



Research Article /Review Article:

Determination of landslide risk areas in Giresun province using Google Earth Engine (GEE) and Best Words Methods (BWM)

Eda Aydın^{*1}, Yasemin Sisman²

¹ Ondokuz Mayıs Üniversitesi, Mühendislik Fakültesi, Harita Mühendisliği, Samsun, Türkiye

² Ondokuz Mayıs Üniversitesi, Mühendislik Fakültesi, Harita Mühendisliği, Samsun, Türkiye

Article History:

Received: 07.08.2025
Revised 1: 09.10.2025
Revised 2: 16.10.2025
Published: 23.10.2025

Keywords:

Disaster Management
Landslide;
Landslide Sensitivity
Map;
Landslide Susceptibility
Parameters;
Google Earth Engine
(GEE);
Best Worst Method
(BWM).



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Abstract

Our planet has been facing natural hazards since the human population has existed. Numerous events have caused millions of casualties and significant destruction. On the one hand, natural hazards are a major threat to human communities all over the world. However, on the other hand, these events help us learn from our mistakes, help scientists to better understand nature, protect society and benefit from this knowledge.

When analyzed in terms of the number of events in our country, landslides are one of the natural disasters that we frequently encounter. In this article, the concept of disaster and landslide is mentioned in general. It is aimed to produce landslide susceptibility map of Giresun city Centre. In the production of the susceptibility map, GIS stratified best-worst method (BWM) method, which is found to be widely used in the literature, was used. In the evaluations, eleven factors that are mainly effective by reviewing the literature on the occurrence of landslides in Giresun province were taken into consideration: Topographic index, elevation, slope, aspect, land cover, proximity to the river, surface water, NDVI, surface temperature. During the study, these factors were downloaded using Google Earth Engine software language and then mapped in ArcGIS and a new landslide susceptibility assessment model was proposed by integrating GIS stratified best-worst method (BWM).

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Contribution to the field statement:

This study develops a landslide susceptibility assessment model for Giresun by integrating Google Earth Engine, geographic information systems, and the stratified Best-Worst Method. It combines 11 environmental, topographic, and hydrological factors to map susceptibility levels and identify high-susceptibility areas, supporting regional risk assessment and land-use planning.

Highlights:

- Google Earth Engine supports the extraction of landslide-related factors.
- Eleven factors are integrated into a susceptibility assessment model.
- The stratified Best-Worst Method is used to weight assessment criteria.
- High-susceptibility areas are identified near residential settlements.

Cite this article?

Aydın, E., & Şişman, Y. (2025). Determination of landslide risk areas in Giresun province using Google Earth Engine (GEE) and Best Worst Methods (BWM). *Advanced Geomatics*, 5(1), 83–93.

1. INTRODUCTION

Based on the information collected over the years through natural disasters and various changes in climate and nature, scientists have developed technologies and methods to control and assess the level, scale and timing of hazard damage. With the application of new technologies, people have made possible better forecasting and monitoring systems that help mankind to avoid possible victims and destruction. Landslides are one of the devastating geomorphological hazards that cause significant socioeconomic and environmental damages on a global scale. Knowing the exact number of fatalities from landslides, their spatial and temporal distribution will facilitate a better understanding of the losses and damages, and will



also enable the prevention and minimization of damages from such disasters. Therefore, reliable historical inventories including past landslide events are very important in understanding future landslide hazards and risks. In Turkey, landslides are most common in the Black Sea region and the second most common in Eastern Anatolia. Slope, abundant rainfall, snowmelt, clay soils are effective in its formation. Due to the water saturation of the soil due to snowmelt, 65% of landslides occur in spring. Landslides Every year in Turkey, there are many landslides resulting in the death of dozens of people.

Landslide is the downward and outward movement of a slope consisting of rock or artificial filling material under the influence of gravity, slope, water and other similar forces. The displacement of masses of rocks, debris cover or soil under the influence of gravity is called landslide.

While some landslides occur at a great speed, some landslides occur more slowly. Landslides are a very common type of mass movement on the earth's surface and play an important role in erosion. Large landslides also leave deep marks on the topography. The most common places in Turkey are in the Black Sea Region, especially in the Eastern Black Sea strip. The increasing socio-economic impact of landslides has intensified analyses and research worldwide. Landslide analysis of a slope in a region is carried out according to geological, geomorphological and hydrogeological factors. Analyzing an area susceptible to landslides and determining the risk precisely is very important for that region and society (Özşahin, 2014). In a landslide-prone area, land use planning or construction programmed should be based on the potential landslide risk. Landslide hazard and risk analysis can be used to identify past landslides and their characteristics and to predict future ones based on the data. Many studies have been conducted in the world to assess landslide hazard and produce susceptibility maps by applying different methods (Corominas et al., 2014; Feizizadeh et al., 2014). When these studies are analyzed, it is seen that the majority of these studies were conducted using probabilistic models (Lee and Dan, 2005; Talaei et al., 2004; Cevik and Tolap, 2003; Talei, 2014; Akgun and Türk, 2010; Clerici et al., 2006; Lee and Min, 2001). Data mining methods such as decision tree, artificial neural networks, fuzzy logic are also among the methods frequently used in landslide susceptibility assessment in recent studies (Akgun and Türk, 2010; Clerici et al., 2006; Lee and Min, 2001). In the study, landslide susceptibility maps were created and classified under 5 groups as 'very high, high, medium, low and very low' susceptibility areas.

2.METHOD

Then, unlike the literature, a new landslide susceptibility assessment model was proposed by integrating GIS with the stratified best-worst method (BWM). This model has three main dimensions and 11 sub-dimensions under Topographic and Morphological, Environmental and Surficial, Hydrological factors weighted by BWM. Literature reviews were taken into consideration in determining the importance weights of these dimensions. Weights were calculated for each sub-factor and injected into BWM. Then, maps were created for these dimensions and classifications were made according to the map features for each sub-dimension and finally landslide susceptibility map was created.

2.1. Study Area

Giresun province has a rugged appearance in terms of landforms and mountains, valleys and steep coasts cover a wide area. Giresun Mountains, which cover a coastline consisting of very narrow and low plains along the Black Sea coast and the Kelkit Stream Valley in the south, constitute the roof of the landforms of the province. The average height of these mountains rising parallel to the coast 50-60 km inland from the coast is 2000 metres. The most important elevations of Giresun Mountains, which exceed 3000 m in some places, are as follows: Abdal Musa Hill (3.331 m), Akıl Baba 3300, Cankurtaran Hill (3.278 m), Gâvur Mountain Hill (3.067 m), Küçükkor Hill (3.044 m), Karataş Hill (3.107 m) and Kırkkızlar Hill (3.040 m). On these mountains rising parallel to the coast, Şehitler (2,350 m), Eğribel (2,200 m) passes, Kurtbeli Mevkii (1760 m) and the highland roads of the districts provide transportation between the coastal and inland areas. According to TURKSTAT data, there are 16 districts, 8 towns and 551 villages in the province together with the central district. The study area is give in "Figure 1".



Figure 1. Location map of the study area

2.2 Landslide Detection Methods

Although there are many landslide susceptibility map applications in the literature (Aleotti and Chowdhury, 1999; Lee and Talib, 2005; Tetik Biçer, 2017), there is no consensus on the methods and parameters used in these applications. Statistical methods within quantitative methods are categorized into two groups as bivariate and multivariate parameter analysis. When the studies are analyzed in terms of the methods applied; it is seen that the analysis methods applied are Frequency Ratio (FR), Weight of Evidence (WoE), Logistic Regression (LR), Analytical Hierarchy Process (AHP) and Support Vector Machine (SVM) Logistic Regression, Fuzzy Logic, Artificial Neural Networks Among the statistical methods, Best Worst Method (BWM) was used in this study.

2.3. Best Words Method (BWM)

The best-worst method (BWM) is a popular multi-criteria technique (Mi et al., 2019). It relies on pairwise comparisons to calculate weights. The small number of pairwise comparisons and high consistency rate are the main advantages of BWM over other weighting methods (Rezaei, 2015). Since BWM uses a non-linear model to calculate weights, an optimal range of weights is possible (Rezaei, 2016, Rezaei, 2020). This is a serious problem because the decision maker has to choose a weight, which is a difficult task. His choices will affect the outcome of the problem. In the current work, we provide guidance on how to select weights according to the decision maker's behaviors (i.e. balanced, risk-taking or risk-averse; (Liu et al., 2017, Yoon and Kim, 2017). To this end, as a new contribution to the literature, we consider the behaviors of the decision maker and the performance of the alternatives from the perspective of criteria for decision-making problems, aiming to calculate the optimal weights for the criteria in the range provided by BWM. Three mathematical models that take into account these two aspects were developed to calculate the weight of each alternative. These models are used to select the best point for the weight in the range provided by the BWM. The three models minimize the anchoring bias (Rezaei, 2021) in decision-making problems by adjusting the trade-off between decision-making criteria (Kheybari, 2021). In other words, through the presented approaches it is possible to rank the alternatives in three ways and select the correct option with more confidence and in accordance with the behaviors of the decision maker.

The pairwise comparison scale used in the study is given in "Table 1."

**Table 1.** Paired Comparison Scale Used in BWM

Importance Level	Oral Expression for Comparison of Criteria
1	Equally important
2	Equally moderately important
3	Moderately more important
4	Moderately much more important
5	Strongly important
6	Strongly very important
7	Very strongly important
8	Very strongly more important
9	Very very important

In this method, the steps followed to calculate the weights of the criteria are

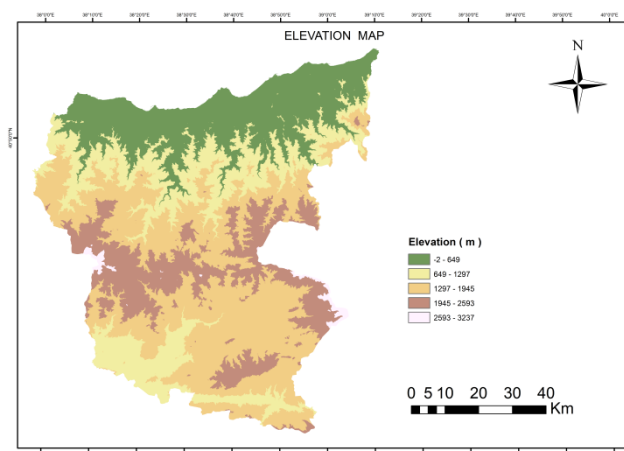
1. A set of criteria is defined.
2. The best and worst criteria are defined.
3. The preferences of the best over the other are defined. (determination of the pairwise comparison matrix).
4. Define preferences according to the worst of all criteria. (determination of pairwise comparison matrix)
5. Search for the best solution. (finding the best solution)

2.4 . Factors Affecting Landslide Formation And Obtaining

Landslide occurrence can be influenced by a number of factors. The scientific selection of the factor is an important step in regional landslide risk assessment studies. These factors are generally categorized in four aspects: geomorphological factors (elevation, slope, slope condition), geological factors (stratigraphy, distance from fault, lithology), hydrological factors (rainfall, distance from water) and environmental factors (NDVI, distance from road, land use).

Firstly, the analyzed factors were extracted from the Google Earth Engine (GEE) with the help of the necessary codes. Then, with the help of ArcGIS, a map of each factor was created on the basis of Giresun province. After the maps were created, weights were determined and reclassification was made. Landslide susceptibility map was created with the Best Worst Method (BWM) method from the classified maps.

2.4.1.Elevation: The influence of elevation on the distribution of landslides is primarily indicated by the intensity of human activity, vegetation types and vegetation coverage, as well as the difference in atmospheric precipitation (Umar et al., 2014). Therefore, elevation plays an important role in landslide risk assessment studies. The elevation map of the study area is given in "Figure 2".

**Figure 2.** Elevation map of Giresun province.

2.4.2. Slope: Slope affects shallow landslides by influencing the shear force and stress distribution of the rock soil. For slopes with homogeneous and isotropic material composition, the probability of landslides

increases with increasing slope (Rozos et al., 2011, Papathanassiou et al., 2013). The slope map of the study area is given in "Figure 3".

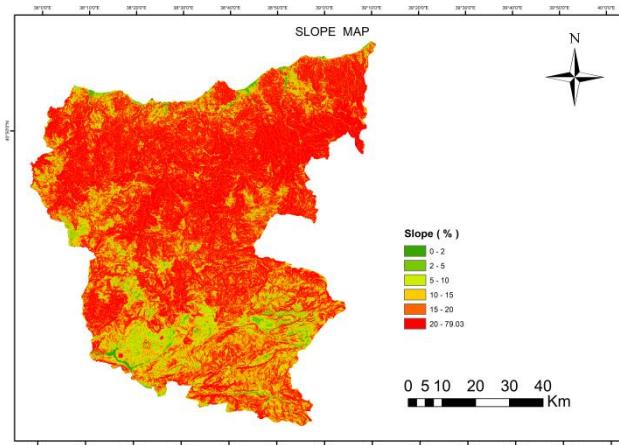


Figure 3. Slope map of Giresun province.

2.4.3. Topographic Index: It is the material basis of landslide, and different lithological strata have different slope stability performance in terms of strength and permeability, so the degree of landslide development within the region is different (Wu et al., 2016). It is an important structural component affecting landslide occurrence because it can influence not only the degree of landslides but also the type and size of landslides. The topographic index map of the study area is given in "Figure 4".

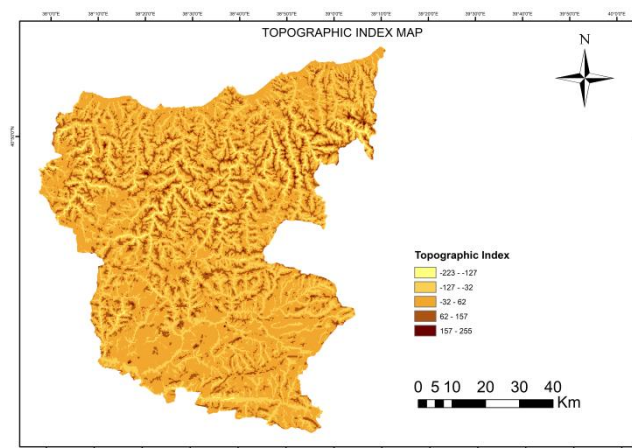


Figure 4.Topographic index map of Giresun province.

2.4.4. Precipitation: Precipitation can increase the pore water pressure and reduce the shear strength of the soil, which can lead to landslides (Hong et al., 2018). Since the study area is located in a region with a subtropical monsoon climate, landslides can be easily triggered in heavy rainfall, torrential rainfall or continuous rainfall. These waters that receive precipitation after heavy rains stand out as a factor that triggers landslides. Rainfall-induced shallow landslides affect superficial deposits of small thickness (usually less than 2 m) and are a common phenomenon all over the world. Shallow landslides are often triggered by very heavy rainfall events (Howard et al., 1988, Montrasio and Valentino, 2008). Although they contain small volumes of soil, they can be densely distributed across regions, especially as a result of intense and heavy rainfall (Zizioli et al., 2013), and can also affect slopes close to urbanized areas. They can therefore have negative impacts on agriculture, infrastructure and sometimes human casualties. The precipitation map of the study area is given in "Figure 5".

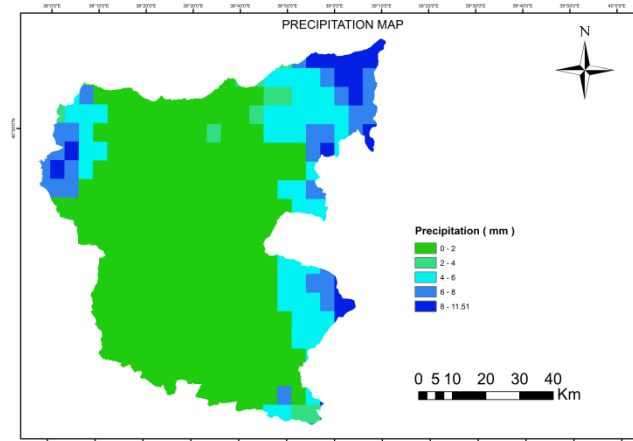


Figure 5. Precipitation map of Giresun province.

2.4.5. Aspect: The concentration of landslides on the slopes in a certain orientation, the morphological structure of the area, sunlight intake, general precipitation direction of the region, etc. meteorological events are effective. The material on the slopes in the direction of the dominant aspect reaches saturation in a shorter time compared to the other slopes, depending on the slopes with intense rainfall, slope and the type of soil, permeability, porosity, moisture and organic matter content, vegetation cover and percolation capacity affected by the season in which the rainfall occurs. The aspect map of the study area is given in "Figure 6".

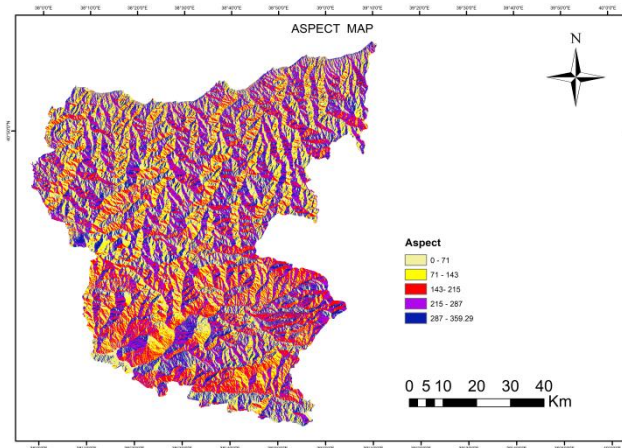


Figure 6. Aspect map of Giresun province.

2.4.6. Proximity to Stream Water : The distance from the water is used to represent the state of the water system. The water system erodes and erodes rocks-soil at the confluence of surface runoff. This affects the stability of the regional geological environment, which affects the occurrence and development of regional landslides (Hong et al., 2018). The proximity map of the study area to the river is given in "Figure 7".

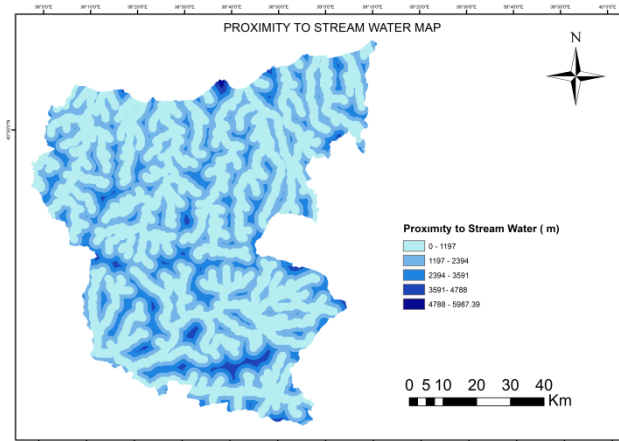


Figure 7. Proximity to stream water map of Giresun province.

2.4.7. Normalized Difference Vegetation Index (NDVI): The stability of a slope is significantly influenced by vegetation cover. Studies have shown that vegetation can strengthen the shear capacity of the soil through the root system, which has the effect of soil consolidation and slope protection. Therefore, the stability of slope increases with increasing vegetation density. Therefore, NDVI is used to quantitatively assess the degree of vegetation cover. NDVI map of the study area is given in “Figure 8”.

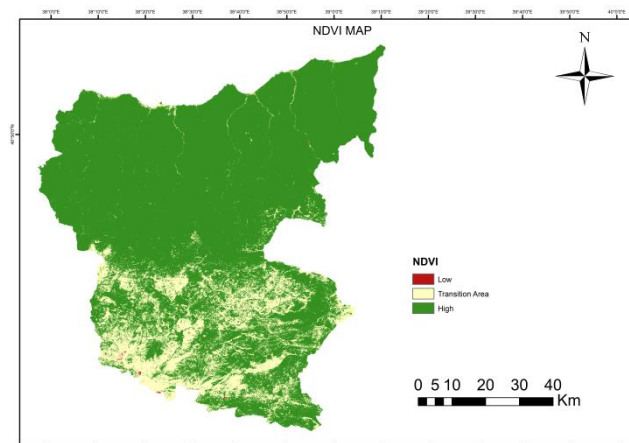


Figure 8. NDVI map of Giresun province.

2.4.8. Land Cover : Land use types reflect the intensity of human activities affecting the mountain environment (Carrara et al., 1991; Demir et al., 2013). In general, the degree of human activity in construction areas is the strongest and causes the most damage to the stability of rocks, which increases the risk of landslides. In addition, human activities such as farming and deforestation can also affect the stability of rocks and cause landslides. The land cover map of the study area is given in “Figure 9”.

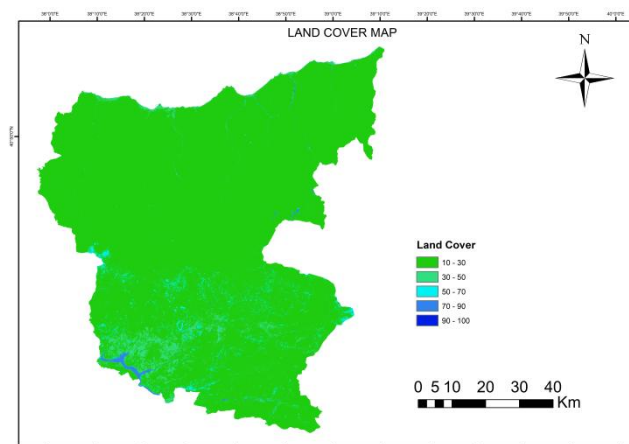


Figure 9. Land cover map of Giresun province.



2.4.9. Land Surface Temperature : The warming of the world climate system is certain. It is also indisputable that climate changes affect the stability of natural and engineered slopes and lead to landslides. Less clear are the type, extent, magnitude and direction of changes in stability conditions and the location, amount, activity and frequency of landslides in response to predicted climate changes. Climate and landslides act only at partially overlapping spatial and temporal scales, making it difficult to assess the effects of climate on landslides. A sudden increase in temperature after heavy snowfall triggers landslides. The land surface temperature map of the study area is given in “Figure 10”.

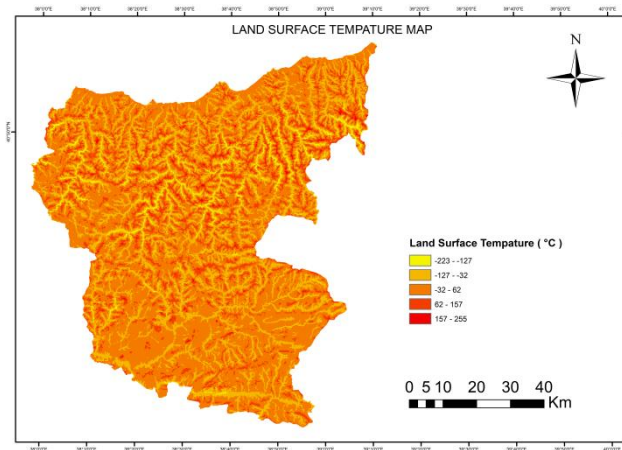


Figure 10. Surface temperature map of Giresun province.

2.4.10. Landforms : In physical geography, land is any piece of earth or soil. Often the altitude of land features affects the terrain, surface water runoff and distribution, and can influence weather and climate patterns over a large area. The landforms map of the study area is given in “Figure 11”.

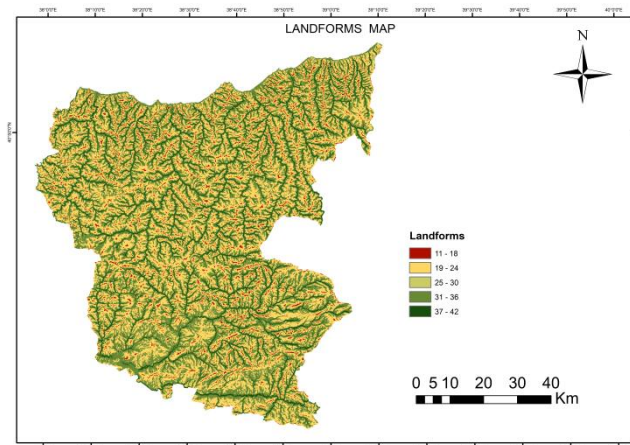


Figure 11. Landforms map of Giresun province.

2.4.11. Surface Water : Generally, landslides occur more frequently in rainy seasons or when the ground is wet. Heavy and continuous rains, or melting of snow, allow more water to infiltrate into the cover on the bedrock or ground. In this case, slipping becomes easier and the angle of equilibrium decreases. Since the weight of the cover increases and friction decreases at the same time, landslide formation becomes easier. The presence of rocks saturated with water accelerates landslide formation. The most favorable formations for this are clayey rocks. Since clayey rocks will absorb water in the rainy season and get wet, they gain a slippery feature. The surface water map of the study area is given in “Figure 12”.

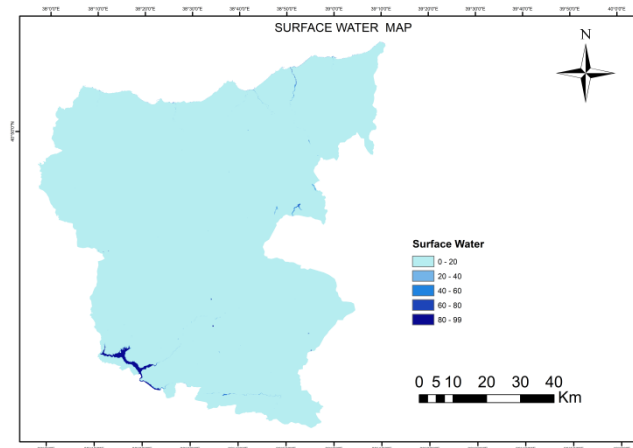


Figure 12. Surface water map of Giresun province.

2.5. Data Collection and Preparation

In this study, landslide susceptibility map was produced by using topographic index, elevation, slope, aspect, land cover, proximity to rivers, surface water, NDVI, surface temperature parameters. These parameters were downloaded by writing appropriate codes using GEE software language and maps of Giresun province were downloaded and then uploaded to ArcGIS. Classified maps were created using the reclassification method and the weight of each factor was determined by evaluating the factors with the Multi-Criteria Decision-Making Method considering the previous studies and the lithological structure of Giresun Province. The Best Worst Method (BWM) method was used by dividing into sub-factors under three main headings, paying attention to the total weight to be one.

3. DISCUSSION

In this study, it was aimed to produce a landslide susceptibility map of Giresun city Centre. According to the landslide risk map, it is seen that there are very high-risk areas in terms of landslide risk in Giresun province. These areas correspond to a very small part of the entire study area. However, since they are located on the residential areas, it is seen that they are the most likely to be damaged in case of a landslide that may occur. When the areas with high landslide risk are analyzed, it is understood that they are generally the ones that are directly proportional to precipitation and slope and where the land cover is relatively sparse.

In the production of the susceptibility map, the GIS stratified best-worst method (BWM) method, which is widely used in the literature, was used. Eleven factors were considered in the study: topographic index, elevation, slope, aspect, land cover, proximity to rivers, surface water, NDVI, surface temperature. During the study, these factors were downloaded using Google Earth Engine software language and then mapped in ArcGIS and a new landslide susceptibility assessment model was proposed by integrating GIS with stratified best-worst method (BWM).

4. CONCLUSION

Mass movements that caused loss of life and property in Giresun province have mostly developed in the form of shallow landslides. Landslides occur in valley floors and areas with high humidity. With this information, the areas that will be affected in the event of a possible landslide in Giresun province have been determined. For this, effective slope, aspect, division, NDVI, land cover, topographic index, land cover proximity to the stream, surface temperature, land surface, surface water criteria were considered in terms of landslide risk. First, these changes were downloaded through GEE software. Then, the maps belonging to these costs were ArcGIS' features. A criterion was separated from the subclasses and weighted between 1 and 9 and reclassified according to these values. Landslide map was carried out using BMW . Landslide susceptibility map of the study area is given in "Figure 13".

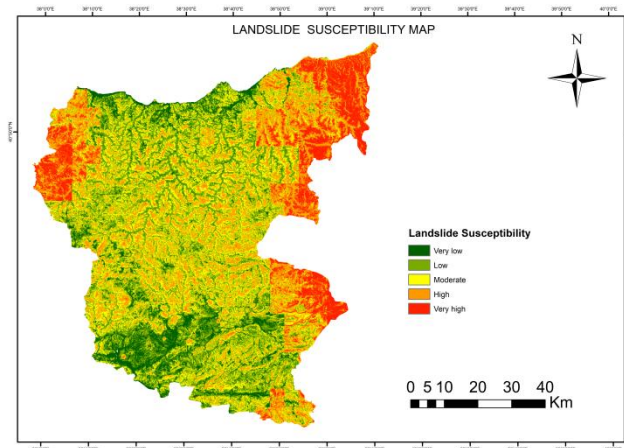


Figure 13. Landslide susceptibility map

Obtaining more comprehensive results of the effective criteria in the analysis. In addition, benefiting from higher data loss and obtaining more sensitive results will be beneficial. Risk studies in the region should be increased and more detailed studies should be conducted. It should be taken in a way that minimizes the risk, and early warning systems should be developed. In order to prevent the damages that landslides will cause, especially in densely populated residential areas, the necessary planning should be made in terms of risk for these areas. Construction should not be allowed in areas where the risk is high, where there is a lot of rain and slope. The masses of people living in the region and the social and economic damages they will cause should be enlightened and their necessary care should be provided. When all the results obtained are evaluated, it is seen that landslide areas are of critical importance in places that are very closely related to human life and are usually crowded, such as schools, hospitals, sports centers, culture and art centers, entertainment centers, and even in places where their distribution is very sparse on the map. Because landslides are not only human-focused, they are a matter that closely concerns all living things. It was stated that landslide maps can be used as a basis for taking the necessary precautions in areas that pose a risk and determining new infrastructure and superstructure facilities. It is very important for growth planning activities in order to protect landslide-related material and moral losses, especially in disasters where landslide maps are kept accurate and up-to-date. The most important issue that should be taken into consideration by researchers in the life of landslide maps is the necessity of re-life of these maps according to the duration of current data. Living conditions and needs are changing data and components of the components that need to be collected.

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