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LANDSLIDE SUSCEPTIBILITY ASSESSMENT OF AROUND BABADAĞ (DENİZLİ) USING LOGISTIC REGRESSION METHOD

MANTIKSAL REGRESYON YÖNTEMİ İLE BABADAĞ İLÇESİ (DENİZLİ) DOLAYININ HEYELAN DUYARLILIK DEĞERLENDİRİLMESİ

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ÖZET

Bu çalışmada, Babadağ ilçesi ve dolaylarını içeren 1133 km^2'lik bölgede, mantıksal regresyon yöntemi ile heyelan duyarlılık çalışması gerçekleştirilmiştir. Toplam alanı 44 km2 olan, 300'e yakın kayma türü heyelan bulunmaktadır. Çalışma alanı içerisinde bulunan yerleşim yerleri, ziraat alanları gibi bölgeler heyelanlardan olumsuz yönde etkilenmektedir. Bölgede yaklaşık 500'e yakın konut boşaltılmıştır. Heyelanları hazırlayıcı faktörler 25 m mekansal çözünürlükte Coğrafi Bilgi Sistemleri ortamında hazırlanmış olup, jeoloji, sayısal yükseklik modeli, yamaç eğimi, kesit, düzlemsel ve teğet yamaç eğrisellikleri, drenaj ağı ve aktif faylara olan uzaklık parametreleri göz önünde bulundurulmuştur. Duyarlılık haritasında yüksek ve çok yüksek duyarlı bölgeler çalışma alanın % 23'üne karşılık gelmekte olup bu bölgelerde heyelanların % 72.13'ü bulunmaktadır.

Anahtar Kelimeler: Babadağ, Heyelan duyarlılık, Mantıksal regresyon

ABSTRACT

In this study landslide susceptibility assessments were evaluated using logistic regression method around the Babadağ town extending to 1133 km^2. Almost 300 slide type landslides corresponding 44km^2 were identified in the area. Some of the residential areas, agricultural lands and lifeline systems has been severely damaged by landslides and more than five hundreds dwellings were evacuated in the region. Among the landslide conditioning factors; elevation, slope, plan and profile curvatures, proximity to faults and rivers and geological maps have been prepared in Geographical Information Systems environment with spatial resolution of 25 m The performance of the susceptibility map when compared to the landslide inventory revealed that high and very high susceptible zones correspond to 23 % of the study area including 72.13 % of the recorded landslides.

Keywords: Babadağ, Landslide susceptibility, logistic regression

INTRODUCTION

Despite the developments in understanding of mechanisms and the availability of a wide variety of mitigation techniques, landslides are still leading to significant casualties and economic losses worldwide. Minimizing the potential damages of landslide hazards requires an integrated approach including inventory, susceptibility, hazard and risk assessments. Landslide susceptibility studies is one of the first stages to help with land management works in landslide prone areas. The landslides susceptibility methods are classified into two main groups: qualitative (inventory-based and knowledge driven methods) and quantitative (data-driven methods and physically based models) (Corominas et al. 2014). Some recent overviews of the methods available for landslide susceptibility assessment can be found in Corominas et al. (2014), Reichenbach et al. (2018); Huang and Zhao (2018). Landslides cause significant problems in and around Babadağ town of Denizli for several decades. Some local landslides in Babadağ settlement using physically based slope stability models and multi-parameter monitoring techniques were studied by Cevik and Ulusay (2005) and Kumsar et al. (2016). Landslide susceptibility assessments has not been studied in the region although the landslides are abundant. In this study, landslide susceptibility assessments were performed using the logistic regression method in the 1133 km^2 area around the Babadağ comprising Karacasu and Sarayköy districts (Figure 1).

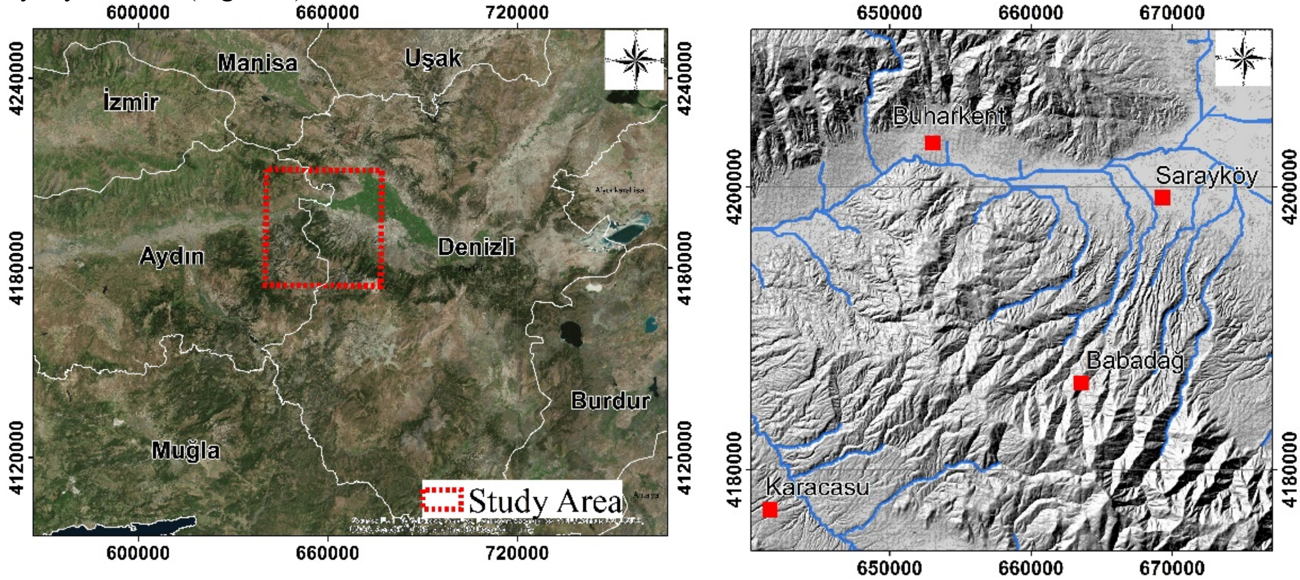
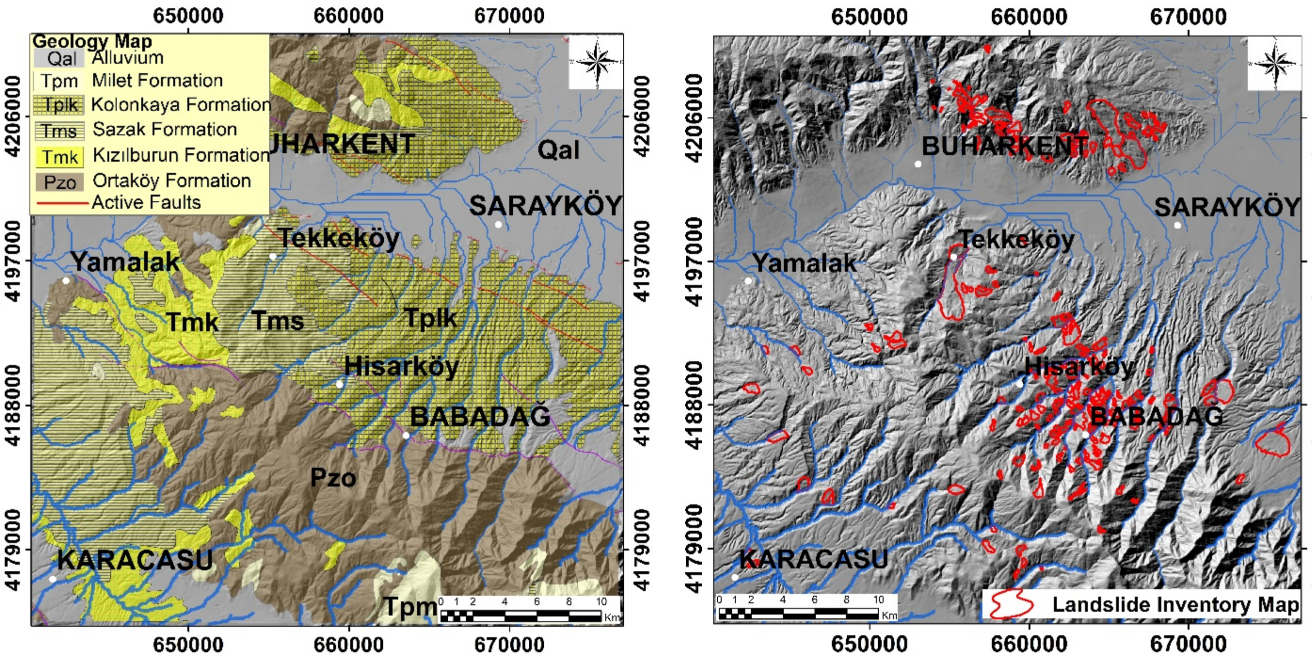


Figure 1. Location map of the study area.

DATA and METHODS

The present geologic and morphotectonic setting of the study area is configured by the Western Anatolian Extensional tectonic regime by means of the horst - graben systems and the E-W trending basins (Westaway 1993). The basement rocks (Ortaköy formation) in the area exposed in the mountainous horst areas composing schists, marbles and gneiss (Bozkurt and Oberhansli 2001). The Neogene cover units (Kızılburun, Sazak, Kolonkaya, and Milet formations) and Quaternary recent deposits overlie uncomformably the basement rocks. Some of the active fault segments related to the Büyük Menderes and Denizli Graben Systems delineated by Emre et al., (2013) are also located in the study area (Figure 2a). A reliable landslide inventory data is essential for quantitative zoning of landslide susceptibility. 300 landslides covering 44 km^2 were identified in the area by Duman et al., 2009 (Figure 2b). Most of the landslides are developed in Neogene cover units (Figure 3a) and numerous deformations are observed in Babadağ downtown (Figure 3b).



(a) (b)

Figure 2. Geological map (Konak et al., 2002) (a) Landslide inventory (Duman et al., 2009) (b) of the study area.

(a)

(b)

Figure 3. Slide type landslide (a) and landslide induced deformation on dwellings in Babadağ (b).

Accordingly; the landform map was prepared according to Jenness (2006) using the topographic position index (Figure 4)., 7.63% small drainage systems, 14.15% ridges, 14.44% steep slopes, 16.04% lower slope, 20.47% upper slopes, 27.27% gentle slopes classes be made of the study area. Landslides, 8.98 % valley, 8.19% ridges, 19.37% steep slopes, 26.34% lower slope, 21.52% upper slopes, 15.60% gentle slopes are found in the area.

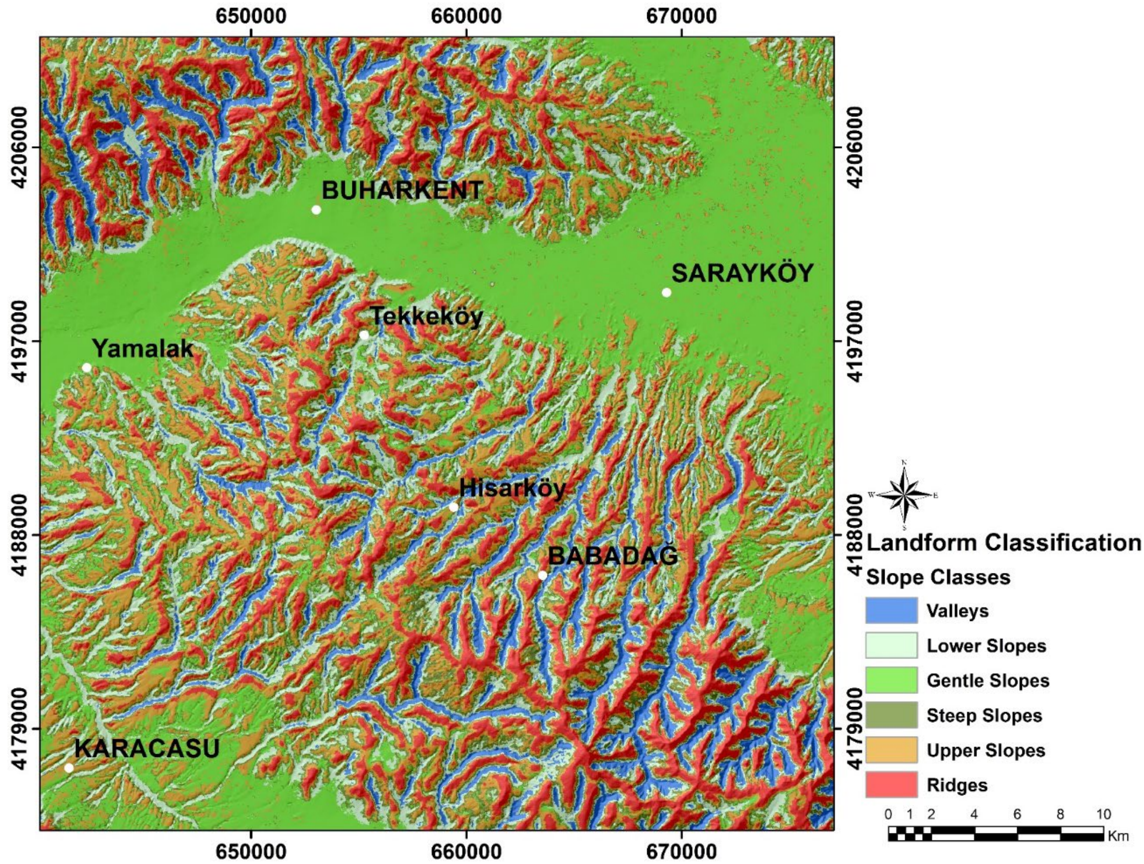


Figure 4. Landform classification.

The mean elevation in the study area is 650 m and the basement rocks constitute the high land areas around Akdağ, where elevation reach up to 2300 m. The lower elevation areas around the Sarayköy plain corresponds to the central part of the Büyük Menderes river where elevation ranges between 84 to 150 m (Figure 5a). The slope ranges between 0-62 degrees with an average of 15 degrees (Figure 5b). Profile and plan curvatures parameters which mainly control the ongoing erosion and deposition processes were also considered (Fig 5c,d). Positive and negative values in the curvature maps indicates convex (≅40%) and concave (≅40%) surfaces and the values close to the zeros (≅20%) are linear surfaces. The maximum distances to active fault (Figure 5e) and distances to stream (Figure 5f) in the study area are 4015 m and 1974 m, respectively.

Geographical Information Systems (GIS) based landslide susceptibility map in the study area was constructed by using logistic regression method. Logistic regression is an efficient multivariate statistical method to investigate the relationship between a binary dependent variable with a set of continuous and / or categorical independent variables. The probability of the observed dependent variable as a function of the independent variables are expressed by the maximum likelihood method and the linear combination of the independent variables $X_1 \ldots X_n$ can be expressed by the following equation (Eq. 1),

$$Z=\beta_0+\beta_1X_1+\beta_2X_2+...............+\beta_nX_n \quad (1)$$

And in order to predict the possibility of landslide occurrences in each grid, the probability was calculated from Eq. 2,

$$P = 1/1 + e^{Z} \quad (2)$$

where P is the probability of landslide occurrence and Z is the weighted linear combination of the independent variables, B_i (i = 0, 1, 2,…,n) is the coefficient estimated from the sample data, n is the number of independent variables and X_i (i = 1, 2, …,n) is the independent variable (Hosmer et al. 2013).

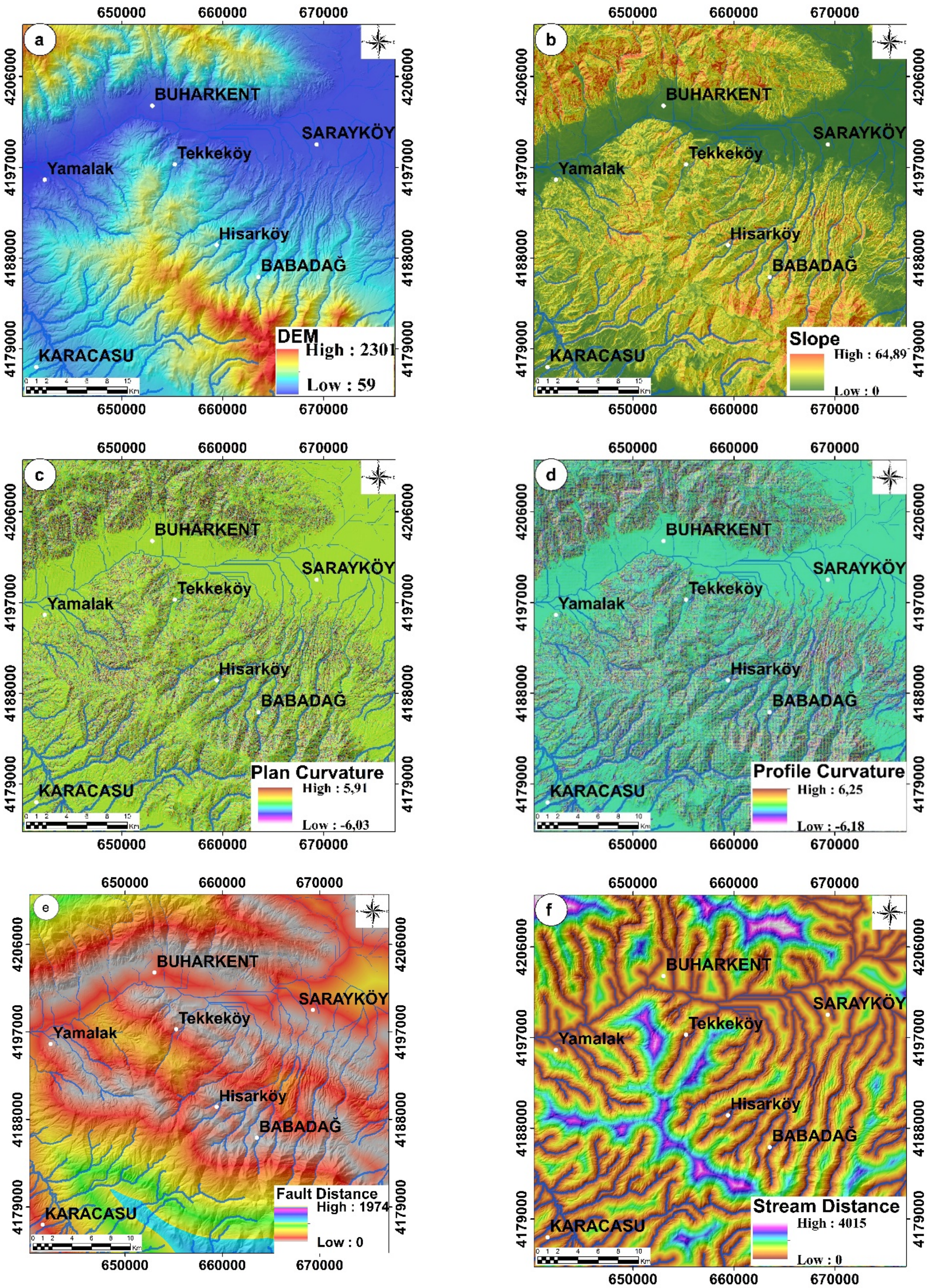


Figure 5. Digital elevation model (a), slope (b), plan curvature (c), profile curvature (d), proximity to faults (e) and proximity to streams (f) maps of the study area.

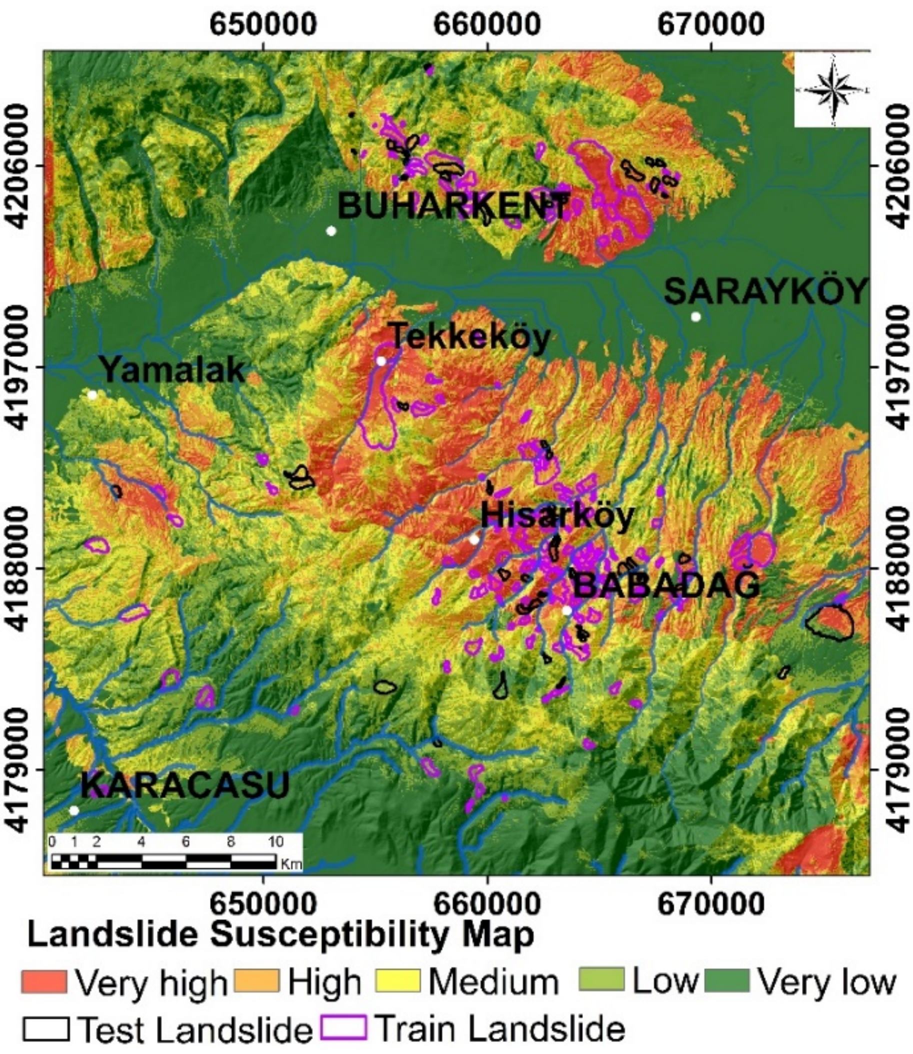
RESULTS

The grid cell size of 25 m was used for terrain mapping unit where the landslide data set is represented by 67655 grid cells (44 km^2) and the total study area has 2178576 pixels (1133 km^2). Landslide affected pixels were randomly divided into two groups, 80% for the training and 20 % for test data set considering the entire landslide polygons according to the sampling method proposed by Tekin and Çan (2018). The geological map of the study area was converted to raster format and each geological unit was assigned by binary value. Several logistic regression analyses were applied, and the final decision was made by two rules proposed by Can et al. (2005) that first, the majority of the landslides should locate in the high and very high susceptibility classes, and second, the high and very high susceptibility classes should cover the small percentages of the area. The variables entered in the best fit logistic regression model were summarized in Table 1. In regression model DEM and slope were found positively related to the presence of landslides.

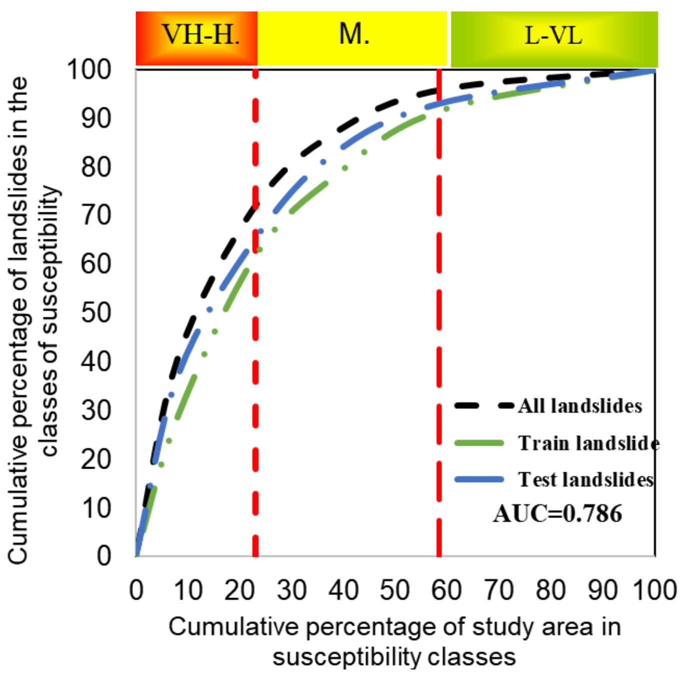
Table 1. Beta coefficients and Wald test statistics of the variables in the regression model.

Variable	Beta	Standard error.	Wald	Explanation (B)
Plan Curvature	-,000311	0,014	626,760	0,707
Profile Curvature	-,157886	0,012	169,731	0,854
Dem	,000454	0,000	323,663	1,000
Fault Distance	-,000282	0,000	6308,313	1,000
Slope	,003117	0,001	14,752	1,003
Stream Distance	-,000394	0,000	795,623	1,000
Constant	,590892	0,015	1579,646	1,806

The landslide susceptibility map was given in figure 6a. According to the success and prediction rate curve the 23.06 % of the study area is located within the high – very high susceptibility classes comprising the 61.81% of test, 65.37 % of train 72.13 % of all landslides (Figure 6b). The area under Receiver Operating Characteristics (ROC) curve was found 0.786 indicating acceptable discrimination.



(a)



(b)

Figure 6. Landslide susceptibility map (a), success -prediction curves (b).

CONCLUSIONS

Landslides occur under different geologic, geomorphologic and climatic conditions. Each type of landslides should be studied separately due to their different movement mechanisms. In this study, slide type landslide susceptibility assessment was made around the Babadağ region in the Western Anatolia. Landslides in the Babadağ town cause long-term socio-economic disruption and settlement evacuation. However, there are numerous landslides in the region which have negative effects on natural environment. The results suggest that the landslide susceptibility zonation is sufficient to be used in early land use planning for public safety and site selection studies for engineering structures.

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