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Effect of the Slope Angle and Its Classification on Landslide

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Abstract. The phase after the determination of the landslide area in landslide susceptibility studies is the selection of methods and parameters to be used. Approximately 1500 randomly selected publications show that it is necessary to select a parameter based on the area. Research has shown that the parameter of slope is greatly preferred. There is nearly consensus of opinion among researchers regarding the use of the parameter. The research included the definition of slope made by different researchers, the advantages and disadvantages of the use of the parameter, different classifications that are used, the formation intervals of landslides, their use together with other parameters, and its effect on the formation of landslides. Classifications were studied based on the slope values at which landslides. Generally, automatic slope classifications are used in the preparation of landslide maps. There isn't standard in parameter maps. Therefore, there isn't class range that is referenced when preparing slope maps.

In this study, preferred class ranges and slope values where landslides occur were determined in the literature. 40 landslides area has been selected in Turkey. These were evaluated in the slope classes determined according to the literature. The results compared with the literature were found to be compatible.

Keywords: Landslide, susceptibility, parameter, slope angle, classification

1 İntroduction

Slope has significant importance in terms of the formation, development, and susceptibility to landslides and is defined as an input parameter in susceptibility studies by many researchers, and it is the expression of the rate of the vertical distance to the horizontal distance between two specified points with the tangent angle (Yomralıoğlu, 2000). In other words, slope is the measurement of surface steepness and is measured as a degree. It has a range of 0-90^0, where 0 represents a horizontal area and 90 represents a vertical area (Yılmaz et al., 2012). In broader terms, slope is the angle between each surface section and horizontal reference point that measures the speed of change in height and that supports the flow of water and other materials in the direction of slope in terms of the steepest drop in slope for elevation (Dehnavi et al., 2017).

Slope is a derivative of the digital elevation model and is evaluated in the topographical parameter classification. In landslide susceptibility studies, the slopes at which landslide frequency is greatest are determined by classifying slope. By superposing the relationship between the slope maps prepared in the specified classification intervals and the landslide inventory maps, the

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relationship between them is attempted to be specified. The slope classifications and the distributions (%) and densities (%) of landslides within the total areas for this are calculated (Çellek, 2013). It emerges that there are differing viewpoints between the relationship of slope and landslides, that this situation could vary regionally, and that the slopes of landslide-prone slopes must be evaluated statistically and interpreted.

The literature ensures consensus among researchers on the notion of the evaluation of slope as an active parameter in the formation of landslides, and this parameter is commonly used in the evaluation of landslide susceptibility. Generally, the highest score is given to the slope angle in landslide susceptibility analyses. A conducted study of the literature determined that most researchers in 1500 studies used slope as an input parameter. Dağ (2007) reported that slope was the most preferred parameter in 96 of 100 examined studies. Hasekioğulları (2011) stated that 109 of the 114 studies examined used slope as an input parameter, and Çellek (2013) stated in a literature review that 281 of 293 studies used slope. Süzen and Kaya (2014) stated that it was used as an input parameter in 97.90% of the studies they examined, while Budimir et al. (2015) found that it was used 95% of the time. Dölek and Avcı (2016) gave the heaviest weighted score to this parameter with 30% in the statistical method in their study, and Mehrotra et al. (1992) provided 35% in theirs. Altın and Gökkaya (2006) showed slope as the main parameter that triggered landslides in their study area. Setting out from here, it is possible to say that slope is the most influential and essential parameter over landslide susceptibility.

The choice of slope class ranges affects the results of the analysis. The important issue in the preparation of landslide maps is to choose the right parameter. The second issue is the determination of the correct class ranges for the selected parameter. For this purpose, the range of classes used in the literature will be tried to be determined. The case study prepared will be compared with the literature. Setting out from here, it is possible to say that slope is the most influential and essential parameter over landslide susceptibility.

2 The Advantage and Disadvantage of the Slope Angles Parameter

The most important property of the slope parameter is that it can easily be produced and analysed from digital elevation model (DEM) data through geographic information system programs and that it can be easily mapped. Slope is an original factor that is used in slope instability, creates the foundation for stability studies, and affects shear and normal tension on shear surfaces. Slope completely controls the movement of materials based on gravity. Slope or the slope angels directly influential in the landslides and creates the foundation for susceptibility studies. For this reason, the literature ensures consensus among researchers on the notion of the evaluation of slope as an active parameter in the landslides, and this parameter is commonly used in the evaluation of landslide susceptibility map. On the other hand, according to Youssef et al. (2015), general decision couldn't be made regarding the slope angle-landslide relationship.

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The classifications of the parameters are the selection of the slope classification, the slope at which the landslide is encountered, the absence of a distinguishing parameter for each area, and the evaluation with other parameters. If we are to complement the prediction that landslide susceptibility decreases as slope increases by setting out from only a slope parameter, the results are largely incoherent. For this reason, other factors musn't be ignored (Gökçeoğlu and Ercanoğlu, 2001). The effect of slope on landslide susceptibility varies based on soil, debris, or rock type in the study area and on the type of landslide occurring in materials.

In most studies in evaluations regarding the use of slope, the classification intervals belonging to the slope values are taken differently. It is thought that this situation is unique to researchers and that classification intervals are determined by considering the intensities of landslides in the study area (Dağ, 2007). Some researchers believe that landslides occur between 30^0 and 40^0, while others believe they occur above 25^0, while others believe they occur below 30^0. As a result, it emerges that there are differing viewpoints between the relationship of slope and landslides among researchers, that this situation could vary regionally, and that the slopes of landslide-prone slopes must be evaluated statistically and interpreted (Hasekioğulları, 2011). There are examples in the literature in which landslide possibilities in all slope groups are close to one another in the landslide susceptibility studies (Van Westen, 2003). Regardless of the extent to which it is thought that this is the most influential parameter in the formation of landslides, it demonstrates that the slope parameter isn't influential for every area.

3 The Effect of Slope Angle on Stability

Slope aspect is one of the most important causal factors that affects slope stability (Kayastha, 2015). Because the component strength of gravity is the tendency of slope, this parameter tests the transportation of material by controlling the progression speed and motion distance. Gravity and shear strength increasing based on the growth of slope values facilitate the activation of materials by deteriorating the balance of the material. It causes an increase in landslide susceptibility. This is why the storage and dimension of the activated materials is related to this parameter (Wang et al., 2016). It is an empirical fact that a landslide incident can occur again in a region at which landslides have occurred previously (Taşoğlu et al., 2016).

The slope security factor is defined with the rate of shear stress for resistance strength (Alexakis et al., 2013). The main parameter of the balance analysis is the slope angle (Moradi and Rezaei, 2014). Slope is the original stability factor that influences shear and normal strength in shear surfaces (Anbalagan, 1992). A steep slope demonstrates how large the shear stress is and how low the security factor is for slope (Nourani, et al., 2014). This is because as slope increases, tangential stress increases in the colluvium in residual or consolidated soil covering, axial tension decreases (shearing strength increases in steep slopes), and stability deteriorates. Thus, with the increase of the slope, the block-creation potential of the material increases, and this leads to the increase in the weight of rock blocks. As a result, slope doesn't only affect stress distribution within masses but also affects the magnitude of shear and normal stress on shear surfaces. Susceptibility deteriorates by increasing shear strength in the soil because the slope value increases and due to decreasing normal stress (Guo et al., 20

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Ullmann et al., 2017). Slope, gravity, and existing external elements create an internal strength and implement a strength directly toward the center of the world along a vertical line. Slope determines how influential that strength is in ensuring the movement of the object; however steep the slope the gravitational strength component that ensures the shear of the slope is, and object is that large. For this reason, slope steepness can be defined as the risk factor tied to the most important soil factor that influences slope stability (Kornejady et al., 2017). Slope angle directly affects the stress distribution in the slope. Different slope angles don't only affect the residual stress magnitudes on existing shear surfaces or potential shear surfaces but also determine the renewal and mechanism of deformation (Fan et al., 2017).

4. The Relationship of the Slope Parameter with the Other Parameters

Slope plays many important roles in the occurrence of landslides because many factors express the result of its combination effect (Rozos et al., 2010). The studies reviewed in the literature reported that slope significantly, either directly or indirectly affects the speed of ~~slope~~ surface and subterranean water flow based on gravity, soil water content, soil structure, erosion potential, and hydrological and geomorphological processes (Anbalagan, 1992; Wilson and Gallant, 2000). When evaluated together with slope, parameters become more important when certain conditions regarding climate condition severity, vegetation type and density, and geological formation discontinuity order and internal geometry are present (Ilia and Tsangaratos, 2016). It was revealed that slope ~~angel~~ is more effective than elevation with slope over landslide susceptibility. However, these assumptions can exhibit change related to regional landslide properties and other parameters, as observed in the study areas.

4.1 The Relationship of the Soil Parameter and Slope Angle

Slope controls the hydraulic continuity and, therefore, the security factor for slopes (Saadatkhahi et al., 2014). Generally, slope stability is dependent on its interaction with material properties such as the friction angle ~~of the slope angle~~, permeability, cohesion, shear, strain, and normal stress (Acharya and Pathak, 2017), and landslides occur as a result of the interaction between slope angle and these properties of the material (Youssef et al., 2015).

Groundwater affects the impermeable layer found above with the effect of slope and facilitates its motion by increasing its plasticity (Avcı, 2016). For example, Jaafari et al. (2015) reported that a steep slope in the working area close to the limits of stability mostly triggered the instability of surface formations when small changes occurred in cohesion and porous water pressure. On the other hand, Rozos et al. (2010) classified the slope values according to the known upper-limit friction angles for silty soils.

Slope also affects stress distribution within masses (Dou et al., 2017). The slope security factor is defined with the rate of shear stress for resistance strength. This means that shear strength is a function of slope angle. A steep slope demonstrates how large

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the shear stress is and how low the security factor is for slope (Abedini et al., 2017; Chen et al., 2018). Conversely, low slopes are expected to have a more stable or lower shallow landslide frequency because of lower shearing stress (Guo et al., 2014).

4.2 The Relationship of Hydrology and Slope Angle

Slope is an important topographical factor that controls both the surface and underground hydrological status of a corrosive material in mountain land, hydrological continuity, groundwater, flow speed, moisture content, and the security factor of slopes because of pour pressure and weathering surface and surface flow speed (Balamurugan et al., 2016), which affect land stability (Saadatkhahi et al, 2014). While able to study moisture content and pour pressure on local scales, the regional hydraulic behavior can be controlled with slope angle models at larger scales (Mancini et al., 2015).

Critical slopes are evaluated in saturated conditions. This is because the critical slope angles in the dry side slope conditions are high values, and the regions at this slope in the field conditions exhibit less spatial distribution (Özşahin, 2015). Slides occur because of the steepness of topographical slope and continuous canal erosion in slope topography. Creep landslides can occur based on surface erosion and drainage at places where the slope values are high.

Slope triggers the landslides in land at which clay layers saturated with water are common. The degree of slope controls the redistribution of surface materials and tension and the thickness of the surface water. Additionally, slope controls the loose material and the discontinuation and emptying of the groundwater (Lee and Min, 2001). In this context, hydrogeological and lithological conditions are present in the landslides triggered by slope. Indeed, Zhuang et al. (2015) reported that slope in the study area affected the rates of infiltration and flow and also the regolith layer and the thicknesses of the other units. Similarly, Avcı (2016) relationships the landslides to the favourability of lithological conditions and the excess amount of precipitation and groundwater.

4.3 The Relationship of Lithology and Slope Angle

It is known that slope stability is largely related to the slope angle and material properties. The effect of slope on landslide susceptibility varies based on soil, debris, or rock type in the study area and on the type of landslide occurring in materials (Zhuang et al., 2015; Avcı, 2016). In other words, while it is known that high-angle slopes are more susceptible to landslides, a general increase in susceptibility to initiate landslides is expected with slope increasing up to the point at which the slope angle takes further steps for the creation of a layer of soil at an adequate thickness. The ground layer is generally expected to be important for the prediction of carrying regions preferred by steep ground (Süzen and Kaya, 2011; Moradi and Rezaei, 2014).

The slope values in studies vary based on lithological units in the study area. For example, slopes gain a state incredibly susceptible to mass motions like landslides if the determined slopes occur together with decomposed and weak lithological rock units (Öztürk, 2002). Some researchers emphasized that the loosening or density of the material with slope in study areas is the effect of the landslides and that the accumulation of loose material is directly related to slope (Chen et al., 2013; Chalkias et al., 2014; Nourani et al., 2014; Jebur et al., 2015; Goetz et al., 2015; Öztürk et al., 2016; Pawluszek and Borkowski, 2017). For example, Çellek (2013) reported that, despite a low slope value in the areas in which the zone that formed due to the decomposition of the flysch-type material is thick, it became more sensitive. As a result of the accumulation in lower-slope topographies with soil that forms due to the decomposition of flysch-type materials form landslides with the influence of the other parameters. Because steep slopes are mostly covered with durable slopes, landslides aren't encountered at these segments. Sakkas et al. (2016) reported that geological formations with low slope values have a lower susceptibility than formations with high values and that a horizontal plane formation will never slide. Avcı (2016) related it to the favourability of encountering different mass motions at different slope values of (0-45°) in the study area and the height of lithological conditions for landslide density between certain slope values (5-15°). Fan et al. (2017) reported that landslides that occur in the Silurian layer occur at slopes with angles of 15°-35°, which constitute approximately 82% of all landslides in the same layer. Although Pachauri and Panta (1992) demonstrated that the frequency of landslides is greater on steeper slopes (> 35°), independent of lithology, Ercanoğlu et al. (2004) reported in their study area that steep slopes generally occur in resistant limestone and quartzite and that these units aren't susceptible to landslides. Although Anbalgan (1992) provided the highest scores for areas with slope angles > 45° in a landslide susceptibility study, Tangestani (2004) conversely encountered solid limestone and changed the classification in steep slopes for areas with slope angles > 45°. Fourniadis et al. (2007) performed a classification in which the threshold angles changed based on lithological competence rather than the slope angle to estimate the critical angles in different lithologies in the susceptibility analysis. Hadji et al. (2016) emphasized that landslides begin to be observed in marn clay formations located in the classification range of (5°-15°), are seen in the lower classifications, and intensify in the upper classifications. Nagarajan et al. (2000), in a study conducted in the Konkan region of India, determined that rockfall-type landslides occur on steep slopes with a slope of greater than 80° and that mudslide-type landslides occurred at slopes with a slope of greater than 35°. And they reported that landslide susceptibility increased with the increase in slope. Dağ et al. (2011) reported in their study that slopes gain a state incredibly susceptible to mass motions like landslides if the determined slopes occur together with decomposed and weak lithological rock units, and that this is emphasized in similar studies conducted in the region.

4.4 The Relationship of Climate and Slope Angle

Slope is related to parameters such as exposure to sunlight, wind, and rainfall, and this in turn affects landslides (Raja et al., 2017). It is generally possible to correlate the reasons for the concentration of landslides at certain slopes with certain slope with meteorological incidents such as the general morphological slope of the field and the region in particular getting more general precipitation and/or sunlight. Slopes that receive heavy rainfall quickly reaches saturation relative to the slopes with inclinations other than a dominant inclination and can cause the development of higher pore water pressures over time based

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on the capacity of permeation controlled by many factors such as topographic slope, soil type, permeability, porousness, moisture and organic substance content, vegetation, and season in which the precipitation occurs. It is possible for the slopes this event to make slopes that receive more intense precipitation more susceptible to landslides (Ercanoğlu et al., 2004; Lee et al., 2004; Lee, 2005).

Some steep natural slopes such the bedrock mostras aren't susceptible to shallow landslides triggered by rain (Kritikos and Davies, 2014). Slope affects the amount of accumulated rain and has a longer flood duration at low slopes (Yüksel, 2007). Avcı (2016) related the prevalence of landslides in the 5-15^{0} group to the favourability of lithological conditions and the excess amount of precipitation and groundwater.

Wind speed is a variable related to slope degree. Wind speed is a variable related to slope degree in sloped lands. Wind speed blowing up the slope is 10-30% less on ground with a 6-20% slope compared with flat ground (Yiğiter, 2008). This affects stability.

4.5 The Relationship of Aspect and Slope Angle

According to many researchers, aspect and slope angle are more effective than elevation. This is why the steepness and direction of slope can be clear variables that affect landslides (Tsangaratos and Benardos, 2014). Slope controls the intensity and scope of landslides because it determines impression direction (Sadr et al., 2014). Özşahin and Kaymaz (2013) reported in a study that the slope values of areas highly susceptible to landslides direction to the south and east of the region. Additionally, the author reported that because the vegetation of slopes looking to the east, southeast, and northeast in the study area, slope in the region had an important role in the development of mass motion. Avcı (2016) reported that the north section was under the danger of landslides because the slope values were high. Champati et al. (2004) connected this to the absence of vegetation in slopes direction north for the most important role in the weathering of stability in the evaluation of slope in steep slopes in the Himalayas. Based on this, it can be said that landslides develop according to slope value and impression in different areas.

4.6 The Relationship of Vegetation and Slope Angle

Avcı (2016) encountered expansive landslides in slopes at which the slope was high and the vegetation was sparse in the study area. Sadr (2014) reported in the study field that vegetation at high slopes plays an important role in the development of fewer and mass motions. Contrary to both studies, Alkevli (2015) didn't encounter any landslide record in the areas covered with dense vegetation and forested areas with a high slope value of 60^{0}-80^{0}. Yüksel (2007) reported that approximately 82% of landslides in the study area occurred at slopes ranging between 10°-30° and that there generally wasn't vegetation, or it was sparse.

4.7 The Relationship of Erosion and Slope Angle

Slope has the potential to create erosion and affects soil formation and many other processes (Wilson and Gallant, 2000). In slopes where the slope angle is very high, the soil material is expected to be unable to reach efficient thickness value (at least 1-2m) because of erosion, and fewer landslides are expected because of the existence of solid rock materials. Conversely, landslides can occur because the zone of decomposition is thick at low slopes (Gökçeoğlu and Ercanoğlu, 2001; Bui et al., 2011; Elkadiri et al., 2014; Chen et al., 2015).

4.8 The Relationship of Seismicity and Slope Angle

Erdinç (2000) stated in a study that some faults cause landslides that cause of very steep slopes, while Avcı (2016) expressed that, by increasing slope values in slopes and river valleys in which slope dip-slip faults intersect, landslides decrease in these areas.

Numerous studies regarding the landslide caused by the Wenchuan earthquake that took place in China in 2008 have reported that there are more landslides triggered by earthquakes and that take place at certain slopes compared to earthquakes that occur with the triggering of precipitation before earthquakes (Huang and Li, 2009; Tang et al., 2011). Tanoli et al. (2017) in their study determined that 76% of landslides before earthquakes occur at a slope between 20° and 50°, while 78% of landslides after earthquakes occurred at a slope between 30° and 80°. Yang et al. (2015) reported that the pressure slope for the slides caused by the Lushan earthquake was greater than that of the landslides triggered with precipitation before the earthquake.

4.9 The Relationship of Elevation, Slope Length, and Slope Angle

A relationship is relevant between landslide and the geological formation slope angle and the slope length. It is thought that with an increase of height and slope length also increases slope instability. For this reason, the relationships between landslide and the geological formation slope angle and the slope length must be investigated.

The increase in height have a decrease effect on stability. It is thought that slopes that have the same slope value but are at different elevations aren't the same in terms of hazard and that the possibility that slopes with elevations greater than two slopes at the same slope pass into unstable positions is greater compared to others (Ahmed, 2014).

Hasekioğulları (2011) reported in a study that landslide-prone areas are mostly located at elevation classifications between 250-500 m. The author determined in this situation that it was consistent with evaluations conducted in the slope parameter. The author connected this to areas with high topographies in the study area being covered with steep slopes and to the formation of low topographical heights from soil materials, mostly the product of decomposition. Delikanlı (2010) determined in a study that slope increases landslide with elevation in a logistic regression equation.

5 The Occurrence of Landslides According to Slope Values

Landslides are mostly seen at certain critical slope angles (Lee and Min, 2001; Öztürk, 2002; Rozos et al., 2010; Yılmaz et al., 2012; Özşahin, 2015; Jayanthi et al., 2016; Laldintluanga et al.; 2016; Avcı, 2016). A great many researchers assert that with the increase of slope increases susceptibility to landslides (Pachauri and Pant, 1992; Gökçeoğlu and Ercanoğlu, 2001; Lee and Min, 2001; Öztürk, 2002; Lee, 2005; Özşahin, 2013; Özşahin and Kaymaz, 2013; Taşoğlu et al., 2016) while a portion of researchers specifies that landslides can also form on low-slope angles (Ayenew and Barbieri, 2015). The general opinion is that landslides drop after a certain value, increasing with the slope value (Milewski et al., 2009; Hong et al., 2017; Chen et al., 2017). Conversely, Van Westen et al. (2003) reported in a landslide susceptibility evaluation study they conducted in Italy that slope isn't an effective parameter for the study area because the possibilities of landslides in all slope groups are close to one another.

Landslides are evaluated in different groups. In the literature, there are intervals preferred by different researchers while landslide slope values don't have definitive slope intervals. The most fundamental cause of this is that slope values are different for each land condition. Table 1 provides the slope values generally preferred in the literature review.

Table 1. The realized landslide slope values and groups in the literature

The literature evaluates landslide groups in classes 3, 4, and 5. Values grouped as very low slope, low slope, moderate slope, high slope, and very high (steep) slope based on the conditions of the studied land were categorized based on low, moderate, and high slope values to be able to make generalizations in this study.

5.1. The Effect of High Value (>35^o) Slope Angle on Landslides

The reason for the rarity of landslides in the very high slope range is that the width of weathering zone is few and that this reduces the susceptibility of landslides. It reduces normal stress and facilitates the activation of materials by increasing the shear stress of soil such as an increase in slope values and the strain of land shear. Landslides with high slope values exceeding 45^o comprise sturdy rocks rather than weathered materials in the nature of ground, and these types of rocks are stable. However, any increase in slope leads to an increase in the possibility of breaking away (Wilson and Gallant, 2000; Gökçeoğlu and Ercanoğlu, 2001; Lee and Min, 2001; Öztürk, 2002; Özşahin and Kaymaz, 2013; Lee, 2005; Sadr et al., 2014; Jayanthi et al., 2016; Laldintluanga et al., 2016).

Some researchers have stated that landslides are more common in steep areas compared to moderate and soft-slope areas in their study areas (Rozos et al., 2010; Alexakis et al., 2013; Laldintluanga et al., 2016; Abedini et al., 2017). Nagarajan et al. (2000), in a study conducted in the Konkan region of India, determined that rockfall-type landslides occur on steep slopes with

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a slope of greater than 80° and that mudslide-type landslides occurred at slopes with a slope of greater than 35°. And they reported that landslide susceptibility increased with the increase in slope.

Conversely, there are studies in which a sharp drop is seen in landslide intensity when slope reaches 45° (Tangestani, 2004; Jaafari et al., 2014; Chen et al., 2018). Although Chen et al. (2015) observed in their study that sloped fractures in angle slopes were more common than low angle slopes, they stated that the frequency of landslides didn't decrease because high slope transitions couldn't support the accumulation of soil above a certain threshold. Similarly, Gökçeoğlu and Ercanoğlu (2001) reported that, in order to see landslides in ground soil, the thickness of the present soil must be at least 1-2m and, most of the time, it will be difficult to see landslide activity because it isn't possible to reach these thickness values. Jayanthi et al. (2016) didn't encounter any landslide in areas of > 25 ° because the vegetation was unimportant in the very high slope category. Similarly, no rockfall of any kind was encountered in the research area despite the ability of rockfalls to form at great heights.

5.2. The Effect of Moderate Value (15^0-35^0) Slope Angle on Landslides

This situation is valid for slopes with moderate slope angles values. The increasing angle value in these types of slopes negatively affects the susceptibility of slopes because it will increase the shear stress of the soil. Most researchers reported that most landslides in their area of search formed on slopes ranging from 15˚ to 35˚ (Lee and Min, 2001; Ercanoğlu et al., 2004; Hong et al., 2017; Pham et al., 2017).

The literature contains research that claim the opposite of this. Erener and Lacasse (2007) in their study didn't report a relationship regarding the landslides at locations where the slope was greater than 15^0. Chau and Chan (2005) noted that landslides develop at higher angles, despite slopes with angle of 25˚-30˚ being more suitable for the landslides.

5.3. The Effect of Low Value ($<15^0$) Slope Angle on Landslides

Because slopes with high angle form from rock units and the thickness of the weathering zone increases in low-angle slopes, it is thought that slopes with this slope are more susceptible to landslides. There are studies that demonstrate that landslides form at low slope values (Milewski et al., 2009; Yılmaz et al., 2012).

There are studies regarding landslides that occur on slopes with low angle values beneath 15^0 in the literature). Conversely, there are studies that claim that, because shear stress will be lower in areas with much lower slope values, landslides won't form at these slope values and that encounter few or no landslides in areas beneath 15^0 (Lee and Min, 2001; Ercanoğlu et al., 2004; Dağ, 2007; Pham et al., 2017).

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7 The Classification of Slope

An important issue is the classification of the slope factor. Landslide susceptibility evaluations report which slope classification intervals landslides are concentrated by classifying different degrees of slope to determine the slopes at which landslide frequency is greatest. There isn't slope classification at a standard interval regarding slope values. In most studies, the classification intervals belonging to the slope values are taken differently. Generally, researchers prefer automatic classification because it is a fast and easy solution. On the other hand, because each study has different intervals according to the properties of the land, researchers can use their own classifications based on the land conditions and the concentrations of landslides in the working area (Biçer-Tetik, 2017). For this purpose, the slope angle maps are separated into groups (e.g. 0^0-5^0, 5-10^0, 10^0-15^0, and >15^0). These groups can later be reclassified as low slope, medium slope, and high slope. Other than this there are classifications created in the literature. One of these is the natural fracture optimization technique by Jenks (1967). Some researchers have observed that this classification in their studies is effective in describing the information content specific to the soil regarding the vulnerability of slope and landslides and performed it in their studies (Balamurugan et al., 2016). Most researchers applied equal intervals to determine the lower classifications (Yılmaz et al., 2012). Some of these have performed classifications again with 5^0 intervals (Özşahin, 2013; Chen et al., 2015). Differently, there are researchers who use certain standard classification intervals. For example, while Özşahin and Kaymaz (2013) noted that the slope classifications made by Mcdonald (1975) in the classification of slope values in the study area, Özşahin (2013) examined the effect of this parameter according to the slope classification explained by Bijukchhen et al. (2013). Özşahin (2015) reported the effect of the slope parameter in the examination field in another study according to the slope classification explained by Varnes (1976). Constantin et al. (2011) performed classifications according to the field observations of Balteanu (2010). Mahanta et al. (2016) used the BIS classification, which defines the slope map and slope classifications according to the formation frequency of the specific slope angles.

The evaluation of the reviewed studies attempted to determine the slope angels intervals in which the study areas are generally found (Figure 1), into how many classes slope can be divided (Figure 2), at which slope values landslides are seen (Figure 3), and at which slope angels values non-landslides (Figure 4).

In literature, 50 study areas selected randomly have been drawn (Figure 1). It is seen that most studies were prepared in areas with a slope of 0-90^0 and following that were areas with slopes of 0-70^0.

Figure 1. Slope interval graphs for 50 areas at which landslide research

The classification intervals used in the studies vary. Literatür research provided the slope classification intervals prepared from randomly selected studies. Classification interval graphics were drawn for 125 studies selected using in Figure 2.

Figure 2. Graphs for the classification groups of the selected studies

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As seen from Figure 2, the most frequently preferred classification intervals in the literature are 5 and 6. It is seen that the classification interval selection in the literature offers a wide array from 3^0 to 20^0. The classification interval selection varies based on the slope values and mass motion type of the studied area.

The slope intervals at which the most landslides occurred were separated into three classifications, and graphs were drawn using Figure 3.

Figure 3. The realized landslide slope value graphics

The slopes with landslides were separated into three classifications, as seen in Figure 3. The most landslides are occurred at slope values below 30^0. The literature mentions the slope intervals at which landslides occurred or not rarely.

Graphs for non-landslide slope values were prepared (Figure 4). These have been evaluated in three groups, being <15^0, 150-45^0, and >45^0. It was seen that more landslides are not encountered below 15 degrees and above 45 degrees.

Figure 4. Slope angels intervals at which non-landslides or rarely landslides

3. Determination of Class Slope Range: The Case Study of Turkey

In this study, the effect of slope in landslide is tried to be determined by literature research. The conclusions of the analysis done of the landslide in Turkey in order to become 1 / 25,000 scale 65 sheet were selected. 40 of these layouts were used for the study. The selected maps belong to 10 different locations. For the correct result, 4 sheets were chosen from nearby areas. Figure 5 shows the location map of the maps.

Figure 5. Location map of the maps used in the study

The landslide areas in the 40 layouts selected are classified according to their degree of slope. The classification process was examined separately in 8 groups, automatic, 3^0, 5^0, 8^0, 10^0, 15^0, 18^0 and 20^0. In classifications, area values for each group were calculated for each group based on the total. The graphics below are drawn (Figure 6).

Figure 6. Landslide distributions according to the total areas devoted to slope classes

General expression of total landslide areas by classes is given in Table 2. In the groups that are ranked from 1 to 10, 1 represents the most landslide slope interval and 10 represents the least seen landslide interval. As the interval values increase, the row number decreases.

Table 2. Slope intervals, which are the most landslide according to the total areas

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When the table is examined, in the classification obtained with 3 degree slope intervals, the total landslide area was found mostly in the 9^0-12^0 slope range. It is followed by a 6^0-9^0 grade class range. Looking at other groups, 5^0-10^0; 8^0-16^0; 10^0-20^0; 0^0-15^0; 0^0-18^0; 0^0-20^0 is the most visible landslide.

According to the graphics, the ideal selection range was evaluated as 5 degrees and automatic classification. In the study, the effects on the visuals were compared on the maps by class. The best results visually belong to automatic classification. The biggest reason for this is that the area prepares the classification according to the slope values irregularly but with good results.

The literature research showed that each landslide susceptibility study had unique characteristics. For this purpose, the study attempted to examine the effect of the slope parameter, most preferred in the literature, in the landslides. The relationship of slope angle with other parameters was evaluated. Studies specify slope values at which there isn't activity, just as they mention slope values at which landslide intensity is encountered. This is a situation that varies based on soil type, and standard values are thus not relevant. In addition to this, the preferred classification intervals were examined.

The slope intervals at which landslides occur vary as well. The biggest reason for this is the types of mass motions. Rock falls with a flow-type landslide will occur at different slope values. For this reason, there isn't consensus among researchers regarding classification interval. The same situation is valid within areas at which landslides aren't seen. While some writers said that it was stabile because of solid rocks in the area 45 degrees and greater, some researchers state that stability deteriorates when exceeding this value.

Mass motions at which landslides are seen have been separated into very different classifications in the literature. Just as there were mass motions encountered at slopes of 0-5 degrees, mass motions are encountered at 70 degrees and greater. The reason for this, again, is the type of mass motion. The slope value formed varies based on the mass motion that occurred for each study area.

The case study for classification has shown that the slope parameter can't be evaluated alone. The differences in the slope value in the literature vary according to the landslides in the soil or rock type area. The case study includes landslides with different lithologies but formed on the soil. Class ranges are determined in 3^0 to 20^0 ways, as in the literature. In general, in low-range classifications such as 3^0, 5^0, 8^0 and 10^0 degrees, the slope values gradually increase and then decrease gradually. At 15^0, 18^0 and 20^0, the slope is distributed with a sharp decrease after the peak value. Some expressions for their use in studies have been misused due to class ranges. For example, for the first 4 classifications (3^0, 5^0, 8^0, 10^0), the landslides increase with respect to the slope values, then decrease, while in the remaining classifications, the landslide values decrease with increasing slope. Looking at the classifications, the distribution of landslides according to the slope varies. In automatic classification, it shows an increasingly decreasing distribution in some areas while it shows a decreasing distribution in some areas. It is observed that those who are prepared with 30 intervals increase gradually, then gradually decrease and decrease in an

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exceptional area and have fluctuations with fluctuations in several areas with fluctuation. At 5 degrees, one area gradually decreases, while in other areas there is a gradual increase and then a gradual decrease. In addition to the gradual increase and decrease in those prepared with an interval of 8 degrees, it decreases only gradually. An unbalanced display prevails in 8^0 screenings. In the 10 degree interval, it starts with a certain slope value and decreases gradually. Unlike the small degree, the gradual decrease following the gradual increase is less. The general expression falls with the exception of three exceptions at 15 degrees. It only decreases in intervals of 18 and 20 degrees.

Landslides for an area decrease according to the slope values or increase first and then decrease, according to the selected slope interval value. It gives different graphic distributions of 5 degrees and 15 degrees prepared for the same area. While the landslide with a slope of 5 degrees passes from an increasing trend to a gradual trend, the pole prepared with a 15 degree class range gives a gradually decreasing graph.

Consistent with the literature, landslides have occurred below 30 degrees. Looking at the table in general, the area with the most landslides between 8-10 degrees. Landslides are rare if it is over 30 degrees. As seen in the literature, landslides above 45 degrees and 15-45 degrees are not found, whereas landslides are less random than landslides less than 8 degrees below the landslide. In the literature, it was determined that the automatic classification made a more accurate representation in the map expression, where the 5 degree interval, which is very preferred, gives better results than the others.

As a result, the classification with 5 degrees is possible, where the place to be meticulously looked at when preparing the slope map in a landslide area is between 8-10 degrees. It is recommended to be used in an automatic map for visual inspection. It is recommended to check the other classifications before making a general statement in the area and to express the landslide formation according to the slope values in this way.

As a result, this article tried to prepare a base for landslide susceptibility maps. Slope angle is the most used parameter in the literature. The effect of slope on landslide, its use with other parameters and landslide slope values are tried to be given. Preliminary preparation was attempted among the researchers using the slope parameter.

Examined studies showed that slope intervals were selected at different intervals from 3o to 20 o. The most preferred classification intervals are 5 and 6.

In conclusion, this study attempted to bring to light the issue of the determination of slope classifications, which are open to discussion in the literature. Publications in which researchers can compare the slope intervals determined in the susceptibility study to be prepared and the observed values of the landslide density have been provided in list form. The study attempted to reference new research.

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Table 1. The realized landslide slope values and groups in the literature

Milewski et al [220]	**0-10°**	**10-30°**	**>30°**		
	low slope	moderate slope	steep slope		
Guo et al. [104]	**0–10 °**	**10–20°**	**20–30°**	**30–40°**	**>40°**
	very soft	soft	moderate	steep	very steep
Kayastha [45]	**<15°**	**15–25 °**	**25–35 °**	**35–45 °**	**(> 45 °**
	flat	moderate slope	rather moderate slope	steep slope	very steep slope
Ercanoğlu et al [79]	**<6**	**6 and 16**	**16-25**	**25-33**	**> 33**
	very soft slopes	light slopes	moderately steep slopes	steep slopes	segments
Duo et al [111]	**0 ° -15°**	**15 ° - 30 °**	**30 ° -45 °**	**> 45 °**	
	soft slope	moderately steep slope	steep slope	cliff	
Özdemir [222]	**0-2**	**2-15 °**	**15-25°**	**25-45°**	**>45 (68)**
	very small slope (flat)	small slope	light slope (moderate)	steep	very steep
Özşahin and Kaymaz [188]	**0-3 °**	**3-10 °**	**10-20 °**	**20-30°**	**>30**
	very small slope	small slope	moderate slope	steep slope	very steep slope

Table 2. Slope intervals, which are the most landslide according to the total areas

Class	3	5	8	10	15	18	20
1	9-12^0	5-10^0	8-16^0	10-20^0	0-15^0	0-18^0	0-20^0
2	6-9^0	10-15^0	0-8^0	0-10^0	15-30^0	18-36^0	20-40^0
3	12-15^0	15-20^0	16-24	20-30^0	15-45^0		
4	3-6^0	0-5^0	24-32^0	30-40^0			
5	15-18^0	20-25^0					

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6	18-21^0	25-30^0					
7	21-24^0	30-35^0					
8	0-3^0						
9	24-27^0						
10	27-30^0						

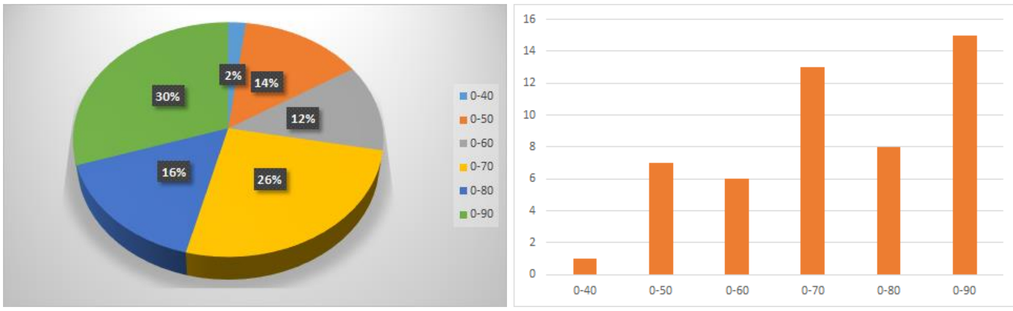

Figure 1. Slope interval graphs for 50 areas at which landslide studies are conducted

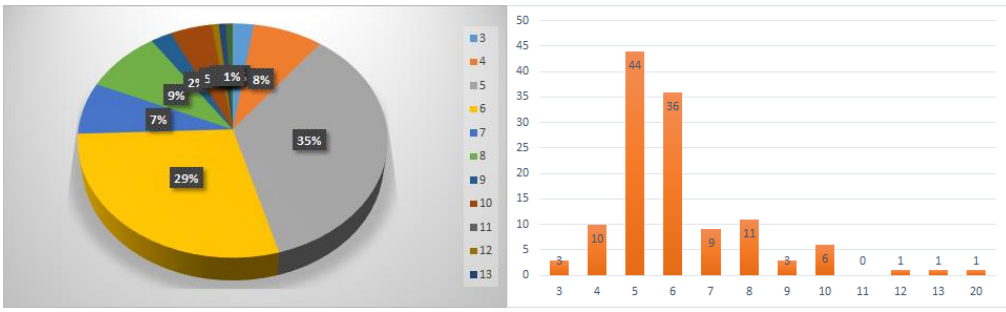

Figure 2. Graphs for the classification groups of the selected studies

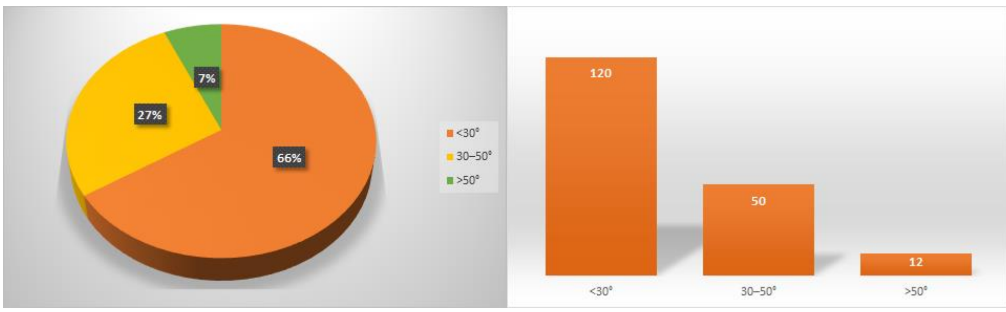

Figure 3. The realized landslide slope value graphics

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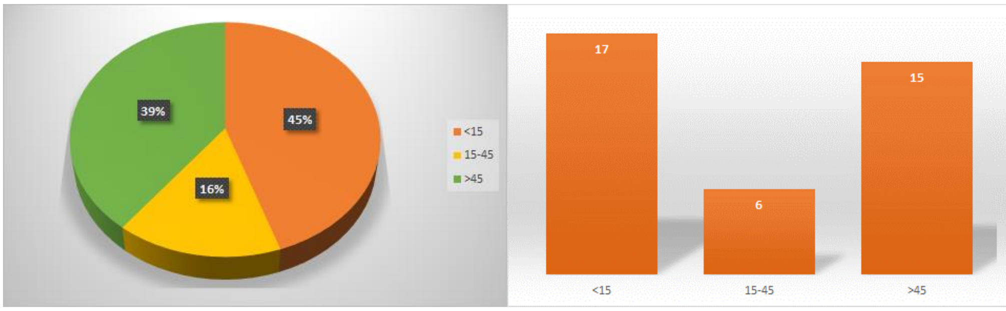
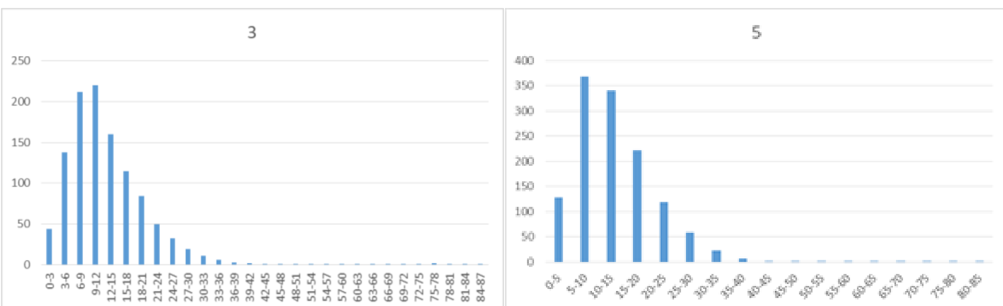


Figure 4. Slope angels intervals at which non-landslides or rarely landslides

Figure 5. Location map of the maps used in the study (taken from http://yerbilimleri.mta.gov.tr/anasayfa.aspx)



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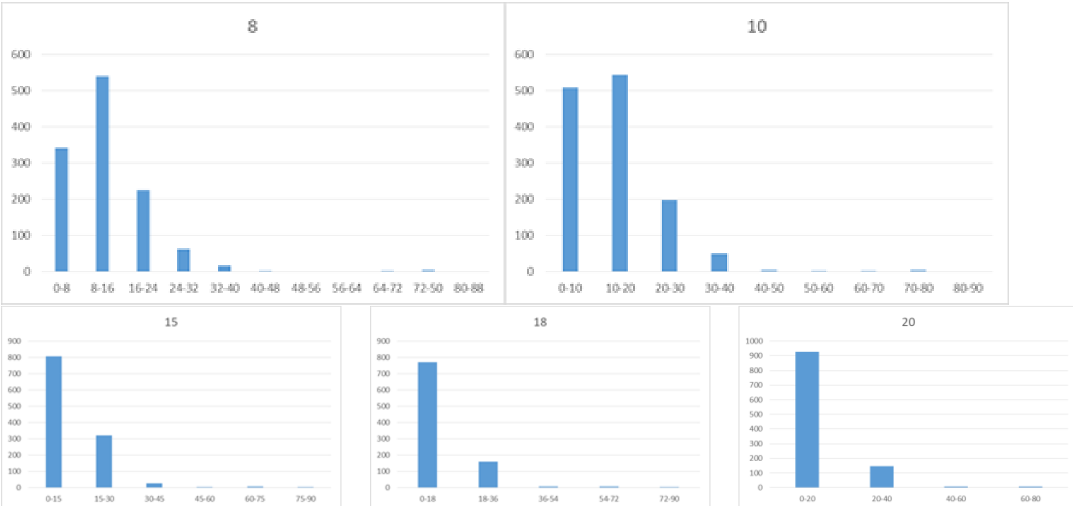

Figure 6. Landslide distributions according to the total areas devoted to slope classes

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