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Chapter

# The Effect of Aspect on Landslide and Its Relationship with Other Parameters

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## Abstract

Aspect is one of the parameters used in the preparation of landslide susceptibility maps. The procedure of this easily accessible and conclusive parameter is still a matter of debate in the literature. Each landslide area has its own morphological structure, so it is not possible to make a generalization for the aspect. In other words, there is no aspect in which landslides develop in particular. Generally, landslides occur in areas facing more than one direction. The biggest reason for this is that those areas are under the influence of other parameters. Therefore, it is wrong to evaluate the aspect, alone. Since it is a part of the system, it should be evaluated together with other conditioning factors. In this research, many landslides susceptibility studies have been investigated. The directions and causes of landslides have been determined from the studies. In addition, the criteria of the used aspect classes have been investigated. In the literature, the number of class intervals chosen, and their reasons were investigated, and the effects of this parameter were tried to be revealed in new sensitivity studies.

**Keywords:** Landslide, susceptibility, aspect, parameter, classification

## 1. Introduction

There are many different definitions of aspect in the literature. These definitions are made in three ways: by direction, by maximum variation, and by degree. The first definition group is the most commonly used. The concept of direction is to the come to the forefront. According to some researchers, the aspect at a point on the land surface is the direction that the tangent plane passing through that point faces and is expressed in degrees (the angle defined in the clockwise direction from the north) [1]. In its simplest form, the aspect is a data type that expresses the geographical direction in which the slopes develop.

According to the second definition, the aspect represents the maximum slope direction of the land surface [2]. Or, for any point, the aspect represents the direction of the maximum variation of the degree of variation of the height value [3]. According to some researchers, it is defined as the compass direction of the maximum rate of change [4, 5]. According to some researchers, it can also be defined as the slope direction, which defines the downward direction of the maximum rate of change in maximum, or as the dip direction, which defines the downward slope direction of the maximum altitude change rate [6, 7].

According to the third and last definition, the expression of the directions in degrees is in the foreground. Aspect defined it as the clockwise faces of a slope varying between $0^0$ and $360^0$, measured in degrees from the north [8, 9]. Generally, the aspect ranges from 0° to 360° and are handled as 45° groups, and the directions are grouped clockwise as north, northeast, east, southeast, south, southwest, west and northwest.

An aspect map shows both the direction and grade of a terrain at the same time. Therefore, it is an important factor in the analysis and production of landslide susceptibility maps. In the literature, there are many studies that accept and use aspect, landslide, as the main conditioning factor [2–12]. While some authors [13–16] consider landslides as a controlling factor, others [17, 18] do not see it as a conditioning factor. While some researchers say that aspect has no significant effect on landslides [19], some researchers have also argued that there is an important relationship between slope aspect and landslide occurrence [20]. According to most researchers, aspect has an indirect effect on landslide [21]. While some researchers associate this relationship mainly with precipitation [22–31], others have associated this with the general morphological trend of the area [27, 32]. According to most researchers, it has been argued that the relationship between landslide and aspect is also related to the dominant wind direction [33–35]. Some researchers, on the other hand, consider the effect of the aspect on the landslide, the general precipitation direction of the region, freeze–thaw, sunlight [35], longer snow retention on sun-drenched slopes, moisture retention, soil type, permeability, porosity, moisture, organic components, land and vegetation (forest, grassland, bushland, farmland), evapotranspiration [36], evaporation transpiration, climatic season, rock structure [37], It explains that factors such as discontinuities and fault orientation decrease the slope stability [10, 11, 24, 28, 30, 32, 38, 39]. Many parameters are used in landslide susceptibility studies, but it is stated that there are very few parameters that are thought to have a direct effect on landslides. The aspect parameter has also been investigated for a long time [3, 16, 28, 40–43], but it is one of the parameters on which no consensus can be reached [3, 44–47]. In the examined studies, it was determined that the aspect parameter indirectly affects the landslide. It is thought that this parameter triggers the landslide together with other parameters. Some researchers, especially in their studies on small-scale landslides, have determined that the angle with the slope affects the stability negatively [48–50]. Many researchers state that aspect is as effective as slope in the formation of landslides [11–13, 23, 24, 28, 30, 45, 51–55]. Apart from slope, aspect is one of the most important parameters in preparing hazard and zoning maps [13, 23, 24, 28, 30, 54].

As seen from the studies examined, the aspect parameter is a parameter that differs in each study area. For this reason, it has been interpreted that it should be examined together with other parameters rather than being an effective parameter in terms of landslide susceptibility alone [46]. According to Ramakrishnan et al. [56] stated in their study that different types of mass movements (plane, wedge, slope and soil slide) play an important role in control. However, there is no determination as to the extent to which the bee affects the landslide susceptibility.

In studies, landslides must be concentrated on slopes with a certain orientation in order to take into account the aspect. In many studies, researchers have determined that landslides are concentrated on slopes with certain orientations in their statistical evaluations [13, 22–30, 51, 57]. However, there are studies using the parameter in studies conducted in areas with equal landslide distribution in all directions. Generally, in such a finding, the lowest score is given to the aspect parameter.

The aspect factor is controlled by the climate process. Elevation and slope angle are also effective factors on this parameter. On the other hand, there are processes

controlled by the aspect factor. The most important of these is plant ecology. This is followed by forestry, site selection and planning. Land morphology is under the influence of structural elements. It takes a long time to change. The biggest factor controlling the view is the structural and dynamic morphological conditions that form the silhouette of the field from past to present [58].

Although there are parameters that are agreed upon among researchers in the literature, look is not among them. For this reason, with this study, the relationship between aspect and landslide was tried to be revealed and this uncertainty in the literature was examined.

## 2. Effect on other parameters and landslide

It is stated that the parameter contributes to the landslides by affecting other parameters. Since wind direction causes precipitation intensity and erosion of sun-facing slopes, aspect indirectly affects landslide [33, 34]. Although it is stated in the literature that the effect increases with the angle of slope and elevation, the effect on landslides is mostly mentioned together with the climatic conditions. Aspect parameter is generally in close relationship with climatic conditions [59]. The parameter determines the effect of rain direction, amount of sunlight, solar heat, soil moisture, wind and air dryness [39, 60]. Since it controls the soil moisture concentration with the effect of climate, it is considered as an important factor indirectly triggering landslides [61–63]. Therefore, due to its morphology, how the aspect factor affects the climatic parameters by modifying it should be correlated.

The conditions for the slopes facing different directions to be affected by atmospheric events such as precipitation, sun, light, freeze–thaw are also different. Therefore, it is possible to evaluate the relationship of the parameter with the climate in 3 parts. These are precipitation, sun and wind.

### 2.1 Aspect-precipitation relationship

The most important factor affecting aspect is precipitation. Most of the researchers studying the aspect parameter associated landslide with precipitation. In the literature, there are studies that argue that slopes that receive precipitation and are in the shade are more susceptible to landslides. In the literature, there are researchers who stated that landslides are very common on the slopes where monsoon precipitation falls more frequently in the study areas [2, 35, 64–66]. After exposure to physical weathering during the dry season, they are prone to landslides with the emergence of strong monsoon precipitation and winds [67]. In their study in Greece, Alexakis et al. [68] and Kouli et al. [69] determined that the slopes facing northeast and northwest received heavy rainfall and the most landslides were observed here.

If precipitation exceeds the threshold value in an area and the area is unstable, landslides are likely to occur. In this respect, precipitation should be considered as a triggering factor and aspect as a preparatory factor. Critical slope angle values of soils in dry and saturated conditions are examined. It has been determined that the saturation or dryness of the soil affects the critical slope angle by about 40%. In this case, the slopes receiving the most precipitation were considered the most dangerous, and the slopes receiving the least precipitation were considered the least dangerous [27, 70].

The reason for the fact that landslides are significantly higher on a slope facing any direction compared to the others is that the torrential rains and heavy rains that developed during the landslide occurred along a line from that direction.

For this reason, it can be observed that landslides are more intense on slopes that receive heavy rainfall. This depends on the infiltration capacity, which is controlled by many factors such as the type of soil, its permeability, porosity, moisture and organic matter content, vegetation and the season in which precipitation occurs. Slopes that receive precipitation reach saturation more quickly and cause higher pore water pressure to develop within the soil. As a result, the pore water pressure on these slopes increases [11, 42, 67, 71, 72].

### 2.2 Aspect-snow water/freeze: thaw relationship

It has been determined that there is a negative effect on the landslide mechanism in the form of the reason that the snow cover stays longer in the places that are not exposed to the sun and the water holding capacity increases accordingly [20, 73–76]. Avcı [76] determined that in the Esence Stream Basin, which is the study area, the south-facing slopes receive plenty of precipitation with the effect of the facade systems, this precipitation falls in the form of snow in the winter season, and the increase in the amount of snow melts and precipitation in the spring season facilitates the landslides.

Landslides occurring in a certain slope direction are associated with long-term freezing and thawing movements [20, 73, 77]. In certain directions it is associated with increased snow concentrations and thus longer times for freeze and thaw action and intense erosion [77].

### 2.3 Aspect- solar radiation and wind relationship

Calligaris et al. [78] defined the aspect as the reflection of the sun's insolation. Aspect affects solar radiation and therefore temperature. Aspect affects the amount of heat energy taken from the sun and thus water loss by transpiration and evaporation [79]. The slopes that are most exposed to the sun's rays reveal evapotranferance [9]. This affects the soil moisture in the ground. In addition, evaporation affects vegetation distribution and type. In the literature, there are researchers who determined that landslides occur more intensely on slopes that are more exposed to sunlight [9, 11, 35, 39, 42, 71, 72, 80, 81]. In the literature, there are studies that determine that slopes that receive sun are more prone to landslides than slopes that receive rain. Bijukchhen et al. [82] determined that in their study areas, in general, slopes sloping towards the sunlight and precipitation region have a higher landslide hazard propensity compared to the slope in the rain shadow. Although this parameter is usually evaluated together with the aspect, Görüm [83] determined in her literature research that 72 studies used aspect and 3 studies used sun exposure as an input parameter.

Remondo et al. [84], on the other hand, used the values on this date in their studies for landslide susceptibility assessment, since 21 March will be the most sun exposure. Tasoglu et al. [85], in their work; they determined that it was exposed to direct sunlight in east, southeast, south and southwest directions and sunlight was quite effective in inducing landslides.

Like exposure to sunlight, the drying wind also controls soil moisture concentration. This is a determinant of landslide occurrence [61, 62, 67, 71]. Slope exposure shows possible effects of prevailing winds, differential weather and related effects.

### 2.4 Aspect-geology relationship

Lithology: indirectly, it triggers the landslide together with the view. Afungang et al. [86] determined that thick pyrolastics as debris in the study areas were more

susceptible to landslides in windward slope directions. Yeşiloğlu [87] evaluated the effects of lithology and landslide together in his study. An aspect map has been created to be used in the evaluation of the relationship between the production of debris material from limestones and aspect. According to Ayalew et al. [70] stated in their study that the distribution of landslides in regions close to the oceans increases with the effect of wave effect, weathering and subsequent coastal erosion.

Along with the fault, there are also those who research the effect of the landslide on the landslide, there are also those who research the effect of the landslide on the landslide. There are researchers who observed that landslides intensified in certain slope directions before and after the earthquake in the study areas [2, 39, 88, 89].

Guillard and Zezere [90] stated that south-facing slopes receive more sunlight than north-facing slopes in their study area, but since the geological structure of the area is characterized by a monocline dipping to the south and southeast, more landslides occur on south-facing slopes.

### 2.5 Aspect- vegetation cover relationship

Aspect plays an important role in stability assessment; because it controls vegetation distribution, type, density and root growth on a land [11, 39, 80, 91]. It also controls moisture content in soil and vegetation growth due to exposure to sunlight, which also affects soil strength, landslide, infiltration and run-off rates [63, 92]. Dahal [93] added aspect data in his research for the purpose of detecting plant propagation and increasing the accuracy rate according to the aspect effect in the study area.

Champati ray et al. [94] and Srivastava et al. [95] found that most of the south-facing slopes in the Himalayan study areas were devoid of or have insufficient vegetation due to low soil moisture, which plays an important role in the assessment of slope stability in their field. On the other hand, the north side is less exposed to the sun's rays, thus conserving the moisture in the soil. For this reason, taller trees are growing, which tends to stabilize the northern slope. The absence of vegetation provides the slope material with dryness and therefore reduces its adhesion strength.

## 3. Relation of aspects to each other

During the literature review, it was determined that while more intense landslides were observed on the slopes facing one direction, less landslides were observed on the opposite side of this direction. Since the "south, southeast, southwest and west" aspects are generally warmer in Turkey, they are called sunny aspects. On the contrary, "north, northeast, northwest and east" aspects are also called shaded aspects because they are cooler. The sun exposure times of these two groups differ markedly. Since the slopes facing south and west are more exposed to sunlight, evaporation is rapid in these regions. Otherwise, since evaporation is slow and the soil stays moist for a long time, the risk of flooding is higher on north and east facing slopes in case of excessive precipitation [96]. Again, in his field study in Turkey, Ozsahin [97] determined the probability of the highest landslide occurrence as N and W directions and stated that the humidity was relatively higher on the slopes facing these directions.

### 3.1 South (S)

In areas where landslides occur on the south side, a higher amount of solar insulation occurs. On slopes with higher insulation and higher temperatures,

erosion increases. Areas where vegetation is removed are exposed to direct sunlight, creating drier soil conditions, which increases the likelihood of landslides [98]. According to Devkota et al. [47], Hong et al. [99] and Chena et al. [11], most of the landslides occurred on the slopes facing south and southeast in the study areas. The biggest reason for this is that the highest precipitation rate is seen on the south-facing slopes. Meinhardt et al. [65] determined that the water saturation of the slopes increased with the effect of southwest monsoon rains in the study areas and the highest slip density was found in the south and southwest. Tombus [100], on the other hand, determined in his study that the erosion value is higher on slopes facing south than on slopes facing other directions.

### 3.2 North (N)

In the studies conducted in the Black Sea, it was observed that landslides were intense on the slopes facing north. The reason is that the region is under the influence of precipitation from the north and north-facing slopes are more affected by precipitation. From this, it can be concluded that the air currents coming from the sea in the study areas close to the sea will affect more areas in the region. It is known that the Black Sea receives more precipitation than the north due to the high evaporation of precipitation. For this reason, north-facing slopes are examined as the most dangerous in terms of soil saturation in the study area, and south-facing slopes are examined as the least dangerous. [101, 102]. According to Hadji et al. [9] determined that the slopes in the study area are mostly in the north-facing directions. In addition, they determined that the most precipitation in winter comes from the northwest. They also determined that they affect the clays in the ground and therefore trigger landslides.

### 3.3 South (S)-North (N)

In their study, Lineback et al. [103] found more landslides in the north and northwest-facing directions than in the south-facing directions. They stated that the southern parts remained drier as the reason for this. Wang and Unwin [104], on the other hand, found evidence in their study that the probability of slipping increases in the north-facing slope direction. As justification, they showed that the main precipitation directions in the Zagros Mountain Belt are north and west, and the main solar direction is east and south [105]. According to Saha et al. [4] determined that, in general, south-sloping slopes have less vegetation density than north-facing slopes, and therefore they are more sensitive to landslide activity in the study areas. On the other hand, Marston et al. [106] observed that, due to geographical conditions, north and west facing slopes have a higher moisture content for a longer period of time and cause higher landslide susceptibility in their study area. They emphasize that exposed soil on south-facing slopes is subject to cycles of wetting and drying, thereby increasing landslide activity in the Himalayas [20]. According to Rahman et al. [79] found that south-facing slopes were more exposed to the sun and north-facing slopes were least exposed to the sun in their study area.

As a result, they determined that the north direction and the least south direction were sensitive to landslides in their fields. They showed that the reason for this is that it takes longer time for the soil to dry in the shaded areas on rainy days. According to Akinci et al. [107] found that in the study areas, the slopes are more north-oriented and again, landslides occur mostly in this direction. They stated that these slopes are more humid with the effect of aspect, while the temperature and evaporation are low on the slopes facing north, and the soil moisture is high.

In addition, they stated that the amount of precipitation and snow melts are high on the southern slopes. Afungang et al. [86] found that north and northwest-facing slopes at higher altitudes received more precipitation and sun than south-facing slopes. Therefore, it was determined that the southwest-facing slopes were drier, less windy, and received less solar radiation with less landslides. Champati ray et al. [94] and Srivastava et al. [95], in their study in Himelaya, found that more landslides occurred on the southern front compared to the northern front. Temiz [101] and Yalçın [102], on the other hand, determined that north-facing slopes were the most dangerous in terms of soil saturation in the study area, and south-facing slopes were the least dangerous.

## 4. Aspect classes

The reasons for the change in the number of class intervals can be counted as the slopes being oriented in a certain direction, the absence of landslides in some directions or the presence of very few pixels. It is usually given to flat areas such as lakes and seas [20]. For example, the probability of landslides in "flat" areas is almost zero [34]. However, Yeşilnacar and Topal [108] with Çevik and Topal [109] stated that the landslides in the study area occurred equally in different slope orientations and emphasized that it is not an effective parameter in their studies. Aspect is measured clockwise towards north and takes positive values between 0 and 360 degrees. Aspect is measured clockwise towards north and takes positive values between 0 and 360 degrees. In order to create a slope orientation map, on the basis of 4 main geographical directions and these main directions (NE, NW, SE and SW), which of these directions the slopes face in the study area and their relations with the directions of the landslides are determined [101, 102]. It indicates 0° north, 90° east, 180° south and 270° west [32]. In the landslide analysis, a categorical structure is formed according to $45^0$ angles. When the researchers grouped the slope orientation values in their studies, they determined which orientations the landslides intensified. The perspective angles and values made in the studies are given in **Table 1**.

In studies, very different grade ranges from 4 to 10 are used. According to the literature, the most preferred 8 grade ranges.

Some researchers preferred to use 4 main aspects in the aspect parameter they used in their studies. There are researchers who use the aspects divided into 4 groups in their studies in different ways. According to Temesgen et al. [110] used 4 cardinal directions: north, south, east and west. Özşahin and Kaymaz [111] have 4 classes; they used it by arranging it as straight/N-NE-NW/S-SE-SW/E-W. There are studies that use the aspect by classifying it in 5 ways [6, 97, 105, 112].

In the literature, three different directions were found in the 5-category. The first of these; flat (−1°), north (315°-360°, 0°-45°), east (45°-135°), south (135°-225°) and west (225°-315°) [113]. The second classification is; (1) SW $181^0$–$225^0$, (2) SE $136^0$–$180^0$, (3) ESE $91^0$–$135^0$ and SWW $226^0$–$270^0$, (4) NEE $46^0$–$90^0$ and WNW

| North | Northeast | East | Southeast |
|---|---|---|---|
| $0^0$–$22.5^0$, $337.5^0$–$360^0$ | $22.5^0$–$67.5^0$ | $67.5^0$–$112.5^0$ | $112.5^0$–$157.5^0$ |
| South | Southwest | West | Northeast |
| $157.5^0$–$202.5^0$ | $202.5^0$–$247.5^0$ | $247.5^0$–$292.5^0$ | $292.5^0$–$337.5^0$ |

**Table 1.**
*Slope directions and angles.*

$271^0$–$315^0$, (5) NNE $0^0$–$45^0$ and NWN $316^0$–$360^0$ [74]. The third and final classification is; It is flat, NE, SE, SW and NW [50].

Aspect maps divided into 6 classes are very common in the literature. Kumtepe et al. [114] prepared this classification as 0–60°, 60–120°, 120–180°, 180–240°, 240–300°, 300–360°.

The second most preferred classification in the literature is 8 classes prepared with groups of $45^0$ divided into equal class intervals [35, 43, 45, 54, 65, 79, 94, 95]. This classification; N (337.5–22.5), NE (22.5–67.5), E (67.5–112.5), SE (112.5–157.5), S (157.5–202.5), SW (202.5–247.5), W (247.5–292.5) and NW (292.5–337.5) [37]. Ramakrishnan, et al. [56], on the other hand, arranged the 8-class classification differently as 45–90, 90–135, 135–180, 180–225, 225–270, 270–155 and 315–360 degrees.

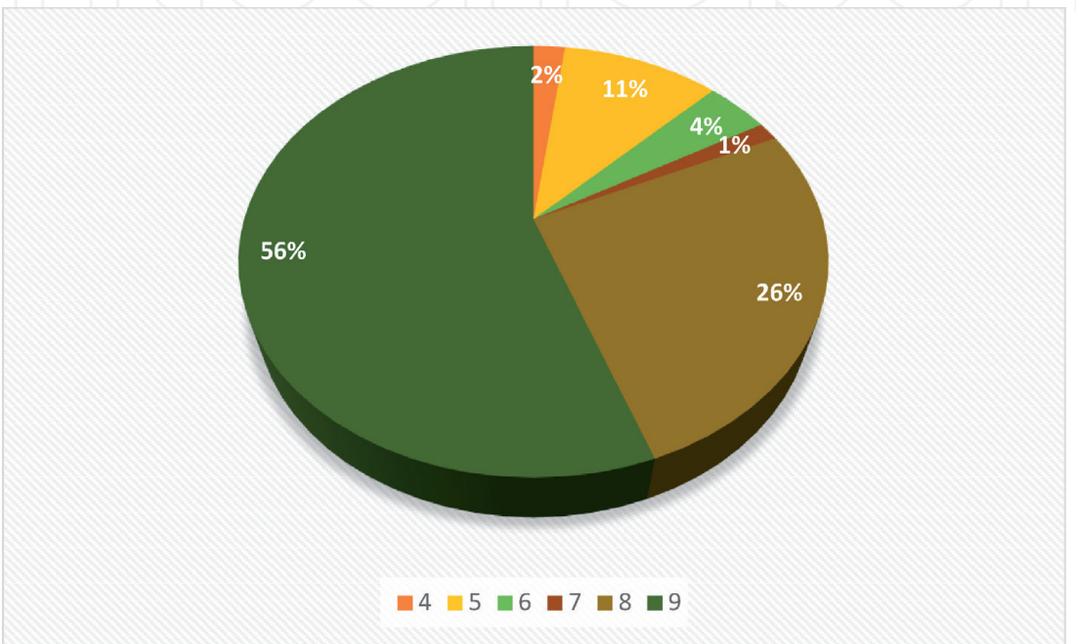



**Figure 1.**
*Distribution of class range values used according to the literature.*

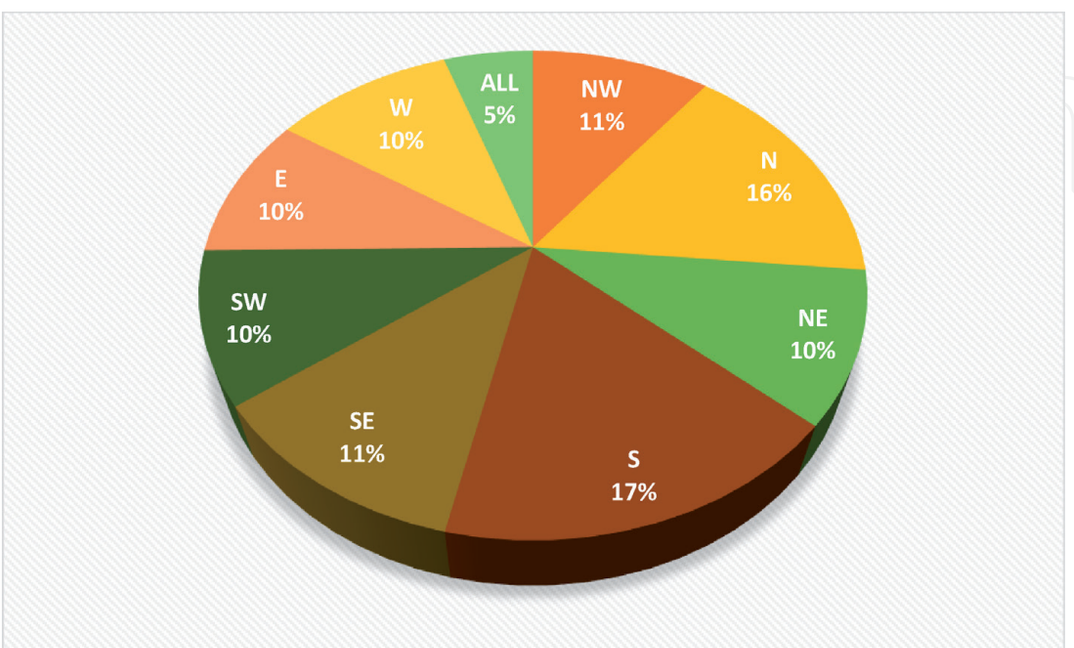



**Figure 2.**
*Distribution of landslide areas according to directions.*

According to the literature, the most preferred classification is groups of 9 [11, 32, 47, 52, 53, 66, 68, 69, 71, 87, 93, 95, 109, 102, 113]. In studies, this classification is; flat area (−1°), north (337.5° -22.5°), northeast (22.5° -67.5°), east (67.5° -12.5°), southeast (112.5° -12.5°) 157.5°), south (157.5° -202.5°), southwest (202.5° -247.5°), west (247.5° -292.5°), and northwest (292.5° -337.5°) [49, 46, 67, 73]. According to Rozos et al. [74] is this group; They used NNE, NEE, SEE, SSE, SSW, SWW, NWW, NNW, as flat shapes. The interesting thing about this classification is that the surface is displayed from 2 different angles.

The graph in **Figure 1** was prepared using the literature data. It is seen that the most used classification is the groups of 56% and 9 percent. Again, it is seen from the graph that the group of 1 to 4 is the least used class.

According to the literature, the most used direction classes are given in **Figure 2**. The direction of the landslide areas varies according to the study areas. However, in the studies examined, it is understood that the directions where landslides occur most are the slopes facing south and west. The probability of landslides in other directions is almost equal. In some studies, landslides were encountered at an equal level in all directions.

## 5. Conclusions

In this study, the use of aspect parameter in landslide susceptibility studies and its effect on landslide were investigated. It is one of the parameters that cannot be agreed upon by the researchers. While some researchers associate landslide occurrences in the study area with this parameter, some researchers argued that landslides are equally distributed in all directions and that the parameter is ineffective.

It is a fact that this parameter should not be evaluated alone, as in other parameters. The parameter is the predisposing factor for the triggers. One of these triggers is precipitation. There are many studies showings that intense landslides occur on slopes that receive rainfall. Climatic events such as sun, wind, snow water, freeze–thaw are also associated with the aspect parameter. The other two parameters most associated with climatic factors are geology and vegetation.

The other subject discussed in the study is the relationship of the directions with each other and with the landslide. The most common landslides seen in the studies examined are south and north directions. There is an opposite relationship between them. If there are frequent landslides on the south-facing slopes, there are almost no landslides on the north-facing slopes. Again, on the contrary, if landslides are concentrated on the north-facing slopes, landslides are not expected in the southern part. If a landslide occurs more in the south, it is associated with sun exposure, drought and lack of vegetation. Those occurring in the north are mostly evaluated by heavy rainfall, humidity and the water holding capacity of the soil.

Finally, the class ranges used in the literature are included in the study. Aspects used in the literature. In the studies, this classification is; flat area (−1°), north (337.5° -22.5°), northeast (22.5° -67.5°), east (67.5° -12.5°), southeast (112.5° -12.5°) 157.5°), south (157.5°) ° -202.5°), southwest (202.5° -247.5°), west (247.5° -292.5°) and northwest (292.5° -337.5°). Depending on the user's preference, some prefer the main classes, while others include intermediate aspects in their work. Some studies do not include aspects that do not appear to have landslides in their studies. In this way, various classifications such as 4, 5, 6, 8 and 9 are used. While the most preferred 9 classes are the least preferred groups of 4. With this study, the use of the aspect parameter in landslide susceptibility studies and its effect on the landslide together with other parameters were revealed.

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