Jeomorfolojik Araştırmalar Dergisi
Journal of Geomorphological Researches
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Teknik Not / Technical Note

Sağlık District Landslide (Ordu, Turkey)

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Makale Tarihçesi
Geliş 15 Ekim 2020
Düzenleme 13 Aralık 2020
Kabul 17 Ocak 2021

Article History
Received October 15, 2020
Received in revised form December 13, 2020
Accepted January 17, 2021

Anahtar Kelimeler
Atterberg Limitleri, Heyelan, Ordu, Karadeniz Bölgesi, Türkiye

Keywords
Atterberg Limits, Sağlık District Landslide, Ordu, Black Sea Region, Turkey

Atıf Bilgisi / Citation Info
Hatipoğlu, İ.K., Uzun, A., Zeybek, H.İ., Hatipoğlu, Ş.C. (2021) Sağlık Mahallesi Heyelanı (Ordu, Türkiye) / Sağlık District Landslide (Ordu, Turkey), Jeomorfolojik Araştırmalar Dergisi / Journal of Geomorphological Researches, 2021 (6): 56-66
doi: 10.46453/jader.811124

ABSTRACT

Landslides cause loss of life and property from time to time. In Turkey, the Black Sea Region is the region where landslides are seen most frequently. In this study, Sağlık District Landslide that occurred on May 15th, 2019 in the Central Black Sea Region was examined. This study aims to investigate the occurrence of landslide and its consequences. For this purpose, area was visited and measurements were performed, soil samples and photos were taken. The region which has a rough terrain, receives precipitation throughout the year. The site has volcanic bedrock and thick debris and ground cover on it. The liquefaction limit of the soil is between 45.7 and 47.8 and the plasticity limit is between 20.51 and 22. Snowmelt is the main factor that triggers landslides in the work area. Also, turning forests into agricultural areas, opening roads crossing the slopes, additional weights created by houses, water leaking from the sewer network to the ground among preparative conditions of landslides. Stress cracks that started to occur in the crown part of the landslide three years ago started to expand on the day of the incident. The authorities who realized this evacuated the houses being under threat. Despite this, 22 buildings were destroyed and 8 hectares of agricultural land were damaged. It has been proposed to establish new settlements far from the landslide zone and the people in the landslide zone be moved to safe areas.

1. INTRODUCTION

Landslides are among natural events that change the earth in the fastest way but they do not attract the attention of people much unless they affect people and their works. Landslides are mostly prepared and triggered by natural conditions, but increasing population, widening residential areas and tightening transportation networks have increased people's probability of encounter with landslides. On the other hand, people who want to benefit more from their living space can sometimes cause the formation of landslides by affecting natural processes.

Landslides are among the most common and deadly natural disasters in the world. Each year, they cause an average of over 1000 casualties and hundreds of millions of dollars of material damage (Clague & Roberts, 2012). According to data, landslides are responsible for about 17% of those who die from natural disasters every year (Kjekstad & Highland, 2009).

Landslides cause loss of life and property from time to time in Turkey as they occur in other regions of the world. For this reason, studies that discuss the causes and consequences of landslides in the literature take a large place (Kopar, 2010; Bayrakdar & Görüm, 2012; Filiz & Avcı, 2013; Aydın et al., 2015; Avcı, 2016a; Kadıoğlu et al., 2017; Zengince & Karakaş, 2018). In addition, GIS-based landslide risk analysis studies prepared by using statistical data are also remarkable (Yalçın, 2007a; 2007b; Acar et al., 2008; Dağ & Bulut, 2012; Eker et al., 2013; Özşahin, 2014; Avcı, 2015, Avcı, 2016b; Cihangir & Görüm, 2016; Sunkar & Avcı, 2016; Akıncı et al., 2017; Akgün, 2018; Demir, 2018; Hepdeniz & Soyaslan, 2018; Aghlmand et al., 2020; Kılıçoğlu, 2020).

The Black Sea Region is the region where landslides are seen most frequently because of suitable climate and ground conditions (Öztürk 2002; Uzun & Uzun, 2003a; Dölek, 2008; Dağ & Bulut, 2012; Filiz & Avcı, 2013; Aydın et al., 2015; Cihangir & Görüm, 2016; Kadıoğlu et al., 2017; Baştuğ & Gürbüz, 2019; Kılıçoğlu, 2020). In this study, Sağlık District Landslide that occurred on May 15th, 2019 in the Central Black Sea Region within the borders of Aybastı District of Ordu was examined (Figure 1).

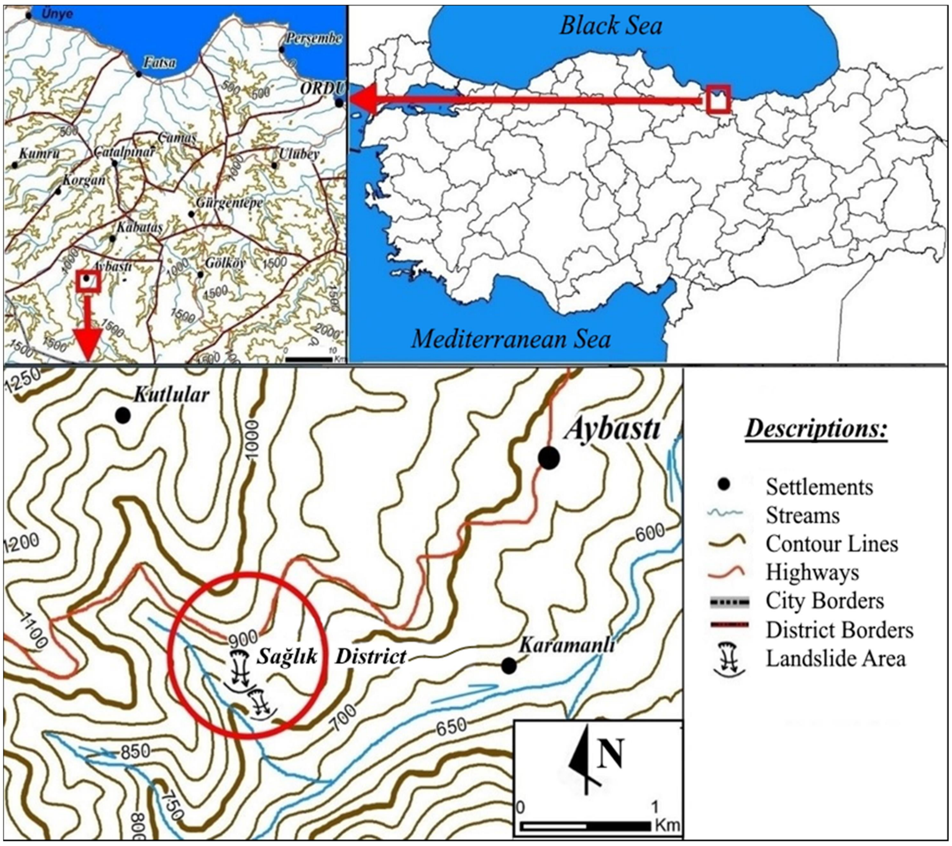

Figure 1: Location Map of Sağlık District Landslide

This study aims to investigate the occurrence of landslide and its consequences. The first findings of this research were presented in the scientific meeting "International Symposium on Geomorphology - 2019" held on 10 - 12 October 2019 and published in the proceedings book as a summary. Black Sea Region has suitable climate, bedrock and slope conditions for landslide formation. The region receives precipitation throughout the year and it falls in the form of snow from time to time in winters. Melting snow and rainwater seep into the ground and weaken the bond strength (Uzun & Uzun, 2005; Yılmaz et al., 2012; Uzun et al., 2016). The scattered settlement pattern dominating the region and radical changes in land use bring about landslide formation (Uzun & Uzun, 2003a; Uzun & Uzun, 2003b). Forests are transformed into agricultural areas, dwellings are spreading to sizeable areas, and car roads that are increasingly frequent and mostly perpendicular to the slope direction make the slopes more unstable. On the other hand, unplanned and uncontrolled settlement especially in rural areas caused the use of high-risk areas, sometimes directly landslide areas, as residential area. Similar problems have been raised in some previous studies (Öner & Çiçek, 1987; Uzun, 1987; Akkan & Gürgen, 1993; Korkmaz, 2000). The Sağlık District Landslide, which is the subject of this study, also contains conditions summarized above and shows a typical landslide area feature. Houses in high-risk areas should be evacuated, as in the Sağlık District; GIS (Geographic Information Systems) and engineering services should be used more in determining new settlements and road routes.

2. MATERIAL and METHOD

The day after the landslide incident, the research site was visited and the first observations were made. Subsequently, necessary permits were got for fieldwork and land work was carried out between 29 and 31 May 2019. The related literature has been examined and evaluated before field studies. Climate data belonging to the site were provided by DMİGM (General Directorate of State Meteorology Affairs), geological maps by MTA (Mineral Exploration and Exploitation) and topography maps by HGK (Map General Command). The pre-landslide images of the site were accessed via the Google Earth software. The collected data were transferred to GIS environment and evaluated using ArcGIS 10 software. Map and block diagrams of the field were created with GIS applications.

While examining the climate of the research area, the data of Aybastı Meteorology Station, which was measured regularly between 1978-1993, were used. This station was closed in 1993 and replaced by an unmanned station in 2012. In the daily precipitation evaluations, the data of this new station were used. During the field studies, photographs were taken, videos were made, rock and soil samples were taken, necessary measurements were made and interviews were done with local people. Within the scope of laboratory studies, the consistency limits of the soils (Atterberg limits) were examined. Liquid limit (LL) and plastic limit (PL) values of samples taken from crown areas were measured, and plasticity indexes (PI) were found by using PI = LL-PL equation. The obtained data were interpreted by reading Cassagrande Plasticity Card.

3. RESULTS

3.1. Natural Environment Features of Landslide Site and Its Surroundings

The landslide site and its immediate surroundings were deeply divided by Aybastı Creek and its tributaries, which one of main tributaries of Bolaman Creek, and a rugged terrain emerged (Figure 2). In this section, Aybastı Creek flowing in the direction of SW-NE formed an asymmetrical valley with a depth exceeding 500 meters in some places. The south-facing hillside of the valley is slightly sloping while the north-facing hillside is very sloping. Sağlık District was established on the south-facing hillside which has more favorable slope and sunbathing conditions for the settlement. The average slope of this hillside was measured as 22%.

The Black Sea coast has a humid and temperate climate. However, since the study area is located in higher and higher point than the shore, especially winter months are colder and snowy. The annual average temperature in the field is 9.8 °C and annual total precipitation is 827.5 mm (Table 1). Rainfall in the region is distributed throughout the year. For this reason, soil moisture is generally high. In addition, the number of snow days in the field is 33.9 days (Table 1). Snowy days start in November and end in May. This situation shows that especially towards the end of spring due to warming of weather, snow melting is also effective in saturating the ground with water. In this way, the water weakens the bond strength by infiltrating the ground (Figure 3). Thus, the field becomes very suitable for landslides. The fact that the ground is saturated with water and the land is divided by deep valleys has led to the emergence of numerous springs. Both rain and melting snow waters and waters coming from springs to the ground are drained by Aybastı Creek. The creek joins Bolaman Creek in the north of Kabataş District center and pours into the Black Sea in the east of Fatsa city center.

In fact, it was thought that it would be more appropriate to use snow depht data instead of snowy days in this study. However, snow depht data were not found among the data of Aybastı Meteorology Station, where measurements were made for a short time (1978 – 1993).

The research area and its immediate surroundings are in the broad-leaved forest area of the Black Sea coastal zone. However, the forests on the site have been heavily destroyed to provide firewood and supplies, and especially to open up agricultural land. In areas that can survive after destruction, forest elements like Beech (*Fagus orientalis*), Hornbeam (*Carpinus sp.*), Chestnut (*Castanea sativa*), Lime (*Tilia rubra*), Common Ash (*Fraxinus ornus*), Alder (*Alnus sp.*), Maple (*Acer sp.*), Oak (*Quercus sp.*) and tree and shrub species like Rowan (*Sorbus sp.*), Rosehip (*Rosa canina*), Hazel nut (*Corylus avellana*) and Rhododendron (*Rhododendron ponticum, Rhododendron luteum*) were found. The places gained from the forest were turned into hazelnut orchards and fields.

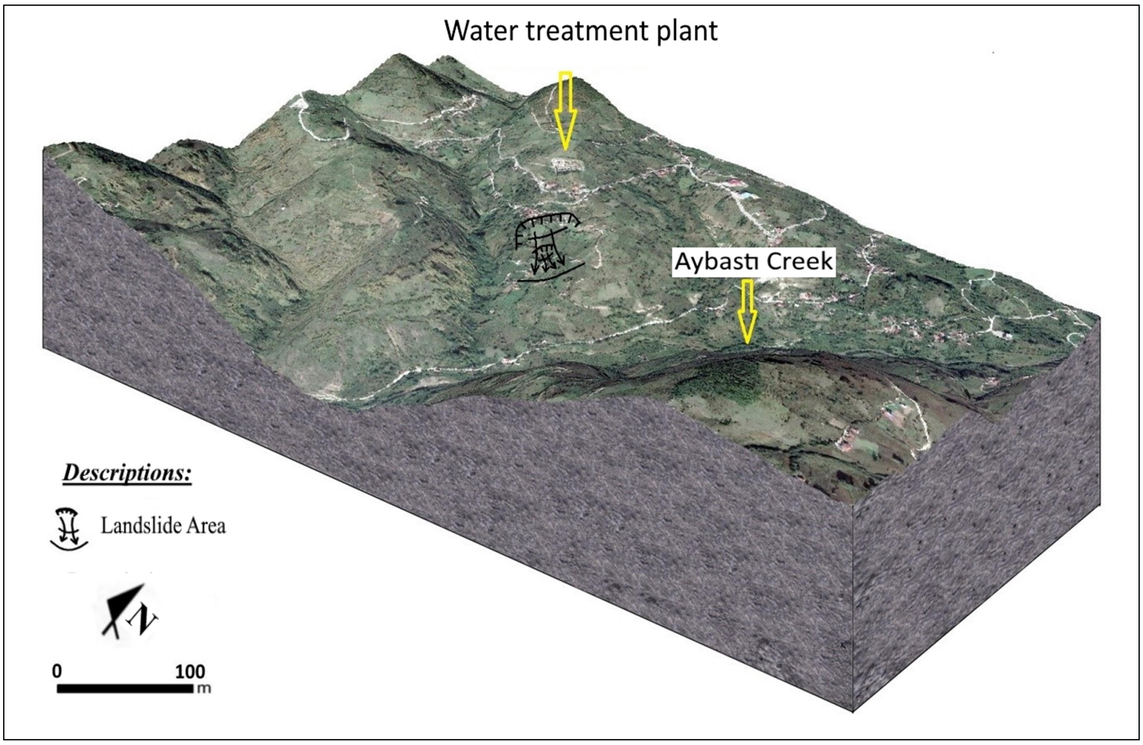

Figure 2: The landslide area and its surroundings were split by Aybastı Creek and its tributaries and a rough terrain appeared.

Table 1: Temperature, precipitation and snowy days values of Aybastı Meteorology Station (1978 – 1993).

Climate Element	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Average Temperature (°C)	1.4	1.2	4.8	9.8	12.5	15.9	17.6	17.7	14.7	11.9	6.8	3.9	9.8
Average Precipitation (mm)	81	70.5	64.5	65.4	86.9	68.8	44.2	24.9	48.3	81.5	106.5	85	827.5
Snow Days	10	7.2	5.8	1.3	0.2						4.0	5.4	33.9

Source: DMİGM 2019, Aybastı Meteorology Station unpublished measurement data.

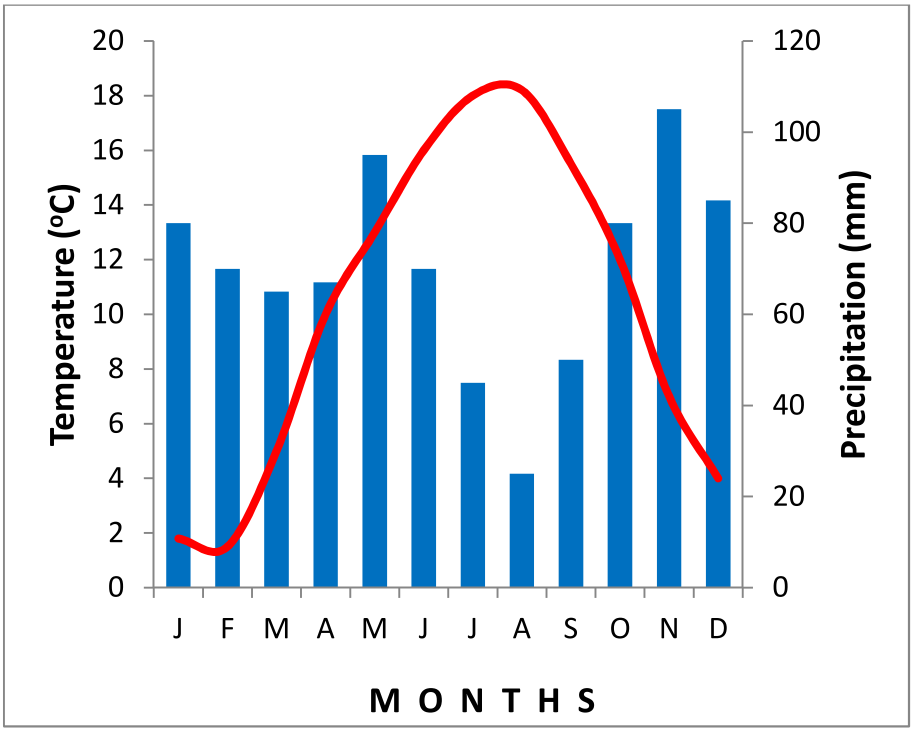

Figure 3: Monthly average precipitation and temperature values of Aybastı Meteorology Station (1978 – 1993).

The bedrock in the study area and its immediate surroundings consist of Middle-Upper Eocene-aged volcano-sedimentary rocks. The landslide area is composed of entirely volcanic rocks. In this section, the volcanic bedrock was dissociated by atmospheric factors and thick debris and soil cover developed on it.

Soil samples were taken from two landslide crown areas to investigate the geotechnical properties of landslide site soils. Consistency analyses were performed to measure the susceptibility of samples taken from landslides (Table 2).

Table 2: Consistency limit (Atterberg Limit) values of landslide zone soils.

Sample number and its place	Coordinates	Liquid Limit	Plasticity Limit	Plasticity Index
S1. Main Scarp	40°40'17.6"N; 7°22'43.3"E	47.8	22	25.8
S2. Secondary Scarp	40°40'12"N; 37°22'47.00"E	45.9	20.51	25.39

Accordingly, landslide area soils have 45.9% and 47.8% *liquid limit* values, 20.51% and 22% *plastic limit* values. The fact that both the liquid limit and plastic limit values of the samples are close indicates that the groundmass is the same. The minor differences between the samples might have resulted from the sample variability. *The plasticity index* values of the samples were also examined and it was found that values were between 25.8 and 25.39. According to the Turkish standard soil classification system (TS 1500/2000), LL values of the samples should be between 35-50, on the A-line and in the middle plasticity clay (CI) group. The consistency limit values of the samples were also evaluated according to the USCS (Unified Soil Classification System) and findings were read on Cassagrande Plasticity Card. The liquid limit values were less than 50, between the U and A-Lines and in-class CL. Accordingly, it was understood that the samples were in low and medium plastic inorganic clays groups with low liquid limit values. The consistency limits of samples on both scales indicate that soils are suitable for landslide formation. These findings are in line with results of other research carried out in the region (Yalçın, 2007a; 2007b; 2011). When all these data are evaluated together, it seems possible that landslides can occur in the field even without any human intervention in poor drainage conditions. Indeed, during the field studies, it was understood that at least one large landslide had occurred in the same hillside in the past.

3.2. Land Use in and Around the Landslide Site

The natural environment features of the landslide area and its surroundings support the formation of landslides even though there are no human effects. However, drastic changes in land use and building activities also support landslide formation. One of major facilities that stand out in this context is the drinking water treatment plant built 250 meters above the landslide main scarp (Figure 4). According to residents, the first movements at the landslide site started after the construction of this facility. In addition to the weight of this facility in the hillside, water leaks to the ground may have supported the formation of landslides.

Figure 4: Aybastı Drinking Water Treatment Plant at the top of the landslide area.

One of the factors supporting the formation of landslides is roads that cross the slope of the landslide. In the region, several roads (e.g. the Aybastı - Reşadiye highway passing through Sağlık District) that cut the landslide slope from seven places have been opened. On the other hand, three of these roads were damaged during Sağlık District landslide (Figure 5).

Another factor supporting the formation of landslides in the field is extra weight created by the houses built along the road. Also, water seeping into the ground from the sewage network that carries the wastewater of these houses supports landslide formation by weakening the bond strength of the ground.

Figure 5: One of roads that cross the slope of the landslide. The road was closed to traffic after the landslide.

3.3. Formation of the Landslide

The Sağlık District landslide occurred on thick cover of debris formed by the decomposition of volcanic bedrock. This landslide initially occurred as a slow-moving deep slide. The cracks that started in the crown part of the landslide continued with the collapse and 34 meters high, 350 meters long crown area was formed (Figure 6, 8).

Figure 6: General view of the landslide main scarp from the west.

During the collapse, the houses on the rupture site were destroyed. However, although vertical conditions of houses on the collapsed block have partially deteriorated, a significant number of them have maintained their integrity (Figure 7).

The mass of the landslide drifted towards the heel following the collapse and led to blistering and stretching there. The swells on the heel triggered a new landslide and a second collapse occurred about 120 meters south of the main scarp. Thus, Sağlık District landslide has acquired the feature of a two-part compound landslide. After the landslide, the terrain profile gained a fresh look (Figure 9).

Figure 7: Some houses maintained their integrity even though their vertical status was impaired during the collapse. A view from the east.

According to residents, the first movements in the landslide site started in 2015 (from the interview with Harun ÖNGE). The landslide that occurred in the form of a slow-moving deep slide during this period caused various problems in the field. These movements have caused cracks on the ground and walls of some houses. However, these cracks were plastered and they continued to live in houses (Figure 10). The second major movement in the landslide site started on 02/15/2019. After investigations by authorities in the site, 29 buildings at high risk have been evacuated (AFAD, 2019). Three months after this date, on 05/15/2019, the main landslide occurred. 22 buildings were destroyed because of the landslide. The mosque in the district which was 400 meters below the main scarp slipped away and about 8 hectares of agricultural land was damaged.

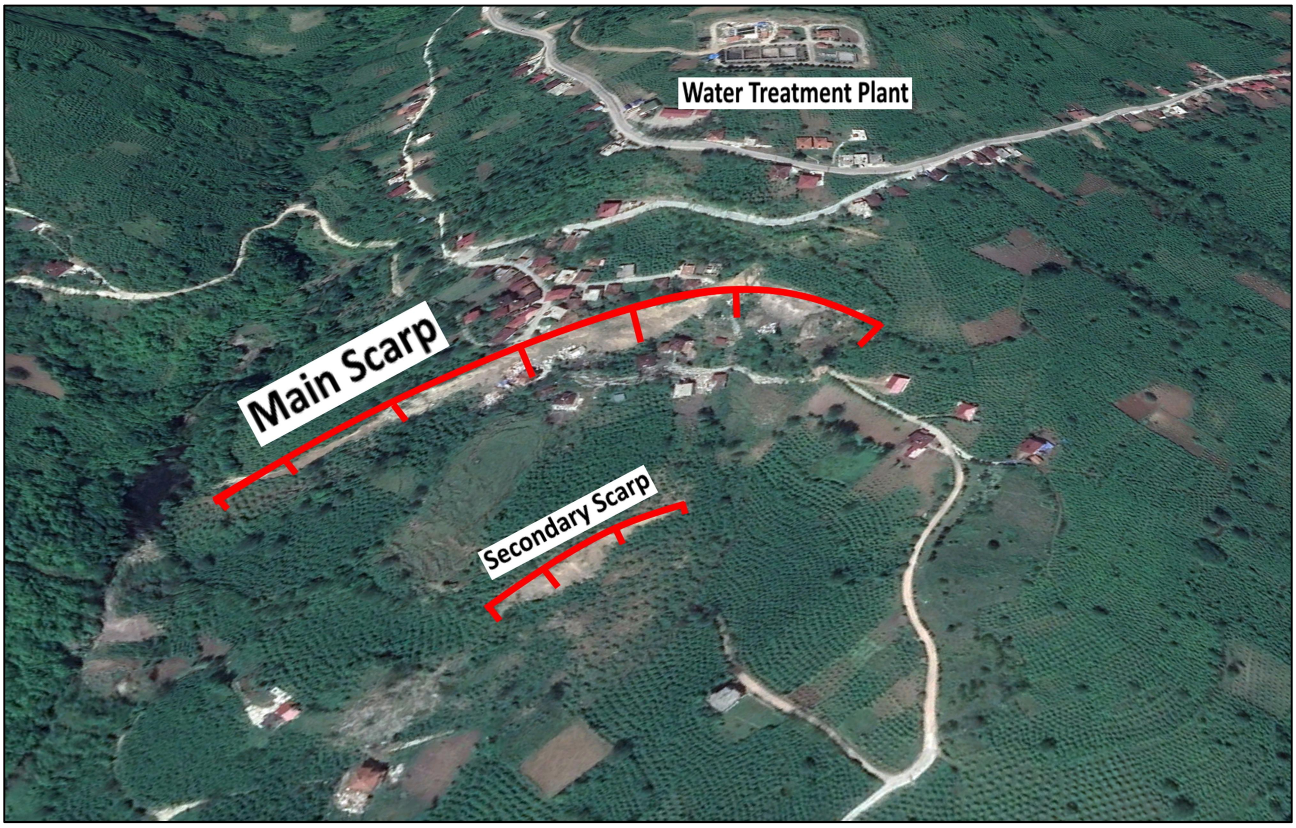

Figure 8: The landslide area and its surroundings.

During field studies, it was understood that there had been some another landslides on the field before this landslide. As a result of the investigations, it was understood that these ancient landslides were flow type. These ancient landslides caused longitudinal profile of the slope to gain a cascading appearance. During investigations in the crown area of main scarp, it was understood that the mass forming the ground was moved and mixed because of an ancient landslide (Figure 12). However, in eastern part of the crown area, volcanic bedrock was revealed and thick debris and soil cover was found on it (Figure 11).

Figure 9: General view of Sağlık District landslide from the northwest, which has a two-part structure.

Figure 10: Some of cracked walls were repaired in 2015 but later these cracks were reopened.

Figure 11: Andesitic bedrock pieces come out in the eastern part of the crown area of main scarp and partially altered.

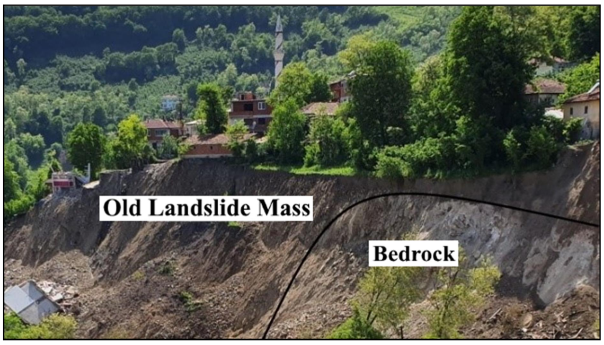

Figure 12: Crown area of main scarp cut partly an old landslide mass and partly the bedrock and debris cover on it.

4. DISCUSSION

The Black Sea region is the geographic area where landslides are seen the most in Turkey. The climate, bedrock features and the terrain of the region support landslide formation. Aybastı territory located in the Central Black Sea part of the Black Sea region also has suitable geographical features for landslide formation. The Landslide Intensity Map of Turkey prepared by AFAD (The Disaster and Emergency Management Presidency) shows the region as one of the most intense areas in terms of landslides.

The high sloping hillsides of the Black Sea region are generally in critical equilibrium condition because of suitable geographical conditions. When water content exceeds the plastic limit, soils become increasingly susceptible to mechanical degradation (Moradi & Ebrahimi, 2013). Therefore, excessive rainfall in the region, which is effective from time to time, activates slopes in critical equilibrium (Uzun, 1987; Uzun & Uzun 2003a; Uzun et al., 2016). When the liquefaction limit is exceeded, they may act with minor force under their weight. Therefore, it has been investigated whether Sağlık District Landslide was triggered by excessive rainfall. According to Ordu Meteorological Station, the region received 2.8 mm rainfall on the day of the landslide. A total of 17.2 mm rainfall was seen during the week of the landslide (Table 3). This datum is normal for the region and the amount of rainfall per day cannot be only reason for the landslide.

Table 3: Daily precipitation amounts of the study area between 11th and 18th of May 2019.

Days (May 2019)	11	12	13	14	15	16	17	18
Daily Precipitation (mm)	0	13,2	1,2	0	2,8	0	0	1,6

Source: DMİGM 2019, Aybastı Meteorology Station unpublished measurement data.

May 15, which is the day of the landslide, coincides with the period when snowfall ends and melting begins in the year. Snow melting is effective in saturating the ground with water. Since the increased moisture content reduces shear strength (Yalçın, 2011), snow melting has played a big supporting role in the landslide. To sum up, local geographical conditions described above support the formation of landslides. It can be said that

Sağlık District landslide emerged as a consequence of all these factors.

4. CONCLUSION

Features of the natural environment in the research area support the formation of landslides. The region is deeply divided by Aybastı Creek and its tributaries and a rugged terrain has emerged. The volcanic bedrock on the site is covered by thick debris and soil. The liquefaction limit of soils is low and the plasticity limit is moderate. The territory has a humid and temperate climate. The average annual temperature is 9.8 °C and the annual rainfall is 827.5 mm. The number of snow days in the field is 33.9 days. Snowy days start in November and end in May.

There have been drastic changes in land use in the area. The places obtained from the forest have been turned into agricultural land and hazelnut orchards. Roads that cross hillsides, additional weights created by houses built along the road, water seeping from the sewer network into the ground supports the formation of landslides. In addition, it is seen that snow melting is effective in saturating the ground with water, especially due to the warming of the air towards the end of spring. This situation is also confirmed by the ancient flow type landslides encountered in the field. In this way, the landslide, which initially occurred in the form of a slow-moving deep slide, later turned into a great disaster.

Cracks that started to occur three years ago in the crown part of the landslide began to expand three months before the incident, and authorities who realized it evacuated houses under threat and ensured the lowest level of damage. Despite this, 22 buildings were destroyed and 8 hectares of agricultural land were damaged because of the landslide. Besides, roads in the district were damaged and closed to traffic. The sewerage and drinking water network were also damaged. Therefore, no drinking water could be supplied to Aybastı for one day.

To avoid negative outcomes of possible landslides in the territory, it is recommended to prepare watershed-based landslide susceptibility maps, to build new settlement units away from potential landslide sites and to move dwellings in high-risk areas to safe locations.

ACKNOWLEDGEMENTS

We would like to thank Yusuf Beran VURAN, the former governor of Aybastı, for his permission and support for the fieldwork, Atilla Tolga HATİPOĞLU, Dinçay İNCE, and geological engineers Ercan BAHAR and Fatma Işınsu YAŞARYILDIZ for their support.

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