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Research Article

Examination of the Highway Between Isparta-Ağlasun (Burdur) in Terms of Mass Movement Susceptibility Geographic Information Systems

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Abstract:

In our country, mass movements such as landslides, rockfalls and avalanches are the most common types of disasters after earthquakes in terms of their destructive effects. The aim of the study is to determine the susceptibility of mass movements on sloping surfaces along the Isparta-Ağlasun road route and its surroundings. The study area includes approximately 41 kilometers of highway route between Isparta city centre and Ağlasun districts. Steep slopes on the road, loose soil properties in places, and torrential rains cause frequent rock falls, slope debris and mud flows on the study area. It is extremely important to identify the areas susceptible to ground movements along the route in order to take necessary precautions and prevent future loss of life and property. For this purpose, the parameters that are thought to cause mass movements along the road route were evaluated together with Geographical Information Systems program and Analytical Hierarchy Method and the areas sensitive to low-medium-high and very high mass movements along the route were determined. The susceptibility map obtained was supported by field observations. With this study, areas sensitive to mass movements along the route were mapped and a database was created to help local administrators and planners.

1. Introduction

Mass movements are a general definition that refers to the movement of all kinds of natural materials down the slope. Landslides have the highest impact among mass movements which are divided into various classes such as soil flow, mud flow, rock fall, snow and debris avalanches [1]. In terms of Turkiye, earthquakes, landslides and floods are the most damaging disaster types. Mass movements rank first in terms of the number of disaster events and the number of settlements affected by disasters, and second after earthquakes in terms of the number of houses affected by natural disasters. The ratio of the places where mass movement events occur to the total settlement units corresponds to a very high value of 15.31% [2,3].

In addition to social and economic losses as a result of mass movements, they also causes significant environmental problems such as damage to forest and vegetation cover, soil losses, and decrease in river quality [4]. Therefore, it is important to create mass movement susceptibility maps to identify landslide areas and minimise losses. These maps are also critical for disaster planning.

Geographical Information Systems (GIS) techniques are widely used in determining disaster susceptibility, hazard and risk areas. Additionally, the Analytic Hierarchy Process (AHP) utilized in this technique is a frequently employed modelling method [5-11].

In this study, a mass movement susceptibility analysis of the approximately 40 km D-685 road route between Isparta and Ağlasun was carried out and the findings were supported by field studies. In this way, it is aimed to guide the local administration and decision-makers in order to minimise the losses and take the necessary measures for mass movements that may occur in the future.

2. Material and Methods

2.1. Study Area

The study area covers a 40 km road route starting from the centre of Isparta Province to Ağlasun District centre of Burdur Province (Figure 1). The study area within the boundaries of M25-d1 and M25-d2 topographic plan is surrounded by high mountains. The road route located in the southern and eastern part of Akdağ on the Western Taurus Mountains is at an average altitude of 1000 meters above sea level. There are transitions between continental climate and Mediterranean climate in the region.

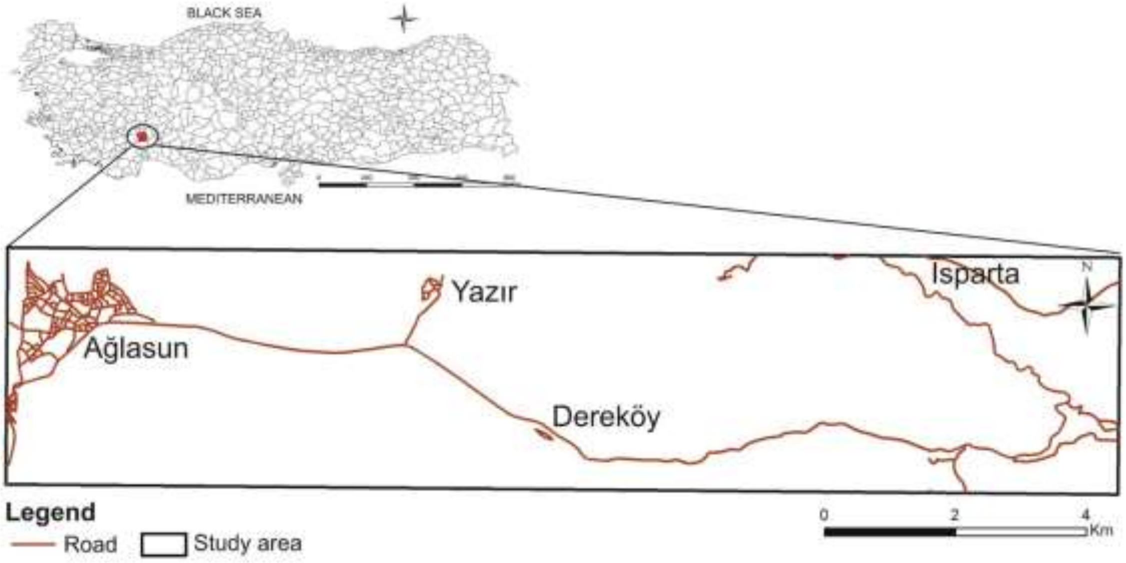

Figure 1. *Location map*

There are volcanic sedimentary rocks, limestone, sandstone and mudstone succession, slope debris and puddle cones and alluvial units along the highway in the study area. During the field studies, it was observed that gravel and block-sized materials were frequently rolled from the slopes towards the road, especially after heavy rains, and from time to time, mud material in the form of runoff blocked the road route.

2.2. Proposed Method

Each mass movement susceptibility assessment method has its own advantages and disadvantages [12-14]. A mass movement susceptibility study is expected to clarify where, under what conditions and in what types mass movement may occur in the future [13]. In this way, potential areas for future mass movements can be identified. There are many factors that can cause mass movements. Lithology, slope, aspect and land use parameters are the most commonly used parameters in the literature [15,16]. In this study, lithology, slope gradient, land use, precipitation, distance to road, distance to fault, aspect, curvature, elevation, distance to stream parameters were used considering the field observations and literature studies.

In this study, AHP and GIS were used in combination to assess the mass movement susceptibility in the selected region. The AHP method is a multi-criteria decision-making process that uses the relative importance of the parameters contributing to the event to produce parameter weights and evaluates the consistency of the pairwise comparison parameters [17-19]. Pairwise comparison is the basic measurement in the context of the AHM procedure, using a scale from 1 to 9, where 9 is the most important and 1 is the least important [20]. With these techniques, each parameter important for mass movement susceptibility maps is organised into a matrix (Table 1). One of the strengths of the pairwise comparison method is the calculation of the consistency index (CI) (Equation 1) and the consistency of the comparison matrix (CR) (Equation 2), which are related to the eigenvalue method. The random index value (RI) corresponding to each n value used in the CR calculation is given in Table 2.

$$CI = (\lambda max - n) / (n-1) \qquad (1)$$

$$CR = CI / RI \qquad (2)$$

Table 1. *The binary comparison matrix of the factors causing the mass movement and the weight of importance*

Slope CR=%2										
0-10	1									0.049
10-20	2	1								0.071
20-30	4	3	1							0.154
30-40	6	4	2	1						0.256
>40	8	6	3	2	1					0.470
Distance to road CR=%5										
200 m	1									0.494
400 m	1/4	1								0.213
600 m	1/5	1/2	1							0.127
800 m	1/6	1/3	1/2	1						0.082
1000 m	1/8	1/5	1/3	1/2	1					0.051
>1000 m	1/9	1/7	1/4	1/3	1/2	1				0.033
Lithology CR=%3										
Limestone	1									0.490
Volcanic sediment	1/3	1								0.193
Ophiolitic rock	1/4	1/2	1							0.128
Hillside rubble	1/5	1/3	1/2	1						0.088
Sandstone-mudstone	1/7	1/4	1/3	1/2	1					0.059
Alluvium	1/9	1/5	1/5	1/3	1/2	1				0.043
Precipitation CR=%6										
650-700 mm	1									0.035
700-750 mm	3	1								0.069
750-800 mm	5	3	1							0.136
800-850 mm	7	5	3	1						0.286
>850 mm	9	7	5	2	1					0.474
Land use CR=%5										
Forests	1									0.163
Mixed agricultural areas	1	1								0.163
City structure	1/7	1/7	1							0.042
Maki or herbaceous plants	3	3	8	1						0.490
Arable areas	1	1	6	1/4	1					0.142
Elevation CR=%6										
680-900 m	1									0.035
900-1100 m	3	1								0.069
1100-1300 m	5	3	1							0.136
1300-1500 m	7	5	3	1						0.286
1500-1630 m	9	7	5	2	1					0.474
Distance to stream CR=%8										
200 m	1									0.377
400 m	1/2	1								0.297
600 m	1/3	1/3	1							0.165
800 m	1/5	1/5	1/3	1						0.088
1000 m	1/7	1/7	1/5	1/3	1					0.047
>1000 m	1/9	1/9	1/7	1/5	1/3	1				0.026
Distance to fault CR=%3										
0-200 m	1									0.446
200-400 m	1/2	1								0.243
400-600 m	1/4	1/2	1							0.125
600-800 m	1/5	1/4	1/2	1						0.081
800-1000 m	1/6	1/5	1/3	1/2	1					0.060
>1000 m	1/8	1/6	¼	1/3	1/2	1				0.044
Curvature CR=%7										
Concave	1									0.690
Flat	1/9	1								0.067
Convex	1/3	6	1							0.243
Aspect CR=%4										
Flat	1									0.036
North	4	1								0.062
Northeast	1/2	1/3	1							0.031
East	4	1	3	1						0.057
Southeast	1	1/3	1	1/4	1					0.030
South	2	1/2	3	1/3	3	1				0.041
Southwest	7	5	8	6	9	7	1			0.293
West	7	5	8	6	8	7	1	1		0.292
Northwest	5	3	6	4	6	5	1/2	1/2	1	0.158

Table 2. *Random index (RI) values*

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57

2.2.1. Slope

Slope gradient is considered as one of the most important topographic factors affecting mass movement [21-24]. Generally, mass movement is expected to occur at the steepest slopes. In obtaining the slope maps, M25d1 and M25d2 topographic maps covering the study area were digitized using ArcGIS 10 software and Digital Elevation Model (DEM) maps with cell sizes of 1*1 meter were obtained using contour lines. Slope maps of the region were produced using DEM maps and these maps were divided into 5 different slope classes (Figure 2a).

2.2.2. Distance to Road

During the field studies, it was observed that a large number of block and gravel sized materials were rolled to Isparta - Ağlasun road route especially after the rainfalls. The main factor here is due to the fact that the stability of the geological material in the region has deteriorated and the potential of the material to move has increased in the cuts opened for road works. At the same time, the vibrations made by the vehicles passing on the road trigger the movement of this material. In this study, the distance to road factor is divided into 6 classes (Figure 2b).

2.2.3. Lithology

Lithological features are directly related to many properties of rocks such as strength, permeability and hardness [25]. The study area consists of limestone, sandstone-mudstone, volcanic sediments, deposition cones, ophiolitic rock and alluvium (Figure 2c). During the field studies, it was observed that these rocks forming the region have many fracture crack systems. It was observed that freezing and thawing in these fracture systems during winter months accelerated the fracturing of the rocks and the block and gravel sized material endangered the traffic flow on the road with the effect of factors such as slope and precipitation.

2.2.4. Precipitation

Precipitation factor is a parameter that should be used in mass movement hazard analyses and its use in susceptibility analyses is mostly associated with topographic height [26]. The stability of the slope, whose weight increases due to precipitation, deteriorates and may cause mass movement. In addition, the water seeping into the ground accelerates the sliding by making the layers containing clay and marl slippery. Considering the precipitation data obtained from Ağlasun Meteorological Station and topographic heights in the study area, the formula of 54 mm precipitation increase per 100 meters determined by Scheiber (1904) was taken into consideration and a precipitation map was created in GIS environment (Figure 2d) [3].

2.2.5. Land use

The presence of vegetation reduces the effect of rainfall on the ground due to its ability to absorb and evaporate water. In addition, while the soil retention of the roots positively affects the slope stability, the weight created by the trees on the slope has a negative effect. Dynamic loads caused by wind are also transferred to the ground by plants [27]. As a result, it is seen that woody plants have an effect in both directions in terms of slope stability. However, it has been reported that areas with dense vegetation have lower susceptibility in terms of slope stability compared to areas devoid of vegetation [28,29]. In the present study, the forest areas that constitute the land area were considered as low susceptibility, while herbaceous and maquis areas were considered as high susceptibility areas. While evaluating the urban structure and agricultural areas within the study area, the slope factor was also taken into consideration together with the land structure. Corine 2018 data of the Ministry of Agriculture and Forestry and field observations were used in the creation of the land use map [30] and mapped in GIS environment (Figure 2e).

2.2.6. Elevation

Altitude is an effective factor in mass movement stability [31]. It has been reported that mass movement is more frequent in regions with high altitude [32]. The minimum altitude of the study area is 680 meters and the maximum altitude is 1630 meters. The elevation map was obtained from the DEM map with 1*1 resolution and divided into 5 class intervals (Figure 2f).

2.2.7. Distance to Stream

Streams may adversely affect the stability by eroding the slopes or saturating the lower part of the material, causing the water level to rise and the ground to become saturated with water [33]. In addition, they may cause erosion on the land and may affect the deterioration of the heel balance on the slopes and the formation of mass movement. In the study, the areas close to the rivers were evaluated as highly susceptibility, while the distant areas were determined as low susceptibility (Figure 2g).

2.2.8. Distance to The Fault

Faults are an important susceptibility factor. High fault zones are areas with a particularly high incidence of unstable slopes and the degree of fracture and slip plays an important role in determining slope stability [34]. In general, it has been observed that the probability of mass movement increases close to the linearity [9]. In this study, six different buffer zones were created for the existing faults at 200 m intervals (Figure 2h).

2.2.9. Curvature

Whether the slope is concave, convex or flat is another factor taken into consideration in the analyses. The slope of convex slopes is higher than concave slopes. Therefore, the flow rate of water is higher on convex slopes and soil moisture is relatively lower [35]. In the maps made with GIS software, positive values indicate convex, negative values indicate concave and values close to zero indicate flat curvatures (Figure 2ı).

2.2.10. Aspect

The aspect factor is mostly associated with the rainfall or lack of rainfall on the slopes and the condition of sun rays. The permeability, porosity and vegetation cover of the slopes that receive intense rainfall can also be associated with the saturation and increase in pore water pressure with the effect of factors such as vegetation cover [26]. In this study, the aspect factor is divided into 9 classes (Figure 2j).

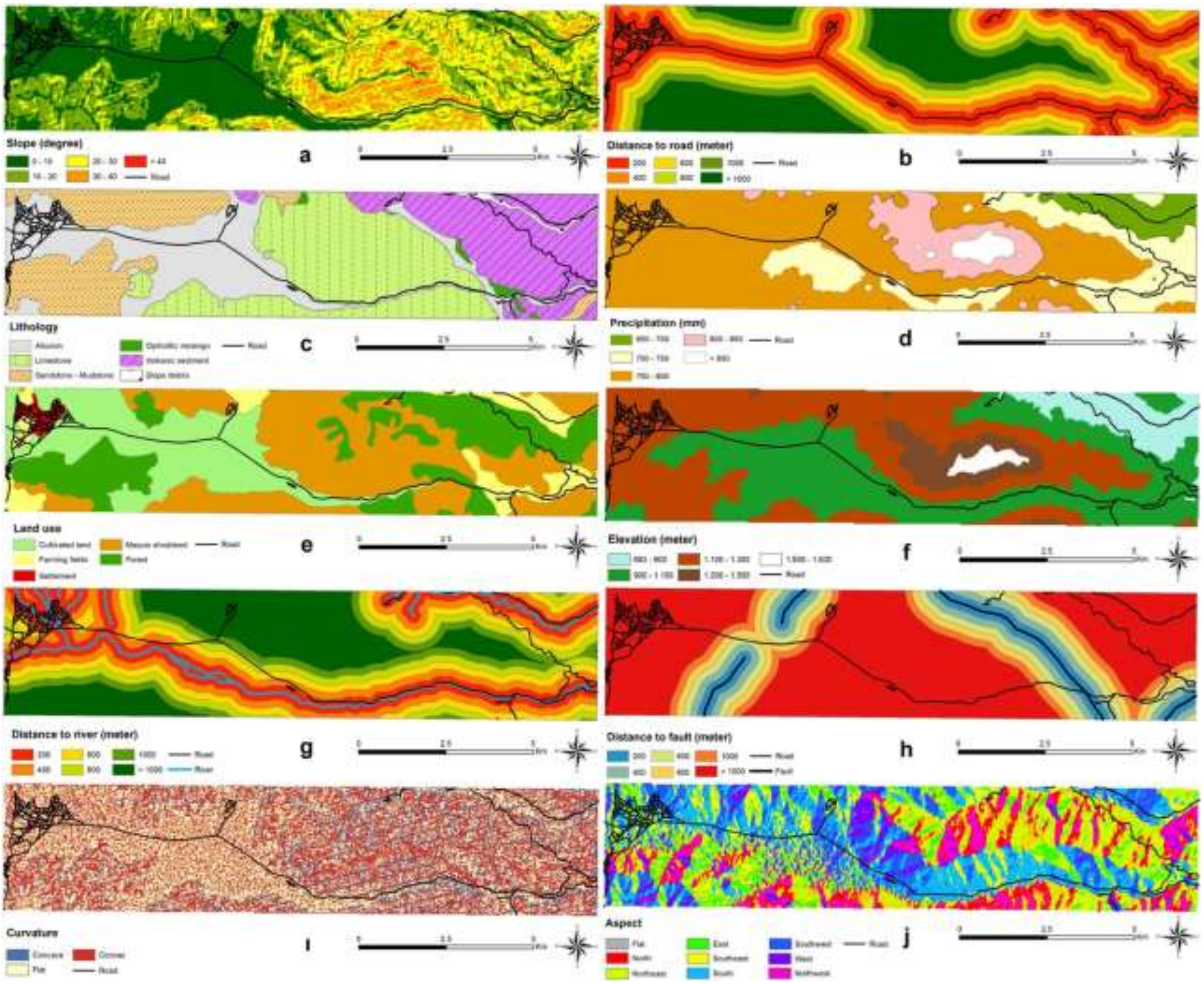

Figure 2. *Factor maps used in mass movement susceptibility are: a) slope b) distance to the road c) lithology d) precipitation e) land use f) elevation g) distance to the stream h) distance to the fault i) curvature j) appearance*

3. Results and Discussions

In the AHM method, each layer is divided into smaller factors and these factors are formed according to their importance. Each factor takes a value between 1 and 9 when compared with other factors. The preference values for the study are given in Table 1. An important advantage of the AHP is the ability to identify rating inconsistencies with the consistency index (CI). As seen in Table 1, all CR values obtained are less than 0.10, which is considered as the highest value. The values given in the last column of Table 1 give the weight values for each causal factor (Table 3). These weight values indicate the degree of importance of the factor or class.

Table 3. *Total weight values of sub-factors*

Factors	Sub-factors	Weight value of factors	Weight value of sub-factors	Total weight value
Slope	0-10	0.292	0.049	0.0143
	10-20		0.071	0.0207
	20-30		0.154	0.0449
	30-40		0.256	0.0747
	>40		0.470	0.1372
Distance to Road	200 m	0.213	0.494	0.1052
	400 m		0.213	0.0454
	600 m		0.127	0.0270
	800 m		0.082	0.0175
	1000 m		0.051	0.0108
	>1000 m		0.033	0.0070
Lithology	Limestone	0.149	0.490	0.0730
	Volcanic sediment		0.193	0.0287
	Ophiolitic rock		0.128	0.0191
	Hillside rubble		0.088	0.0131
	Sandstone-mudstone		0.059	0.0088
	Alluvium		0.043	0.0064
Precipitation	650-700 mm	0.107	0.035	0.0037
	700-750 mm		0.069	0.0074
	750-800 mm		0.136	0.0145
	800-850 mm		0.286	0.0306
	>850 mm		0.474	0.0507
Land Use	Forests	0.078	0.163	0.0127
	Mixed agricultural areas		0.163	0.0127
	City structure		0.042	0.0033
	Maki or herbaceous plants		0.490	0.0382
	Arable areas		0.142	0.0111
Elevation	680-900 m	0.054	0.035	0.0019
	900-1100 m		0.069	0.0037
	1100-1300 m		0.136	0.0073
	1300-1500 m		0.286	0.0154
	1500-1630 m		0.474	0.0256
Distance to Stream	200 m	0.036	0.377	0.0136
	400 m		0.297	0.0107
	600 m		0.165	0.0059
	800 m		0.088	0.0032
	1000 m		0.047	0.0017
	>1000 m		0.026	0.0009
Distance to Fault	0-200 m	0.028	0.446	0.0125
	200-400 m		0.243	0.0068
	400-600 m		0.125	0.0035
	600-800 m		0.081	0.0023
	800-1000 m		0.060	0.0017
	>1000 m		0.044	0.0012
Curvature	Concave	0.024	0.690	0.0165
	Flat		0.067	0.0016
	Convex		0.243	0.0058
Aspect	Flat	0.020	0.036	0.0007
	North		0.062	0.0012
	Northeast		0.031	0.0006
	East		0.057	0.0011
	Southeast		0.030	0.0006
	South		0.041	0.0008
	Southwest		0.293	0.0059
	West		0.292	0.0058
	Northwest		0.158	0.0032

According to these results, among the mass movement factors, slope (0.292), distance to road (0.213) and lithology (0.149) have the highest values, while distance to fault (0.028), curvature (0.024) and aspect (0.020) have the lowest values. Finally, the mass movement susceptibility index was calculated by a procedure based on weighted linear summation. The overlay analysis method was then used to generate mass movement susceptibility maps with Arc GIS Spatial Analysis module and the study area was divided into 4 different mass movement susceptibility zones: low, medium, high and very high (Figure 3).

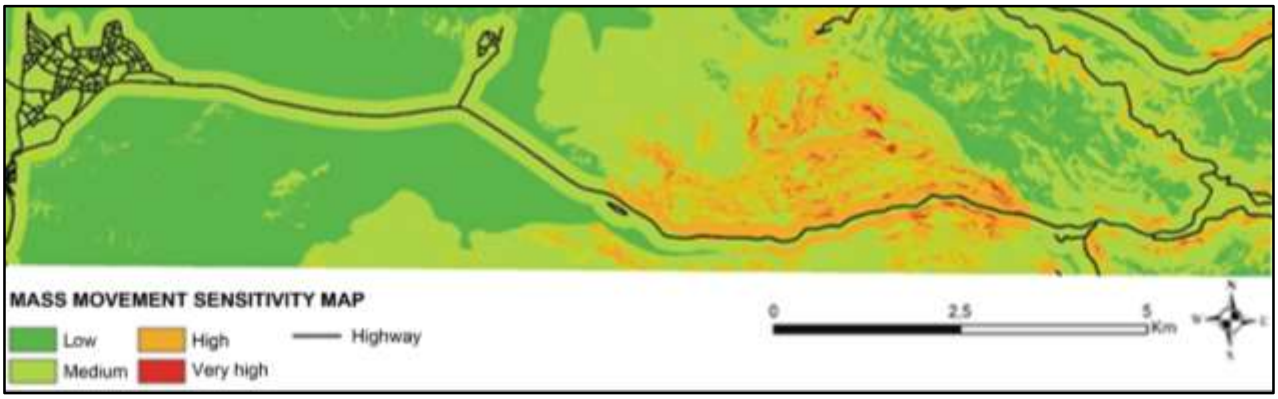

Figure 3. *Study area mass movement susceptibility map*

As a result of this study, it was observed that the road route from Isparta-Ağlasun road junction to Dereköy has the highest values in terms of mass movement susceptibility. The results obtained on the map also support the field observations. It has been observed by the researchers that there is frequent flow of block and gravel-sized material in the area in question, especially during rainy periods, and mass movements in the form of mud flow occur in places.

4. Conclusions

In our country, mass movements are second only to earthquakes among the types of disasters with the most damaging effects. Unplanned and unconscious urbanization and population growth are important factors that increase material and moral losses. While geological, geomorphological and climatic conditions determine the formation of mass movement, human impact can also trigger these conditions. For this reason, it is not easy to predict where and when a mass movement will occur. GIS with AHM is an effective approach to determine mass movement susceptibility.

In the applied method, DEM maps with a resolution of 1 meter were produced in the study area and overlap analysis was performed according to the impact values by considering 10 factors such as slope, distance to road, lithology, precipitation, land use, elevation, distance to stream and fault, curvature and aspect. According to the mass movement susceptibility map obtained, it was found that the route of approximately 30 kilometers from Ağlasun road junction at the 20th kilometer of Isparta-Antalya highway to Dereköy has a high susceptibility in terms of mass movement. During field studies, rock and block falls and mud flows were determined in the area in question, especially during periods of rainfall. The mass movement susceptibility map created in this area will be helpful for planners, engineers and highways in reducing damage risks, planning disaster management, avoiding risky areas when building cities and building retaining walls in appropriate areas.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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