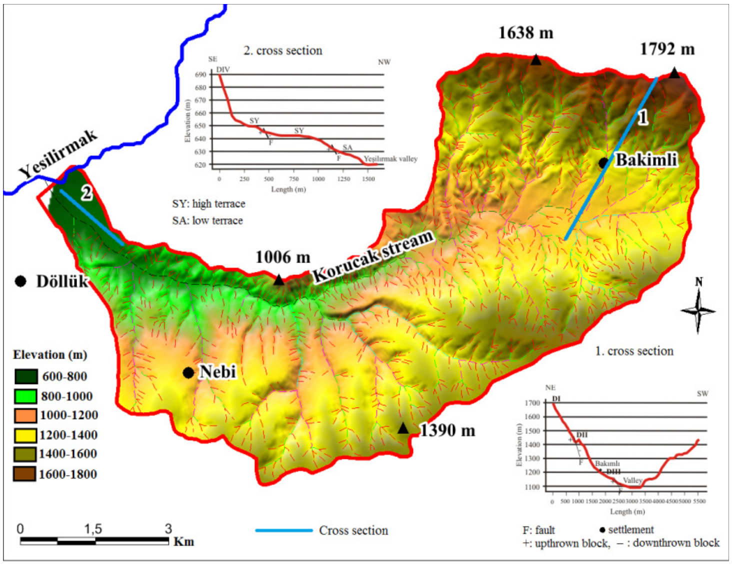

Fig. 3. Landform generations in the study area.

After these maps obtained, these data which is raster format were evaluated using raster calculator on ArcGIS10 and calculated SPI and TCI and ArcGIS10 raster calculator were used and Stream Power Index (SPI) and Topographical Compound Index (TCI) were calculated (eq. 1). TCI is defined as:

$$TCI= \ln (A/\tan\beta), \quad (1)$$

where - A is the local upslope area draining through a certain point per unit contour length and $\tan\beta$ is the local slope (Yılmaz, 2009). The Stream Power Index (eq.2) could be used to identify the erosive effects of concentrated surface runoff (Wilson and Gallant, 2000).

SPI is defined as:

$$SPI=A^{*} \tan\beta, \quad (2)$$

where - A is the specific catchment area and β is the local slope gradient in degrees (Yılmaz, 2009). The hypsometric integral (Hi) is identified (equation 3) as the integral value of the hypsometric curve for the elevation versus area in a basin and is expressed as a percentage (Willgoose and Hancock, 1998; Bishop *et al.*, 2002). It is an important indicator of watershed conditions (Ritter et al., 2002).

Hi is defined as:

$$Hi= (\text{mean elevation} – \text{min elevation}) / (\text{max elevation} – \text{min elevation}) \quad (3)$$

4. Results and discussions

The SPI is a measure of erosive power of the stream. A dynamic equilibrium appears to exist between the tectonic uplift and the bedrock incision through continuous adjustments in available stream power (Burbank et al., 1996). In Fig. 4a, the areas with red colour (high SPI values) are suitable for erosion. Other words, these areas can be eroded by streams. Thus, the southwest and the north parts of the subbasin are more susceptible than other parts. The CTI has been used to study spatial scale effects on hydrological processes (Yılmaz, 2009). The CTI was developed by Beven and Kirkby (1979) within the runoff model. The areas with low values (light blue) of CTI and the areas with high values of CTI imply potential trend of water accumulation. The areas with steep slopes show relatively highlands and vice versa (Fig.4b). Thus, the areas with dark blue colour have maximum level of the potential water accumulation and vice versa. In addition, these areas correspond to high slope values. Thus, the west and the northwest parts of the subbasin are much more susceptible than other parts.

It was observed that the landslides were very abundant at locations having higher CTI and lower SPI values (Yılmaz, 2009). Korucak subbasin has much more the highest slope values than its surrounding (Bayer Altın, 2014). The steep slopes (20-30%) occupy 58% of the subbasin (Fig. 4c). The area with the steep slopes is found widely southwestern, northern and northwestern of the subbasin. The gentle (5-10%) and the moderate (10-20%) slopes are observed along the valley and occupy approximately 12.4% and 17.2 of the subbasin, respectively.

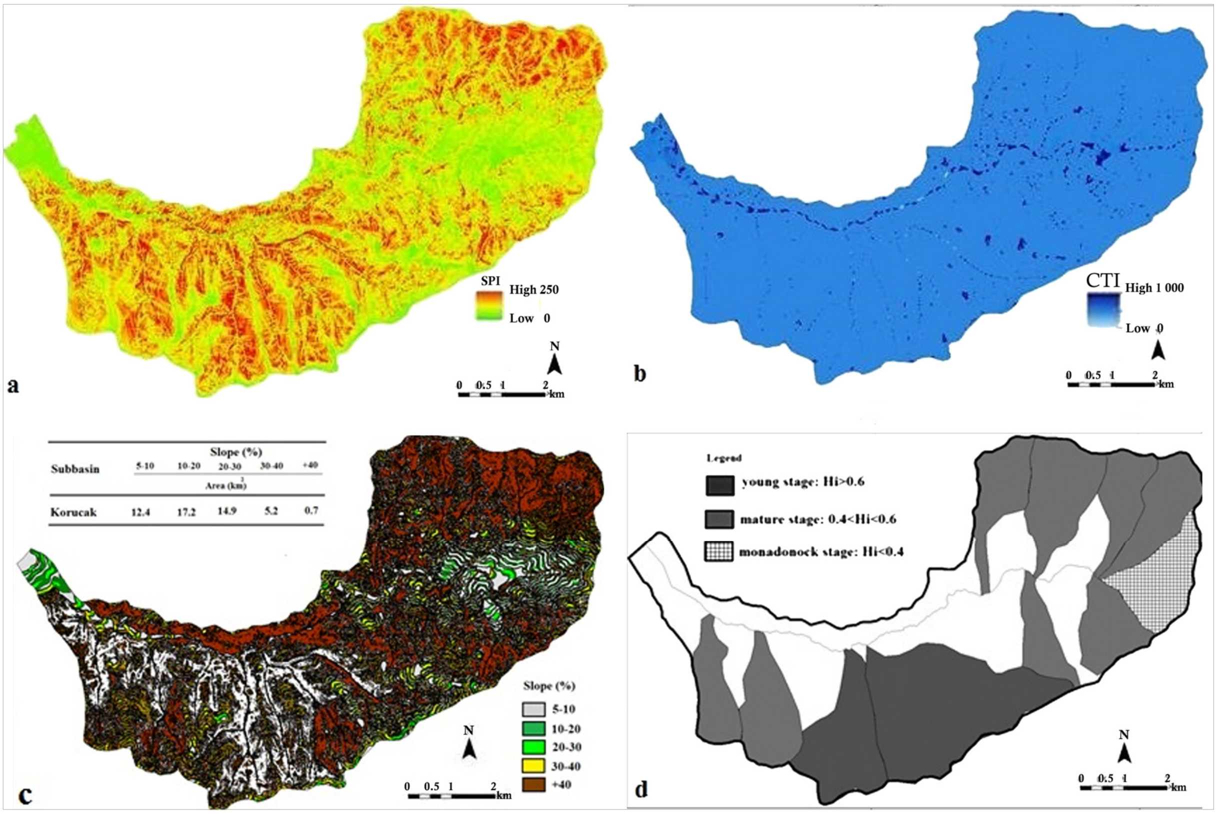

Fig. 4. a) Stream Power Index, b) Topographical Compound Index, c) slope, d) Hypsometric Integral.

Fig. 4d displays the hypsometry for the study area. The Hi values rand from 0.64 to 0.36. The values (>0.4) were found to the southwestern and northern of the areas affected by overthrust and thrust faults. The Hi values above 0.6, which indicate very young topography, are located near the strike-slipe and overthrust faults. Otherwise, the area with the high value of Hi has great deal of first order. The hypsometry implies a strong control and triggering of main thrust on the topography. The same determination was carried out in Iran by Othman and Gloaguen (2013).

As can be seen in Fig. 5, maximum number of first order is found on the schist main rock. Moreover, the former landslides formed are found in the basin of the 1st and 2nd orders in the study area. Continental clastic rock follows the schist, which has high permeability and weakness against erosion and is one of the main causes of the landslides, and has 291 of 1st order and followed by ophiolite.

Lefebvre (1996) suggests that retrogressive landslides tend to be more common along rivers of intermediate age, and are less common along young and fully established drainages. Bjerrum *et al*. (1969) suggest that the occurrence of landslides along rivers through sensitive clay areas can be related to the gradient and flow in relation to a stable condition for a river with similar characteristics. It has therefore been decided to explore characteristics of the drainage systems and attempt to relate them to the occurrence of landslides in the study area (Quinn et al., 2008).

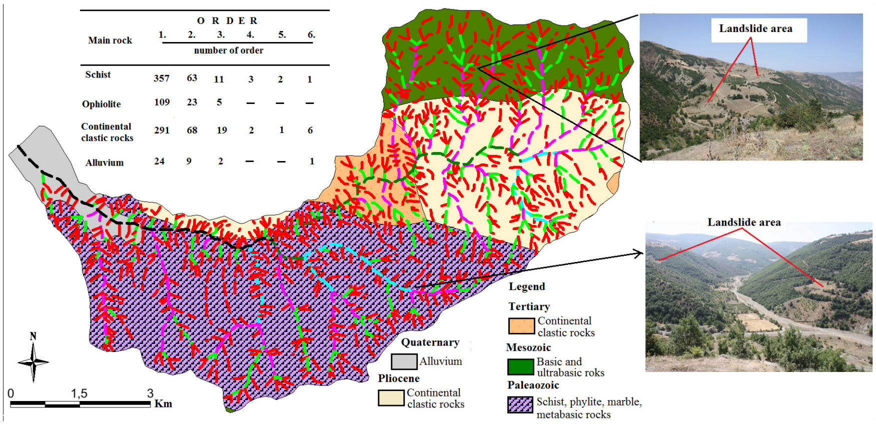

Fig. 5. Stream orders on the main rock and their number. The former landslide formed in the study area. The geology map was compiled from 1/500,000 scaled geological map of Turkey (MTA, 2002).

5. Conclusion

The early results of this work are encouraging, and indicate that is possible to identify triggering factors on the landslides. To identify the highest priority triggering factors, we are served by parameters such as the main rocks, hypsometric integral, stream power index, compound topographic index, slope and drainage. In order of priorities, triggering landslide factors are as follow; schist main rock, slope, number of first order and rugged topography. Thus, it can be said that northern and western of the Korucak subbasin are under the highest-risk landslide areas.

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