Avci V. (2023). Relationship between basin morphometry and flood-overflow: case of tabakhane stream (Ünye-Ordu,Türkiye). Gümüşhane Üniversitesi Sosyal Bilimler Dergisi, 14(1), 1-21.

Relationship between Basin Morphometry and Flood-Overflow: Case of Tabakhane Stream (Ünye-Ordu, Türkiye)

Havza Morfometrisi Sel-Taşkın İlişkisi; Tabakhane Deresi Örneği (Ünye-Ordu, Türkiye)

Vedat Avci[1]

Abstract

In this study, it was aimed to evaluate the areal (two dimensional) and relief (three dimensional) morphometric features of the Tabakhane Stream Basin within the scope of flood-overflow relationship. For this purpose, drainage density (Dd), stream frequency (Fs), basin shape (Rf), elongation ratio (Re) and Gravelius index (Kg), basin relief (Bh), relief ratio (Rh), ruggedness number (Rn), time of concentration (Tc), hypsometric curve (Hc) and hypsometric integral (Hi) analyses were performed. In this study, Digital Elevation Model (DEM) is used as the basic data. According to the analysis results, the values of Dd 2,51, Fs 2,97, Rf 0,31, Re 0,63 and Kg were found to be 1,38 in the Tabakhane Stream Basin. According to the results of relief morphometric analysis, the values of Bh were found to be 653 m, Rh as 0,05, Rn as 0.31, Tc as 126, 13 minutes and Hi as 0,30. The high Dd and Fs values in the basin indicate high flood potential. The hypsometric curve of the basin having a concave appearance. This indicates that floods in the upper basin can cause flooding in the downstream basin. When the climate and morphometric characteristics of the basin are evaluated together, it is seen that the flood-overflow likelihood is high and therefore basin morphometric characteristics should be taken into account in studies to reduce flood losses in the basin.

Keywords: *Basin Morphometry, Flood-Overflow, Tabakhane Stream, Ünye (Ordu).*

Öz

Bu çalışmada Tabakhane Deresi Havzası'nın alansal (iki boyutlu) ve rölyef (üç boyutlu) morfometrik özelliklerinin sel-taşkın ilişkisi açısından değerlendirilmesi amaçlanmıştır. Bu amaçla drenaj yoğunluğu (Dd), akarsu frekansı (Fs), havza şekli (Rf), uzama oranı (Re), Gravelius indeksi (Kg), havza reliefi (Bh), rölyef oranı (Rh), engebelilik değeri (Rn)), akım toplanma zamanı (Tc), hipsometrik eğri (Hc) ve hipsometrik integral (Hi) analizleri yapılmıştır. Bu çalışmada temel veri olarak Sayısal Yükseklik Modeli (SYM) kullanılmıştır. Analiz sonuçlarına göre Tabakhane Deresi Havzası'nda Dd 2,51, Fs 2,97, Rf 0,31, Re 0,63 ve Kg değerleri 1,38 olarak bulunmuştur. Rölyef morfometrisi analiz sonuçlarına göre Bh değerleri 653 m, Rh 0,05, Rn 0,31, Tc 126, 13 dakika ve Hi 0,30 olarak bulunmuştur. Havzadaki yüksek Dd ve Fs değerleri yüksek taşkın potansiyeline işaret etmektedir. Havzanın hipsometrik eğrisi içbükey bir görünüm sergilemektedir. Havzanın iklim ve morfometrik özellikleri birlikte değerlendirildiğinde sel-taşkın olasılığının yüksek olduğu ve bu nedenle havzadaki taşkın kayıplarının azaltılmasına yönelik yapılacak çalışmalarda havza morfometrik özelliklerinin dikkate alınması gerektiği görülmektedir.

Anahtar Kelimeler: *Havza Morfometrisi, Sel-taşkın, Tabakhane Deresi, Ünye (Ordu).*

Araştırma Makalesi [Research Paper]

Submitted: 07 / 07 / 2022
Accepted: 15 / 12 / 2022

[1] Dr. Öğr. Üyesi, Bingöl Üniversitesi, Bingöl, Türkiye, vavci@bingol.edu.tr, Orcid No: https://orcid.org/0000-0003-1439-3098.

Introduction

The geomorphological, morphometric, lithological, vegetation characteristics of basins and human causes have an effect in flood and overflow that occur due to cloudburst and snowmelt reaching the disaster level. Morphometric features of basin are among the parameters that have important effect in the formation of flood and overflow. Drainage basin analysis is used to assess groundwater/surface waters potential and management, basin management and to estimate soil erosion (Najar & Pandey, 2018). Topography, climate and geology are the three main elements that control drainage, drainage density, stream frequency, bifurcation ratio and the geometry of fluvial systems (Mesa, 2006). Some important physiological features of the drainage basins, such as the size (area, perimeter, length, witdh), shape (circular, elongated, square), height, relative height, slope (minimum, maximum and mean) of the drainage area, the size and length of the tributaries can be extracted directly from the drainage basin linear, areal and relief morphometric parameters (Gregory & Walling, 1976; Rastogi & Sharma, 1976). Comprehensive information about the formation of basins and landforms can be obtained with detailed morphometric analyzes (Sujatha, Selvakumar, Rajasimman, & Victor, 2015). Geological and geomorphological history of drainage basins can be revealed by morphometric analysis (Strahler, 1964) and these analyzes are also very important tools for understanding main and sub-basin basin dynamics. The dynamics that cause morphological changes in drainage basins can be revealed by basin morphometry (Thomas, Joseph, Thrivikramji, & Abe, 2011; qtd. in Najar & Pandey, 2018). These studies are very important for the sustainable use of natural resources. Quantitative morphometric analysis is based on the measurement of the linear properties of the drainage network, the spatial characteristics of the drainage basin and the relief characteristics of the drainage network (Avci & Sunkar, 2015, 2018; Melton, 1957; Miller, 1953; Schumm, 1956; Strahler, 1964). In the Geographic Information Systems (GIS) environment, morphometric features are easily obtained with the Digital Elevation Model (DEM) compared to traditional tools and methods. In this regard, GIS is an ideal tool (Altaf, Meraj, & Romshoo, 2013; Samal, Gedam, & Nagarajan, 2015). Some examples of studies about floods and overflows related to our country are given (Uzun, 1995; Bayrakdar, Döker, & Keserci, 2020; Canpolat, Dinç, Usun, & Geçen, 2020; Işık, Bahadır, Zeybek, & Çağlak, 2020; Koç, Petrow, & Thieken, 2020; Ocak & Bahadır, 2020; Zeybek, 2009). In recent years, there has been an increase in the number of floods due to global climate change. This situation is particularly evident in the Black Sea Region of our country. Major losses are experienced in many flood-overflow disasters that occur almost every year. Destruction of natural vegetation, rapid and irregular urbanization, wrong land use, opening of stream beds for settlement are other causes of floods and overflows. In this study, areal and relief morphometry characteristics of the Tabakhane Stream Basin, which cause floods and overflows in Ünye (Ordu), were evaluated in terms of their effect on the formation of floods and overflows. As a result of the floods and overflows that occurred in August 2018, Tabakhane Stream overflowed. As a result of the overflood; Tabakhane Stream, which passes through Çatalpınar District, which is approximately 5 km upstream from the Black Sea, overflowed to Ünye Akkuş road, created coastal gullies, and caused flood damages in low-level houses, gas stations, mosques and cemetery. In the flood-overflow experienced in the basin in 2018, clogged bridges by sediment transport, insufficient culverts on stream beds, closing some stream beds and converting them to development roads, and construction of agriculture, plantation and garbage stations in the natural beds of rivers are examples of human factors that cause floods (DSİ, 2018). Ordu is a province where the hazard of floods and overflows is at least as high as the landslides (Dölek, 2010). Between the years 1950 and 2019 in Ordu, there were a number of 50 floods and overflows on a disaster level and it has been observed to have increased in the last years (AFAD, 2020, Fig. 1). The Tabakhane Stream, which is the subject of the study, derives its source from the mountainous areas in south of Ünye. 11, 5 km long stream flows from Ünye district to the Black Sea (Fig. 2).

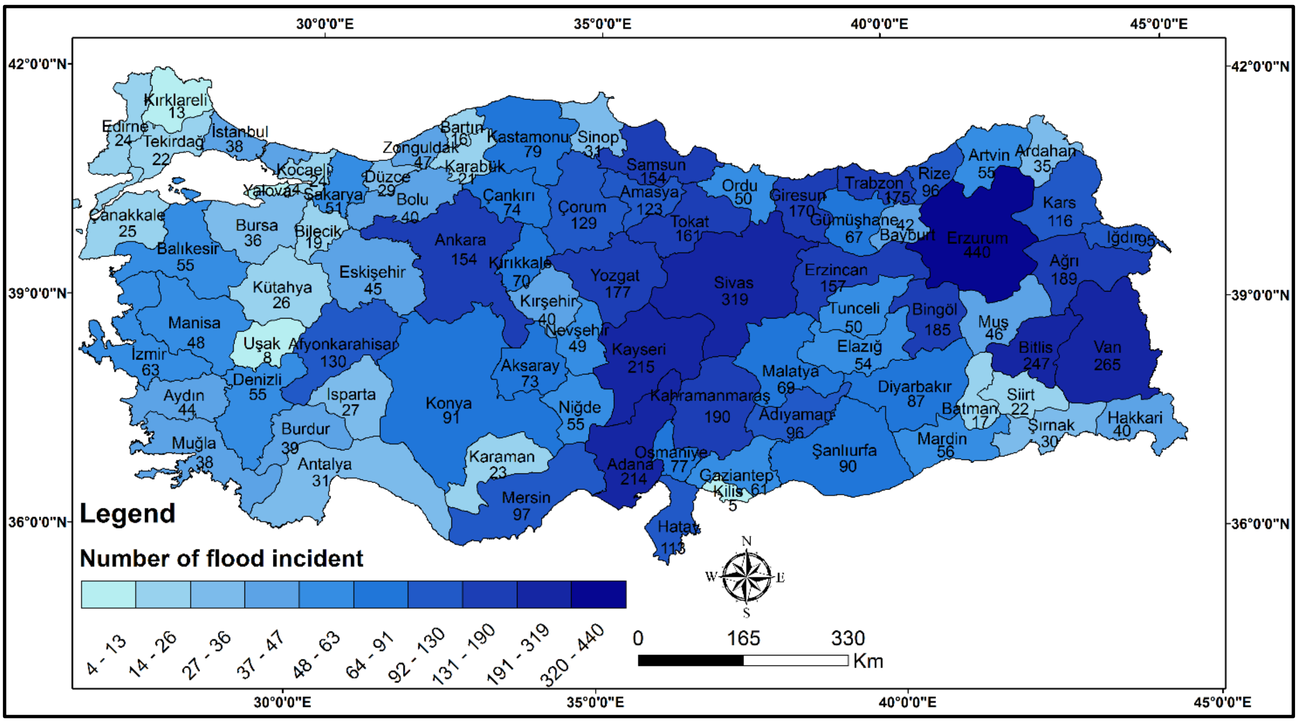

Figure 1. Distribution of The Number of Flood Incidents (1950-2019, (AFAD, 2020))

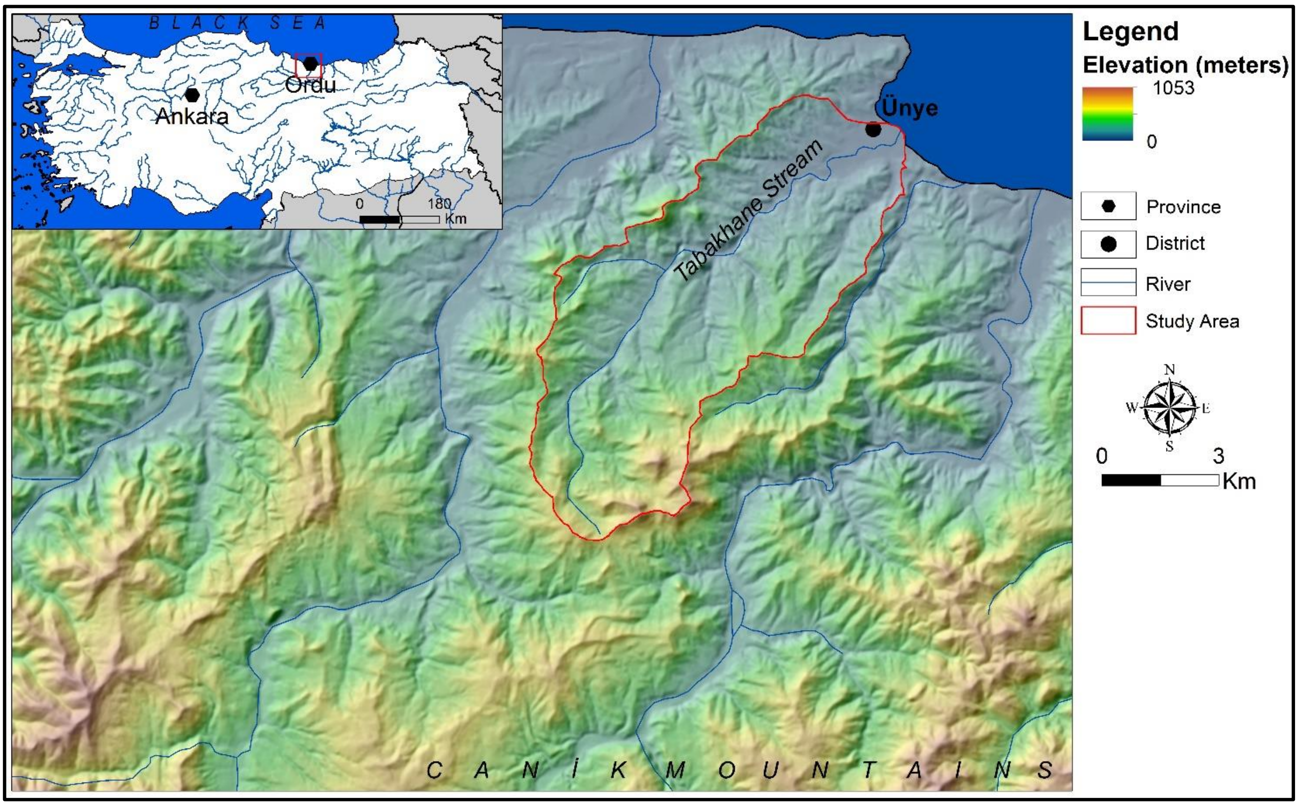

Figure 2. Location Map of Tabakhane Stream Basin (Ünye-Ordu)

The economic losses caused by floods and overflow disasters in the province are much bigger than that of other types of disasters. Especially in Ordu, flood-overflow disasters and the economic losses caused by them are observed more frequently in the coastal districts mainly in Merkez, Perşembe, Fatsa, and Ünye (Görüm, 2016; Ocak & Bahadır, 2020). The findings of this study reveal the effects of basin morphometry characteristics on the flood and overflow formation. The impacts of the basin morphometric characteristics on the flood-overflow formation include high Dd and Fs, high Bh and Rn value, the elongated form of the basin.

1. Material and Methods

Digital Elevation Model (DEM) is the major data set for different applications including hydrology, morphotectonics and morphometry studies (Jenson, 1991; Patel, Katiyar, & Prasad, 2016; Wise, 2000). Morphometric analysis used in determining the hydrological properties are made with the DEM. (Bastawesy, Gabr, & White., 2013; Li & Wong, 2010; Moore, Grayson, & Ladson, 1991). The obtain of drainage morphometric parameters from DEM is efficient, fast, precise and economic (Moore et al., 1991; qtd. in Kabite & Gessesse, 2018). The resolution of DEM plays an important role in obtaining morphometric parameters. “Morphometric parameters are emphasized in the studies carried out in river basins (Morisawa, 1959) and these can be grouped into three main categories as dimension, shape, and relief (as slope, aspect, three dimensions)” (qtd. in Verstappen, 1983). In this study, the areal and relief morphometric properties of the Tabakhane Stream basin were analysed. The analysis was done by taking the formulas in the literature into account (Table 1). In the study, F 38 d3, F 38 c1, F38 c4 sheets (HGK, 1978), Landsat TM 5 and 2018 Landsat 8 OLI-TIRS satellite images (https://earthexplorer.usgs.gov/) of the topographic maps of 1/25.000 scale were used as basic data. From the topography maps, ArcGIS 10.1 Spatial Analysis-Topo to Raster Module was used to create Digital Elevation Model (DEM). Elevation, slope and aspect maps were created from the DEM, and the relationship of these geomorphological factors with flood-overflow was analyzed. Normalized Difference Vegetation Index (NDVI) was obtained from satellite images by band ratio. NDVI measures vegetation from the difference between NIR (reflecting vegetation) and RED (absorbing vegetation) bands. NDVI values range from +1 to -1. Negative values most likely indicate water areas, while values close to +1 indicate areas with dense vegetation (https://gisgeography.com/ndvi-normalized-difference-vegetation-index/). Changes in land use were analyzed with Corine data and Google Earth images.

Table 1. Formulas Used to Determine The Morphometric Properties of Tabakhane Stream Basin (Ordu)

İndices	Formula	References
Drainage Density	$D_d = \frac{\sum L}{A}$ where the total drainage length is Dd in the formula, the basin area is A.	(Horton, 1932, 1945)
Stream Frequency	$F_s = \frac{N}{A}$ while the total number of segments is N, A is basin area..	(Reddy, Maji, & Gajbhiye, 2004; Strahler, 1964)
Basin Shape	$R_f = \frac{A}{L_b^2}$ Basin area is A where the maximum basin length is Lb.	(Horton, 1932, 1945)
Elongation Ratio	$R_e = \frac{2}{L_m} \times \left[\frac{A}{\pi}\right]^{0.5}$ A is the basin area, Lm is the maximum basin length.	(Schumm, 1956)
Gravelius İndeks	$K_G = \frac{P}{2\sqrt{\pi A}} \approx 0.28\frac{P}{\sqrt{A}}$, The basin perimeter is P, while the basin area is A.	(Gravelius, 1914)
Basin Relief	$B_h = H_{max} - H_{min}$, The maximum basin height is Hmax, and the minimum basin height is H min.	(Schumm, 1956)
Relief Ratio	$R_h = \frac{H\ (m)}{L\ (m)}$, H is the elevation difference within the basin, L is the maximum basin length.	(Schumm, 1956)
Ruggedness Number	$\mathbf{R_n = B_h \times D_d}$ Bh is basin relief where Dd is drainage density.	(Melton, 1957)
Time of Concentration	$T_c = \frac{0{,}0195 \times L^{0.77}}{S^{0.385}}$ L is the main stream where S is the slope.	(Kirpich, 1940)
Hypsometric Curve	$y = \frac{h}{H}$ $x = \frac{a}{A}$ The relative relief is y, while the relative area is x.	(Strahler, 1952)
Hypsometric Integral	$H_i = \frac{H - H_{min}}{H_{max} - H_{min}}$ H is the mean height, Hmin is the minimum height, and Hmax is the maximum height.	(Strahler, 1952)

2. Findings

In this section, the geographical features of the study area were evaluated, the areal and relief morphometric analyzes were made, and the morphometric analysis results are shown in Table 2. It is seen that the drainage density, stream frequency and basin relief are high in the basin.

Table 2. Morphometric Measurement Results of Tabakhane Stream Basin

	Dd	Fs	Rf	Re	Kg	Bh	Rh	Rn	Tc	Hi
Tabakhane Stream Basin	2,51	2,97	0,31	0,63	1,38	653	0,05	1,63	125,73	0,30

2.1. The Study Area and Its Major Geographical Properties

While the elevation is minimum 0 m (Photo 1) in the lower course of the Tabakhane Stream, it reaches up to 653 m in the upper course. The mean elevation value in the basin is 200 m (Fig. 3a). The elevation difference in the basin is high. In 56% of the basin area, the elevation is below 200 m. The ratio of elevation above 200 m is 44%. Temperature and precipitation show variation depending on the elevation in the basin. This situation affects the flood-overflow formation. Resulting from high elevation, abundant precipitation in the upper basin cause overflow in the lower basin. Regions with low elevations are also important considering the amount of precipitation accumulated because they collect precipitation from higher regions (Görcelioğlu, 2003).

Photo 1. A View from The Tabakhane Stream Basin

Elevation difference reaches 350m in the upper basin. Reaching this elevation difference in short distances shows ruggedness and cleavage. This situation indicates that the branches originating from the upper basin have flood character.

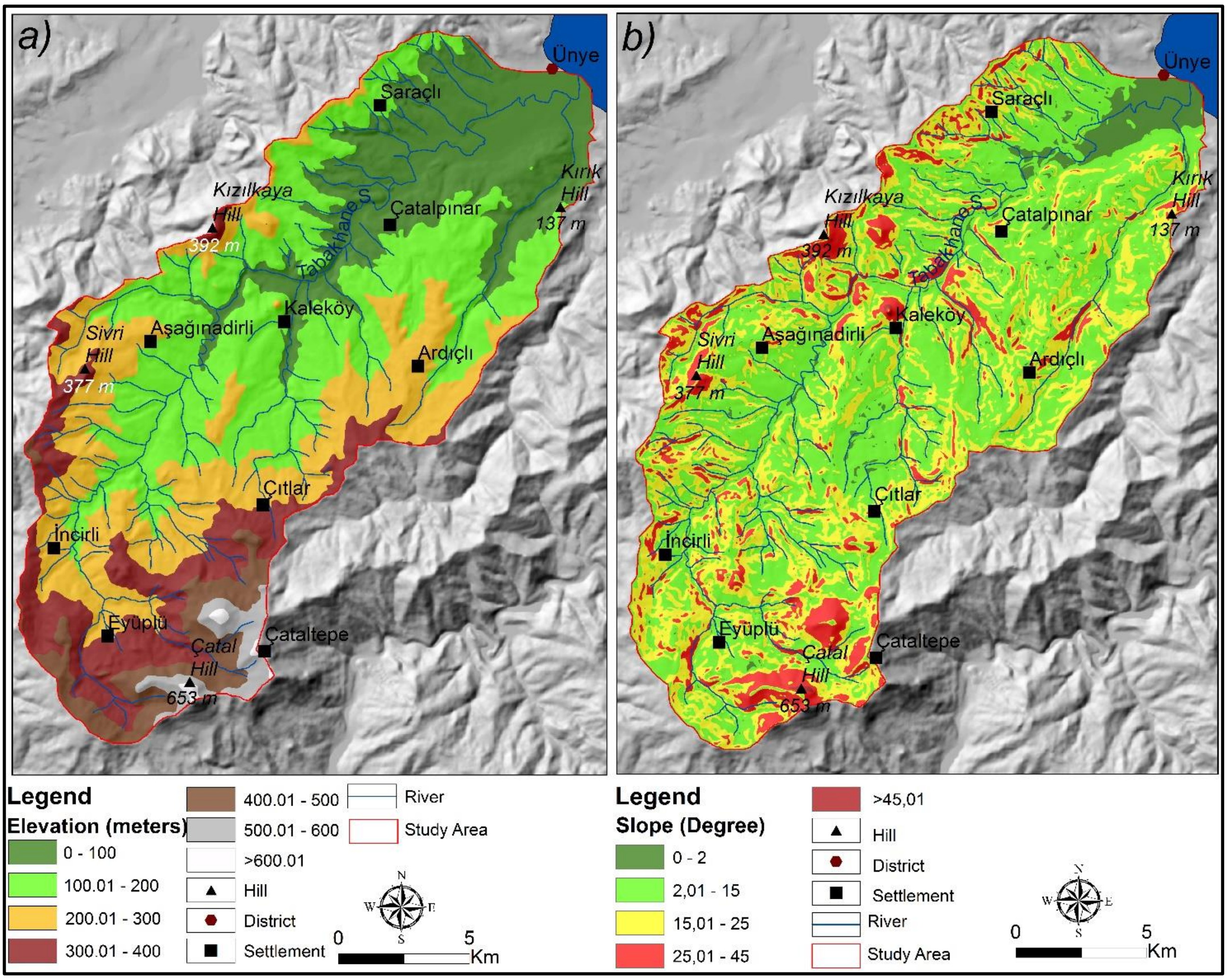

Figure 3. Elevation (a) and Slope (b) Map of Tabakhane Stream Basin (Ünye-Ordu)

It is obvious that while the precipitation amount in Ünye, a district situated at sea level, is 1066 mm, it will reach 1500 mm in the south of the basin when the elevation is taken into account. Since the high amount of precipitation affects the amount of water flowing, it affects the formation of flood-overflows (Photo 2).

Photo 2. View Of The Flood Event (DSİ, 2018)

In the Tabakhane Stream Basin, the minimum slope is 0°, the maximum slope is 53°, and the average slope is 15°. While the slope values increase towards the south of the basin, they decrease on the shore. According to the classification by Verstappen (1983), 0-2° slope group accounts for % 4, 2-15° slope group accounts for % 50, 15-25° slope group accounts for % 35 and 25-45° accounts for % 11 (Fig. 3b, 4a).

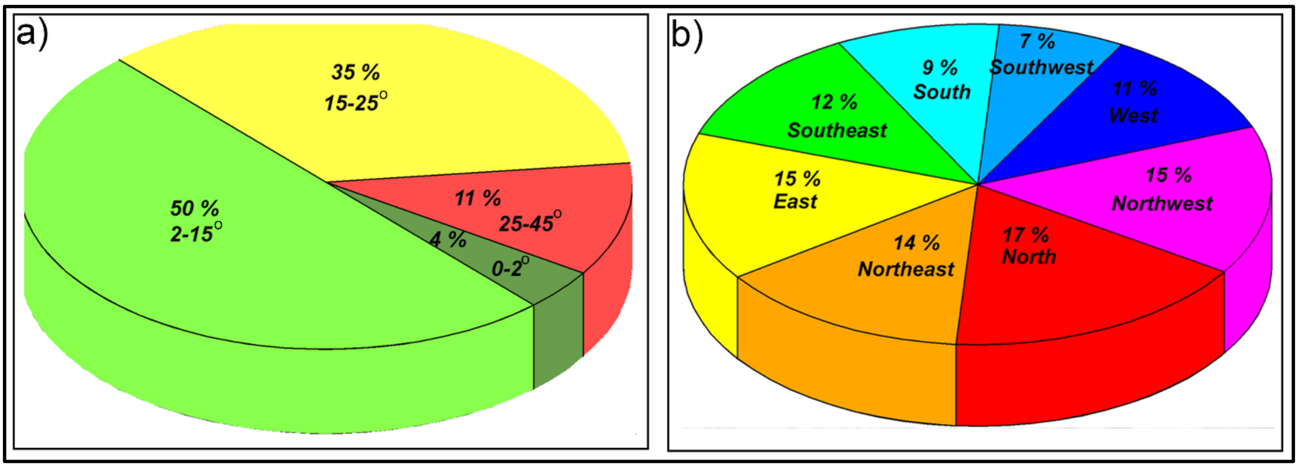

Figure 4. Proportional Distribution of Slope (a) And Aspect (b) in The Tabakhane Stream Basin (Ünye-Ordu)

The slope is a predisposing factor in the formation of floods. When other conditions are favourable, increasing the slope increases the probability of flooding. By determining the amount of surface flow, soil moisture and the amount of groundwater, the slope factor effects floods-overflows (Yalçın, 2013). Steep slopes increase the amount of material carried by erosion, increasing the velocity of runoff. The sediment carried accumulates in the valley and plain floors. As a result, the river bed fails to carry the water incoming in the rainy periods and thus overflows occur. Since the waters coming to the surface and accumulating in the surface can start flowing rapidly, these waters can trigger large flood incidences in areas where the slope is high (Karakuyu, 2002; Kopar,Polat, Hadimli, & Özdemir, 2011). The fact that the speed of the waters running off is high in sloping basin and valley slopes increases both the river erosion and causes the water to be accumulated in the river beds in a short time. Thus, flooding incidents occurring in sloping places are more severe than those with low slope values (Atalay, 2016). When the slope is high, the rain falling in the river basin joins the mainstream from the tributaries at a great speed (Hoşgören, 2004). This situation results in the development of the peak flows in a short time and shortening of the flow accumulation time. It is seen that the slope values in the basin are high. The standard deviation of the slope values is 8.06. The rate of areas with a slope value above 15° is 46%. In areas with a high slope, flood likelihood is high and in areas with low slope values, the likelihood of overflow is high. Although the rate of areas with 0-2° slope is low, these areas correspond to Ünye settlement. This situation increases the loss caused by floods. The slope distribution in the basin is on a level where it promotes floods and overflows. The fact that fields cover much of the areas means that there will be more floding flows. The slope is low and the areas where the water collects are very few. In this case, it is inevitable that flooding flows cause overflow in downstream of the basin. The aspect in the Tabakhane Stream Basin generally faces the north. The north-facing slopes cover 48%, southern-facing slopes cover 18%, eastern-facing slopes cover 15%, western-facing slopes cover 11%. This shows that the basin is susceptible to the effects of the Black Sea (Fig. 4b, 5a). The abundant precipitation of the north-facing slopes leads to high soil humidity in these slopes, increases the amount of water joining in the surface flow and decreases the infiltration. These conditions facilitate flood and overflow formation.

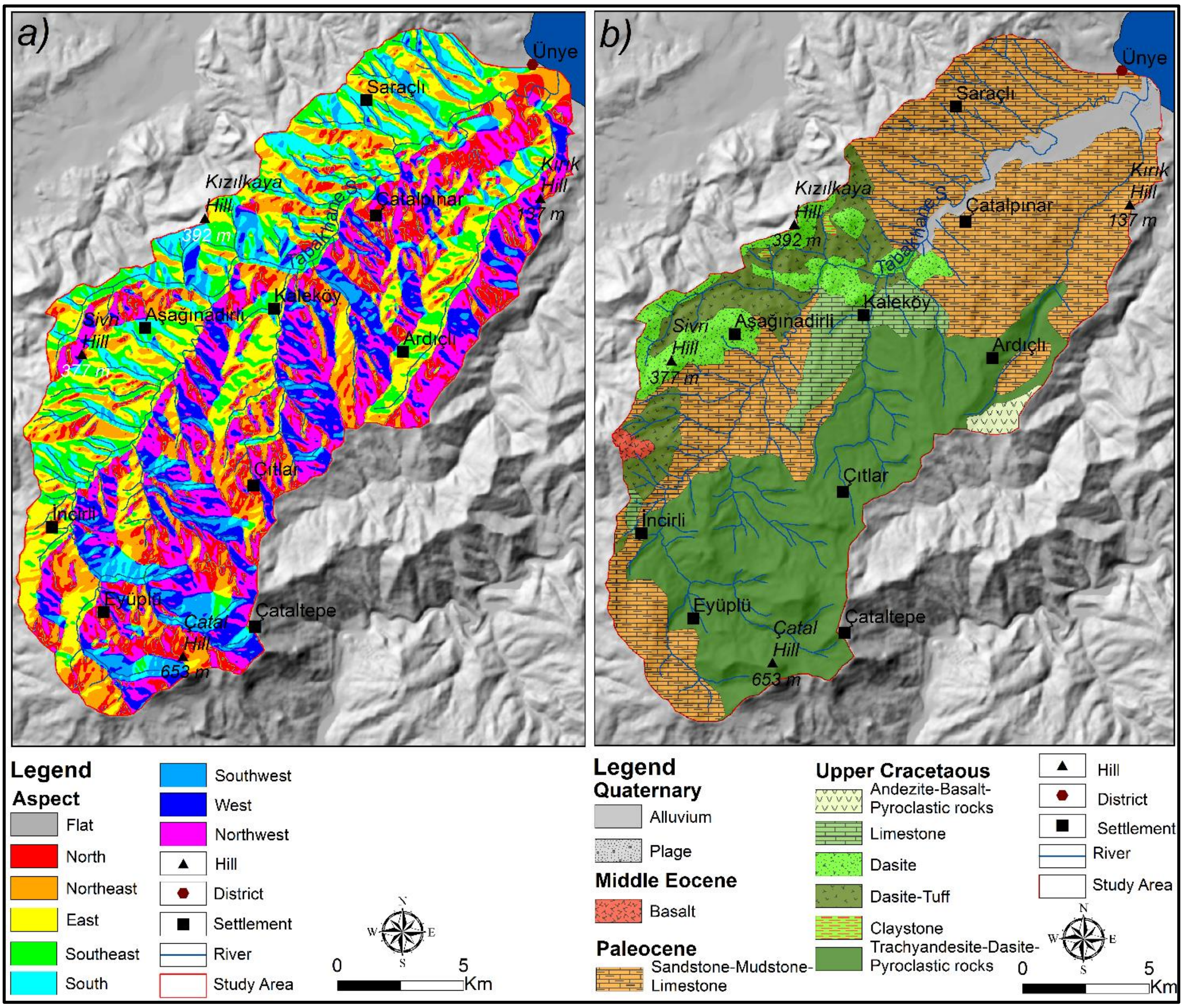

Figure 5. Aspect (a) and Lithology (b) Map of Tabakhane Stream Basin (Ordu) (The Lithology Map was Drawn Using (Hakyemez & Papak, 2002)).

Aspect is an important factor in the formation of floods. Because the aspect, which is the inclination direction of the slope faces, is a factor which influences the amount and duration of heat energy received from the sun, and therefore water loss caused by transpiration and evaporation (Görcelioğlu, 2003). The amount of precipitation also varies depending on the aspect. The relationship between slope direction, precipitation and flood-overflow is valid for northern aspects of the entire Black Sea coastline. In general, receiving more precipitation, the northern slopes of the region increase the possibility of run-off that may cause flooding. The lithology of Tabakhane Stream Basin is formed by rocks of different periods from the Upper Cretaceous to the Quaternary. The rocks formed in the period of Upper Cretaceous are composed of andesite, basalt, dacite, tuff, claystone, trachy-andesite and pyroclastic rocks. These rocks are seen south of Kızılkaya Hill and north of Çatal Tepe. Paleocene rocks form sandstone, mudstone and limestone. These rocks, which have the largest surface area in the study area, are surfaced in the northeast and southwest. Basalts of Middle Eocene period are surfaced in the north of İncirli. Alluvial and plage of Quaternary period, which is the youngest unit, are found in the lower course of Tabakhane Stream (Hakyemez & Papak, 2002, Fig. 5b). The lithological structure has a great effect on flood and overflow formation. In the case of floods, rocks can be divided into two groups as impermeable and permeable. Porous rocks consist of cracked limestone, porous sandstone and conglomerates with a low amount of clay. These rocks significantly reduce the amount of water joining the surface flow due to significant infiltration of precipitation water, thus preventing the occurrence of floods and overflows. Impermeable rocks are composed of rocks rich in clay such as marl, clayey schist pores of which are closed due to swelling upon water infiltration inside. Both the drainage network and the surface flow are more intense on these rocks (Atalay, 2016). In addition, the amount of solid loads in rivers flowing on loose and grounds susceptible to erosion is high. These rivers have more favourable conditions in terms of clogging of the beds in the plains and the formation of overflows (Hoşgören, 2004). The lithology formed by sandstone susceptible to erosion and limestone in the north increases the amount of material carried by the rivers and facilitates flooding events. In Ünye (Ordu), the Black Sea climate, which is rainy every season prevails. In the study area, winters are temperate and summers are cool. According to data from Ünye meteorological station, the average temperature is 14.2 ^{O}C and the annual rainfall is 1066 mm. The least rainy month is May, with 50 mm precipitation, the highest precipitation is recorded in December with a precipitation amount of 132 mm (Fig.6).

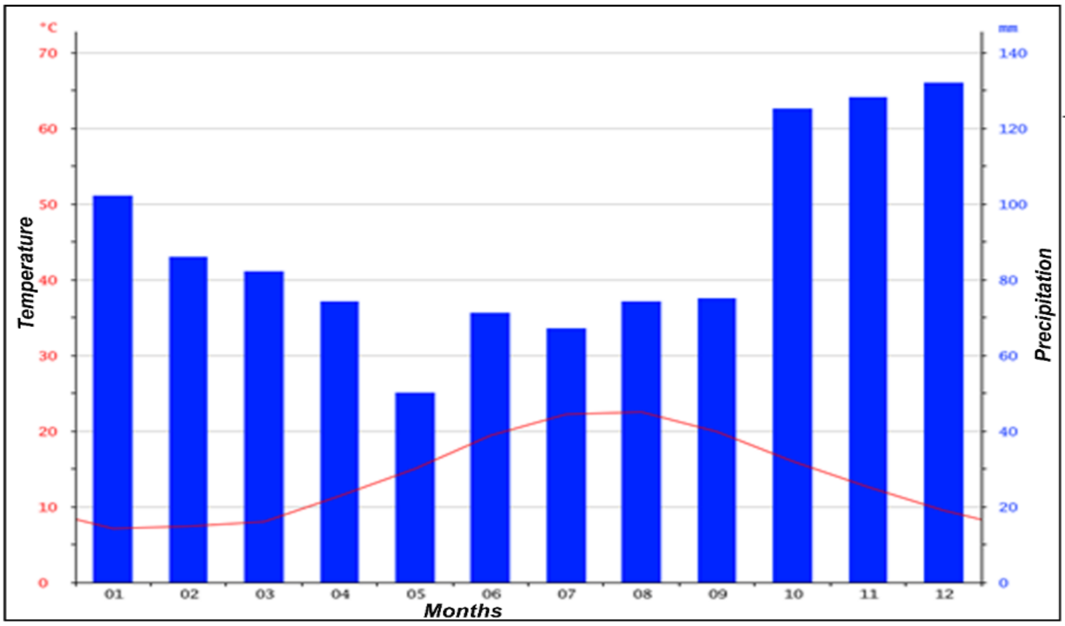

Figure 6. Temperature And Precipitation Graph for Ünye (Ordu) District (Source: Climate. data.org.)

After a long precipitation period, floods and overflows can occur as the ground becomes saturated with water, as well as floods and overflows can be seen after short-term convective precipitation (Atalay, 2016). Before the flood event, there was no precipitation in Ünye on 07-08/08/2018. In the flood that took place on 08-09/08/2018 in Ünye, the amount of rainfall per m^2 during the flood was 55,2 kg. This amount of precipitation is more than the total precipitation in August. For the measurements carried out after the flood in the section of Samsun-Ordu Highway Bridge (Manning formula used), maximum flow rate was found to be 413.26 m3/s. this amount corresponds to frequency flow of 33 years. Qmax.500 flow rate of Tabakhane Stream was determined as 245.8 m^3/s (DSİ, 2018). Climate characteristics of the study area facilitate flood-overflow formation. Because, heavy precipitation, low evaporation, and transpiration reduce the infiltration and increase the amount of water starting to flow on the surface. It is predicted that the amount of precipitation will increase in the future climate scenarios in Ordu. Expected precipitation increase will also bring about a rise in the number of natural disasters such as floods, overflows, and landslides which are commonly seen in the field (Gönençgil, 2016).The geographical location of Ordu, the peculiar landforms, climate, soil, and natural vegetation characteristics have led to the formation of various vegetation characteristics and the formation of various plant communities. In the province, plant formations, which have occurred under the ecological conditions, include forest formation, shrub or bush formation, and alpine plants. One of most common of these is the forest formation, which is concentrated on mountainous areas and plateaus. Forest formation is mostly characterized by moist forest. Natural vegetation in Ordu has been largely destroyed. The use of many plant species by the local people as construction materials and fuel, hazelnut fields, and other agricultural fields built, road construction and expansion work cause the shrinkage of natural vegetation (Günal, 2016). This situation can be seen from the Normalized Difference Vegetation Index (NDVI) values of different periods. In the NDVI data of 1999, while the ratio of the areas with an intense vegetation cover was between 0.6-0.9 was the highest, according to the data of 2018, the areas with intense vegetation cover in which NDVI values ranged between 0,2-0,4 covers a bigger place (Fig. 7a, b).

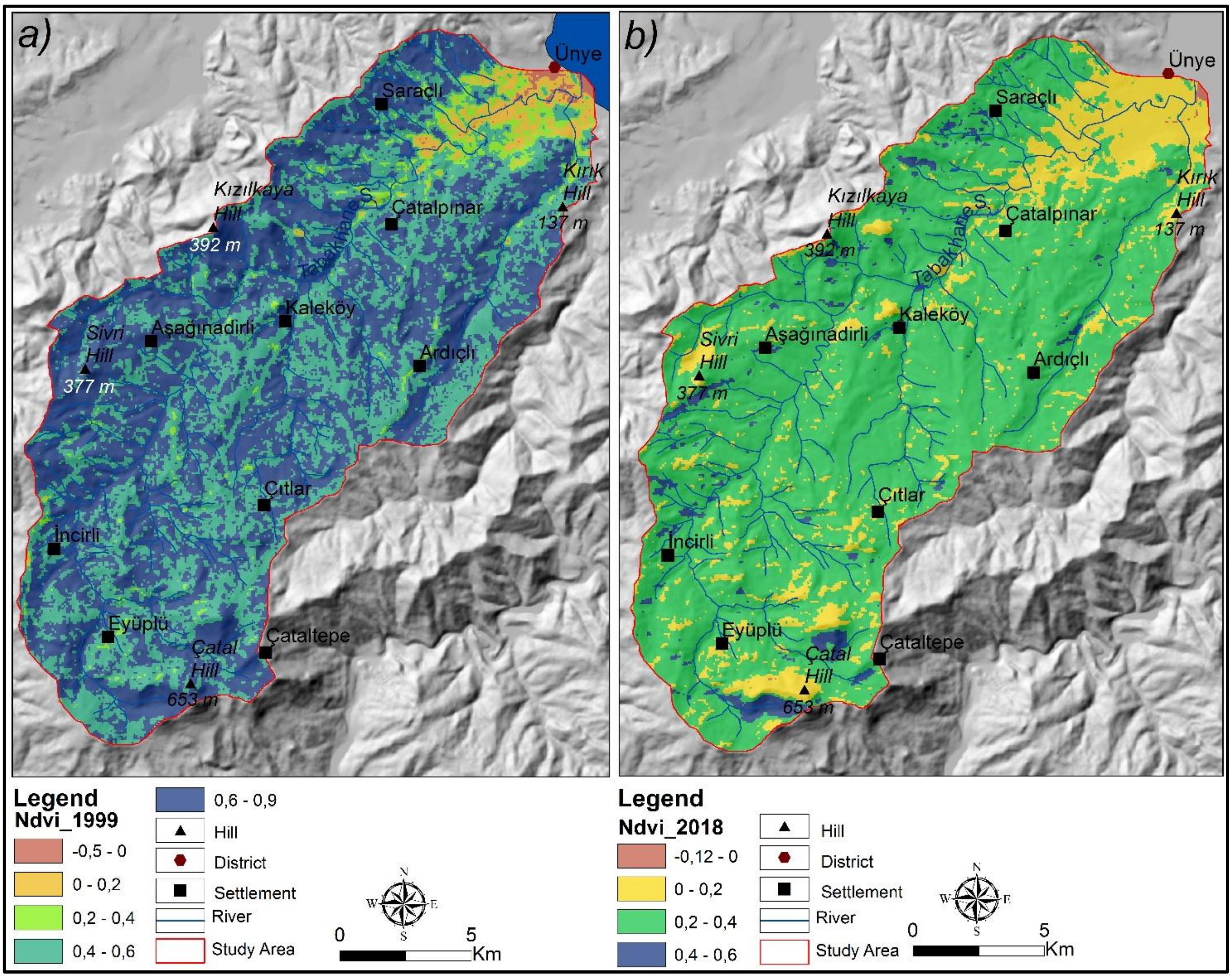

Figure 7. NDVI Data from Different Periods in The Tabakhane Stream Basin (Ordu) a) 23/09/1990 Landsat TM 5 b) 29/10/2018 Landsat 8 OLI-TIRS

While the mean value of NDVI histogram data for 1999 was 0.58, this value decreased to 0.27 in 2018 (Fig. 8).

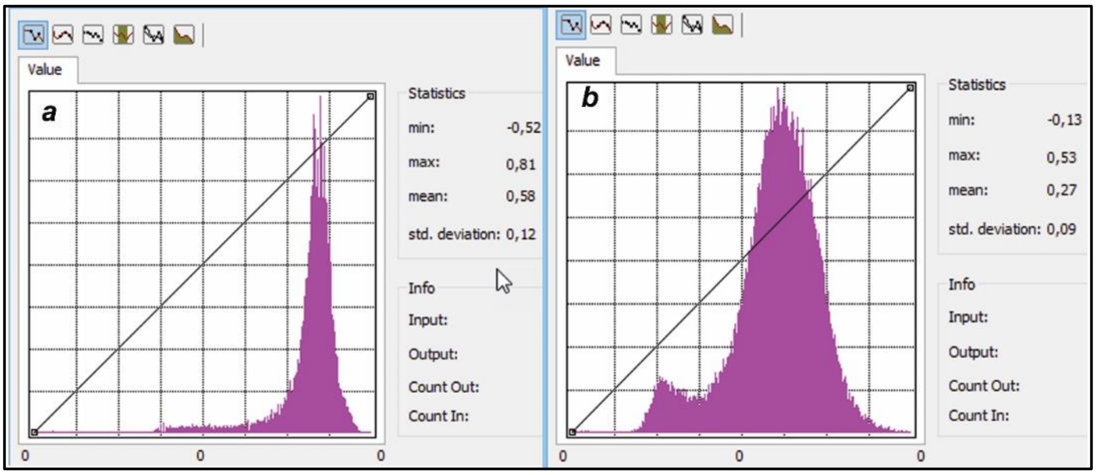

Figure 8. Histogram of NDVI Data from The Years 1999 (a) and 2018 (b) in The Tabakhane Stream Basin (Ordu)

This results from the destruction of the forest cover in the basin and transformation of the forests into hazelnut orchards. This change in natural vegetation facilitates the formation of floods-overflows. Artificial areas (buildings, roads, etc.) cause a decrease in the amount of water leaking to the soil and thus, the amount of water starting to flow on the surface becomes higher than the areas with high surface permeability (Önsoy, 2008). According to the CORINE (Coordination of Information on the Environment) data, the proportion of urban areas in the study area increased by 40% between 1990 and 2000. This facilitates flood and overflow formation by reducing infiltration (Fig. 9).

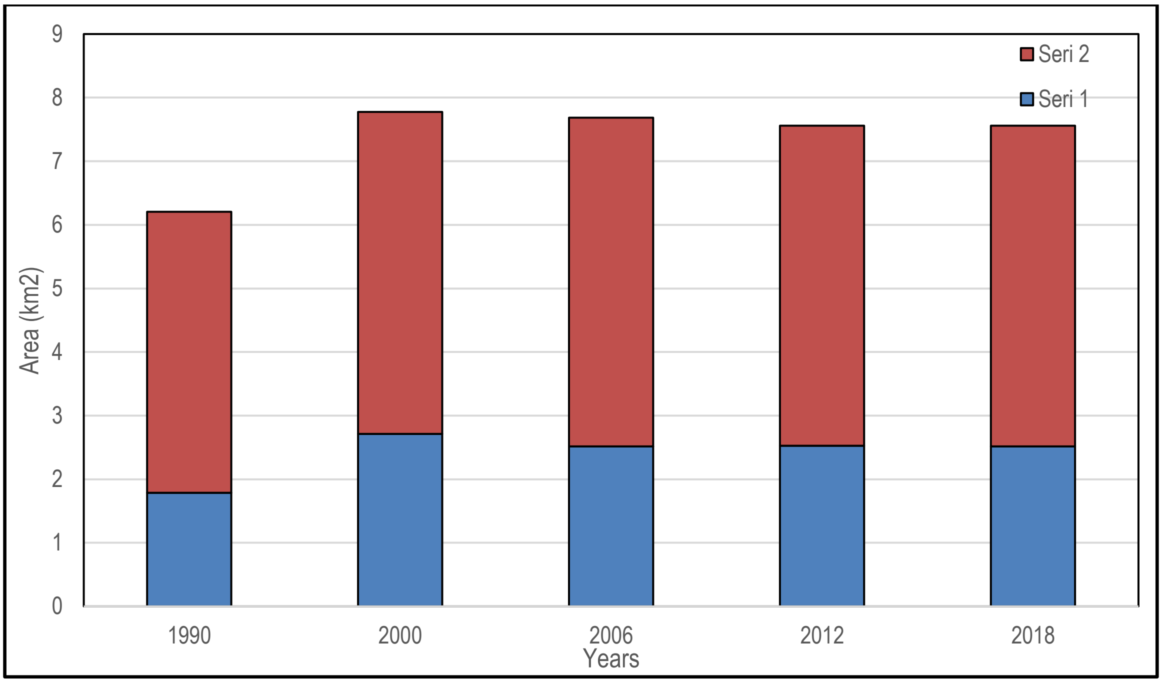

Figure 9. The Change That Occurred in The City Area (Series 1) and Forest Area (Series 2) in The Basin between 1990-2018 (Generated From Corine Data, https://land.copernicus.eu/pan-european/corine-land-cover)

In this period, the change that took place in the urban area is related to the migration to Ünye City. As a matter of fact, the city population increased more than 50% between 1990 and 2000. From the Google Earth images of the study area, it is seen that the city of Unye expands along the coastline and the river valley (Fig. 10).

Figure 10. From The Google Earth Images, It is Seen That The Urban Areas Expanded in Ünye Between 1990 (a) and 2018 (b). (Source: Google Earth Pro, 2022)

This situation reduces land permeability and increases the hazard of flooding. Population growth has a great impact on rapid urbanization. The increase in the city population between 1990 and 2018 is more than 3 times of the population in 1990 (Fig. 11).

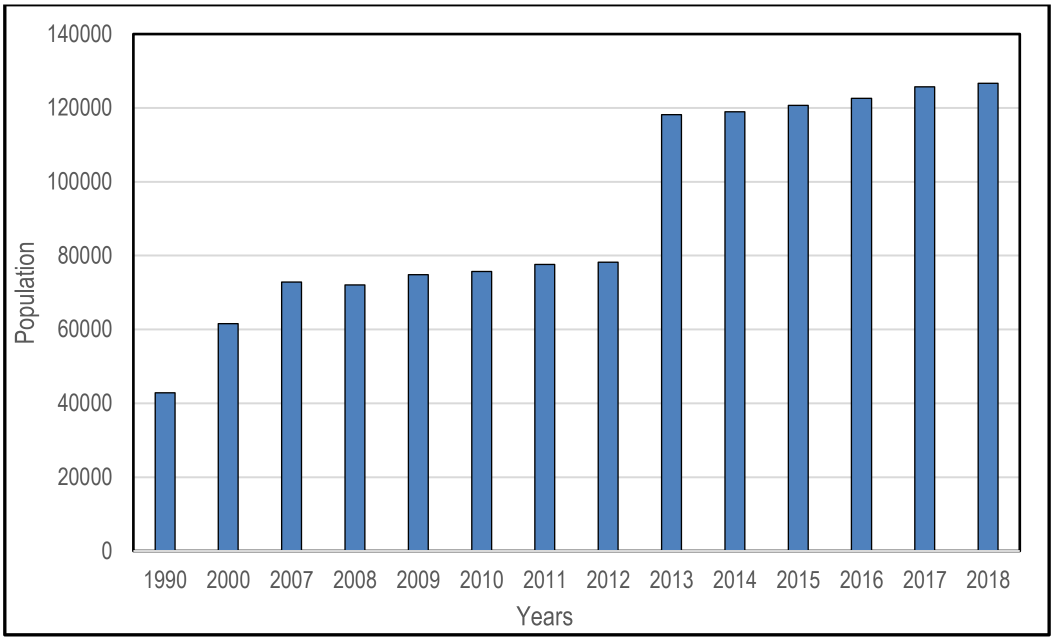

Figure 11. The Change in The City Population in Ünye Over The Years (Population Data for The Years 1990 and 2000 were taken from (Yılmaz, 2005)**, others from the TSI (2021))**

2.2. Areal Morphometric Properties

Within the scope of area morphometric analysis; Dd, Fs, Rf, Re and Kg analyses were done in Tabakhane basin. Results of analysis shows the Dd and Fs values to be high.

2.2.1. Drainage Density (Dd)

Drainage density, which is an important morphometric parameter, indicates the degree of erosion cleavage of topography (Strahler, 1964). In this study, the distibution of drainage density in the basin has been found by dividing the basin area into grids of 1000*1000m. In the calculation made by taking into account the valley densities in the Tabakhane Stream Basin, the Dd value was found to be 2.51. Drainage density in the basin was found to be high between Kaleköy and Eyüplü. This situation is rather related to the lithological structure. Because of the fact that slope values are low in the lower course of the Tabakhane Stream, the sandstone, limestone and alluvium lithology drainage density values are low. The lithology consisting of dacite and tuff in the south of the basin and high slope drainage density resulted in high drainage values. (Fig. 12 a). Reddy et al., (2004) stated that if the drainage density value is greater than 1.75 it can be defined as high. If it is greater than 2.5 it can be defined as very high. Deju (1971), grouped the drainage density values as 0.5 (low), 0.5-1.5 medium and above 1.5 as high. Langbein (1947), reported that the drainage density ranged from 0.55 and 2.09 km/km^2 in the humid regions and the average density value was 1.03 km/km^2. Malik, Bhat, & Kuchay (2011), classified drainage density as Low: 0-2, Medium: 2 – 2.5 High: 2.5 - 3 Very High: 3 and above. According to these classifications, the drainage density in the basin is high.

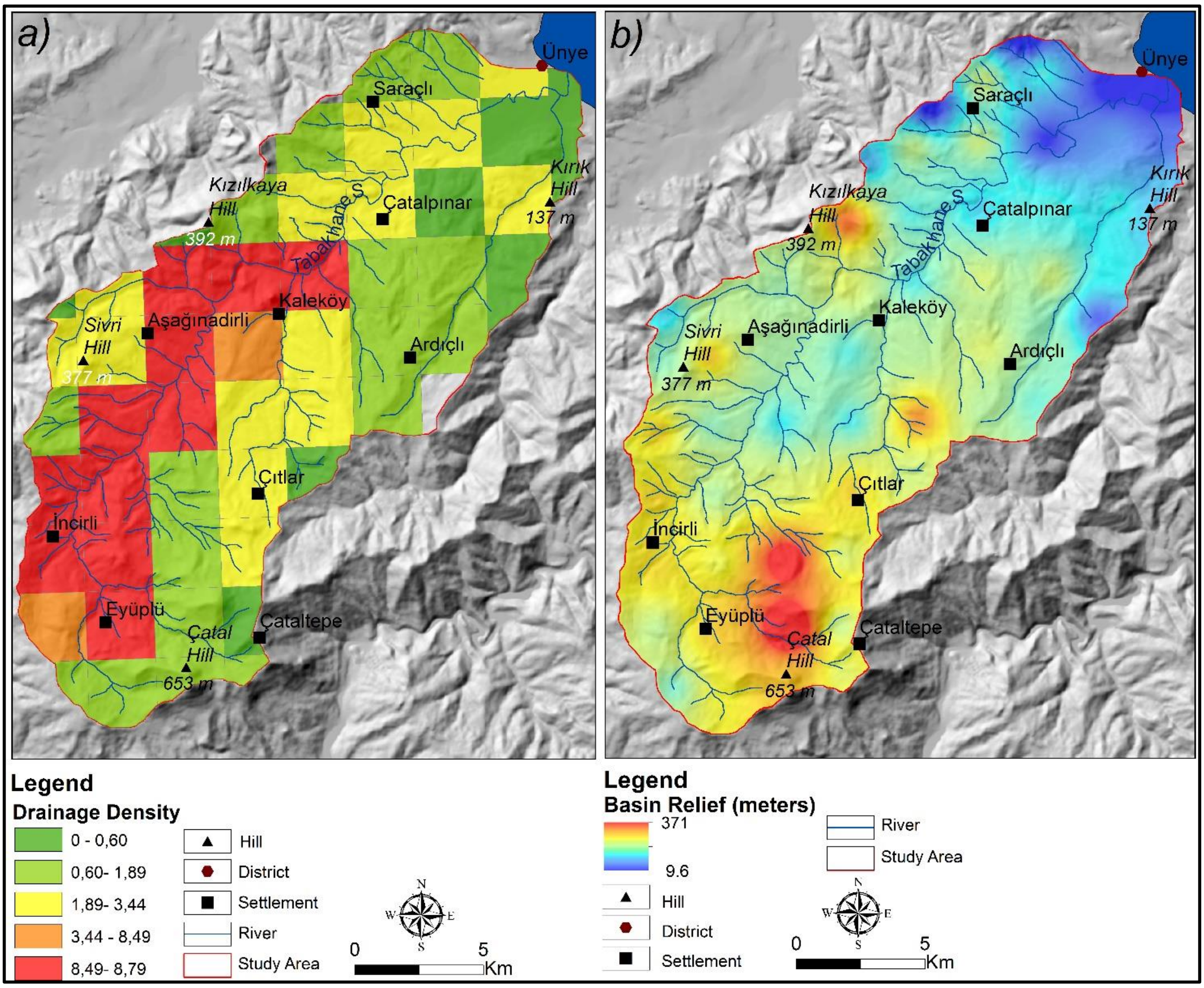

Figure 12. Drainage Density (a) and Basin Relief Map (b) of Tabakhane Stream Basin (Ünye-Ordu)

The basins, in which the drainage density value is high, can be considered as basins where overflow susceptibility is also high (Turoğlu & Aykut, 2019). Considering all the classifications, it is seen that Dd is high and very high in the basin. This situation shows that the effect of drainage density on flood and overflow formation and the flood-overflow hazard is high.

2.2.2. Stream Frequency (Fs)

Fs is the number of stream segments per unit area in a study area (Strahler, 1964). Various factors such as climate, lithological characteristics of the ground, geomorphological features, vegetation, time and human play a role in this parameter (Hoşgören, 2004). While high Fs values, in terms of the stream frequency (Fs), represent sparse vegetation, high relief, and low infiltration capacity, low Fs values represent the contrary (Pawar-Patil & Mali, 2013). High Fs value generally represents non-permeable soil characteristics, sparse vegetation and high relief characteristics (Reddy et al., 2004). Scheidegger (1961) correlated river stream density with drainage density. Peltier (1962) found the stream frequency value high in the semi-arid sections of the regions with average slope values, very low in arid regions and moderate in humid regions. Stream frequency in the basin was found to be 2.97. High stream frequency (Fs) value point out water coming from rainfall starts flowing on the surface with a minimum loss for reasons such as infiltration, interception, etc. and the presence of high flow potential and therefore the high flood potential. The high frequency of streams in the basin is a result of high precipitation, high slope values, and high drainage density.

2.2.3. Basin Shape (Rf)

One of the morphometric features affecting the flow character is the form of the basin. Differences in the characteristics of the basin shape cause the hydrograph of rivers to differ. For this, it is important whether the basin has a circular shape or a elongated (Verstappen, 1983). The shape of a basin has a great impact on the shape of the flow rate hydrograph observed at the outlet of that basin and the peak value. For example, the behaviours of a circular basin and the behaviours of a elongated basin, with the same area and exposed to the same precipitation, cannot be the same (Usul, 2008). The flow rate is increased suddenly in circular stream basins. Because the flow coming from the tributaries is collected more or less in the main bed at the same time. For example, in the eastern Black Sea, overflows occur immediately after heavy rains in circularly shaped river basins. Examples include floods and overflows near Artvin and Giresun. In the river basins showing linear extension, the flow does not rise suddenly as the accumulation of the water in the main bed does not coincide with the time when the water reaches the main bed (Atalay, 2016). Rf value for Tabakhane Stream Basin was found to be 0.31. That the Rf value is greater than 0.8 and closer to 1.0 means that the basin shape is so close to the circle. Rf low basin shapes define a elongated form. In this type of basin, the side tributaries stand out usually with shorter and fewer sequences and with smaller water accumulation basins and are intermittently connected to the main tributary. This drainage structure prevents the water coming from extraordinary rainfall to join each other at the same time and turn into large volume water body (Turoğlu & Aykut, 2019). Accordingly, lower but continuous flows are seen in the Tabakhane Stream Basin with a value of 0.31 Rf. This shows that the tributaries join the main stream in the basin at different times. In addition, the water level in the basin does not rise suddenly and the hydrograph line is straight.

2.2.4. Elongation ratio (Re)

The elongation ratio is an important morphometric parameter. Re has important hydrological consequences because, unlike circular basins, water delivered during a downpour in elongated basins has to travel a wide variety of distances to reach the basin outlet. The delay in the arrival of water left by the downpour eventually leads to a flattening of its hydrograph (Summerfield, 1997; qtd. in Kumar, 2011;). The shape of a drainage basin, gives information about the duration of the flood (Apaydın, Öztürk, Merdun, & Aziz, 2006; Strahler, 1964). In general, Re varies between 0.6 and 1.0 depending on climatic and geological features (Singh & Singh, 1997). Strahler (1964) explained that when Re is close to 1.0, the range of 0.6-0.8 with very low relief is often associated with high relief and steeper slope. Re value for the study area was found to be 0.63. This shows the high relief and the excess of steep slopes in the basin. High relief accelerates flood-overflow formation by increasing surface flow velocity and erosion.

2.2.5. Gravelius Index (Kg)

There are many indices that evaluate the basins geometrically. These indices show the relation between the shape of the basin and flood regime. Gravelius index is also used when evaluating basin shape properties. The small value of Kg shows that the basin has gained a circular appearance (Hoşgören, 2004). If the index value is equal to 1, the basin displays a circular appearance(Batista DA Silva & Carvalho, 2006). It was found to be 1.38 in the Tabakhane Stream Basin. This shows that the basin has a elongated shape. Lower but continuous flows are seen in elongated basins.

2.3. Relief Morphometric Features

Areal morphometric properties determine the overall plan form and dimensions (2D) of drainage basins, while relief morphometric properties (3D) determine elevation differences (Summerfield, 1997). Relief morphometry are parameters that provide information about erosion in a river basin (Oruonye, 2016), morphological features of the surface such as slope and elevation (Hadley & Schumm, 1961) and basin steepness and erosion processes (Sharma, 2013; qtd. in Kabite & Gessesse, 2018). In this section, basin relief, relief ratio, ruggedness number, time of concentration, hypsometric curve and integral were evaluated.

2.3.1. Basin Relief (Bh)

Bh is found from the elevation difference between the highest point and the lowest point of the basin (Schumm, 1956). With the increase in relief, steep slopes and stream gradient, the concentration time of the surface flow decreases and thus the flood peak point increases (Baker, Kochel, & Patton, 1988; Patton & Baker, 1976; qtd. in Ansari, Rao, & Saran, 2013). The Bh value in the Tabakhane Stream Basin was found to be 653 m. Although the basin area is small, the elevation difference is quite high. This situation affects flood-overflow formation. According to the map, which was formed on the basis of 1 km^2 grid for the basin, the basin relief varies between 0-371 m. The highest basin relief value is observed in the south of the basin. This shows that the basin is more rugged in this area. Accordingly, flows characterized by the flood are recorded in the upper basin (Fig. 12 b). Basin relief value is low in the area where the stream reaches the sea in the north. Therefore, flood events are observed. Generally, the high Bh value in the basin shortens the flow accumulation time, increases the flood peak, decreases the retention of the water starting to flow and helps the water flow without infiltration.

2.3.2. Relief Ratio (Rh)

The ratio of the basin relief to the maximum basin length is expressed as the relief ratio (Schumm, 1956; Vincy, Rajan, & Pradeepkumar, 2012). The relief ratio indicates the steepness of the drainage basin and the intensity of the erosive processes (Babu, Sreekumar, & Aslam, 2016). The Rh value for the basin was found to be 0.05. This value is a result of high drainage density and slope. Consequently, there is a high hazard of flooding in the basin.

2.3.3. Ruggedness Number (Rn)

Rn provides information about water flow gravity, infiltration and surface flow conditions, and erosive activities in the basin (Reddy et al., 2004). High-value areas indicate areas where water loss is low and the conditions for surface flow are appropriate. Moreover, the basins with high roughness value are areas with high flood potential (Baker et al., 1988; Patton & Baker, 1976; Ritter, Kochel, & Miller, 1995). "The low 'Rn' of basin suggests that area is less prone to soil erosion and have structural intricacy in relation with relief and 'Dd'" (Rai, Chandel, Mishra, & Singh, 2018). The Rn value of the Tabakhane Stream Basin was found to be 1.63. The Rn value is high in the basin, the water loss is low and the surface flow is high. High Rn value indicates the areas where slope is high and that number of erosive activities are high. A high Rn value indicates that water remains on the surface and the ponding will be less. While this situation affects the infiltration negatively, it results in increasing the amount of runoff. The amount of water transforming to runoff phase has also an important role in forming a flood and has an effect on erosion as well. Because, in this case the velocity of water increases. As a result, the hazard of flood-overflow is high.

2.3.4. Time of Concentration (Tc)

It is one of the empirical methods for revealing the time passing until the water starting to flow after the rainfall reaches the sea or the main tributary from the highest point of a river basin (Grimaldi, Petroselli, Tauro, & Porfiri,2012). Different methods (Carter, 1961; Kirpich, 1940; Verstappen, 1983) are used to calculate the flow accumulation time. In this study, (Kirpich, 1940) formula was used to calculate the flow accumulation time. The flow accumulation time was found to be 125.73 minutes. There is an inverse relationship between the Tc value and the overflow susceptibility level. The overflow susceptibility of river basins with high Tc values is low (Turoğlu & Aykut, 2019). In the Kirpich formula, the most important variable for the collection time of flow is the slope. For this reason, the collection time of flow is directly related to the basin slope. According to this evaluation, overflow was found to be high in Tabakhane Basin Stream. Because the time required for water falling to the farthest point of the basin to reach the downstream is approximately two hours. Since the destruction of the vegetation in the basin will increase the surface flow, collection time of flow is reduced.

2.3.5. Hypsometric Curve (Hc) and Hypsometric Integral (Hi)

Hypsometric curves show the height distribution of the area of investigation. The hypsometric curve is determined by the projection of the overall height ratio (h/H) to the total area (a/A) (Strahler, 1952). The relative area (a/A) value always varies between 1.0 and 0.0 from the lowest point of the basin where the relative height (h / H) is 0.0 to the highest point of the basin where the relative height (h / H) is 1.0 (Keller, & Pinter, 2002). River basins are evaluated in three categories according to the geomorphological development stages. In this classification, the shape of the Hypsometric curve (Hc) and the numerical value of the Hi, are determinant factors. These are (A) youth stage (convex Hc curve, Hi ≥ 0.60), where the basin is very susceptible to erosion; (B) maturity stage (S-shape Hc curve, .30 ≤ Hi ≤ 0.60), (C) Advanced level of slope erosion, low abrasion surfaces or monadnock stage (concave Hc curve, Hi <0.30) (Farhan, Anaba, & Salim, 2016; Singh, Sarangi, & Sharma, 2008; Strahler, 1964; Strahler, 1952; Turoğlu & Aykut, 2019). In some studies in the literature (Topal 2018, 2019), basins with Hi greater than 0.50 were evaluated in the youth stage. Hypsometric integral is the total area under the hypsometric curve and is the simplest way to characterize the hypsometric curve for the studied drainage basin (Keller, & Pinter, 2002). Hi value for basin was found to be 0.30. The hypsometric curve for the main basin was created through Strahler method using Microdem software. When the hypsometric curve of the basin is evaluated together with the hypsometric integral, it is seen that it is in the maturity stage close to an old age (Fig.13).

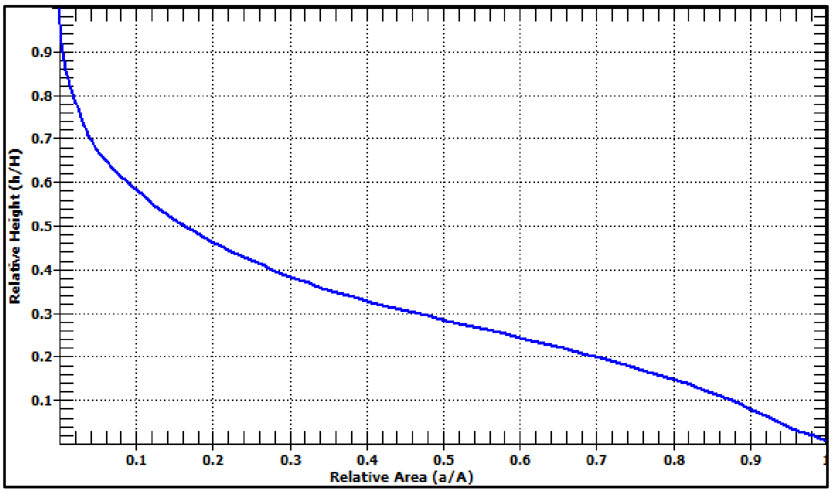

Figure 13. The Hypsometric Curve of The Tabakhane Stream Basin (Ordu)

When the main basin is evaluated according to the catchments, it is seen that there are some drainage areas showing convex hypsometric curve and that the integral values of these basins are high. This situation leads to occurence of flooding flows in some of the southern basins, which is because of basins being relatively young. Flooding flows cause overflow in the downstream. The hazard of overflow is high especially in the north of the basin (Fig.14).

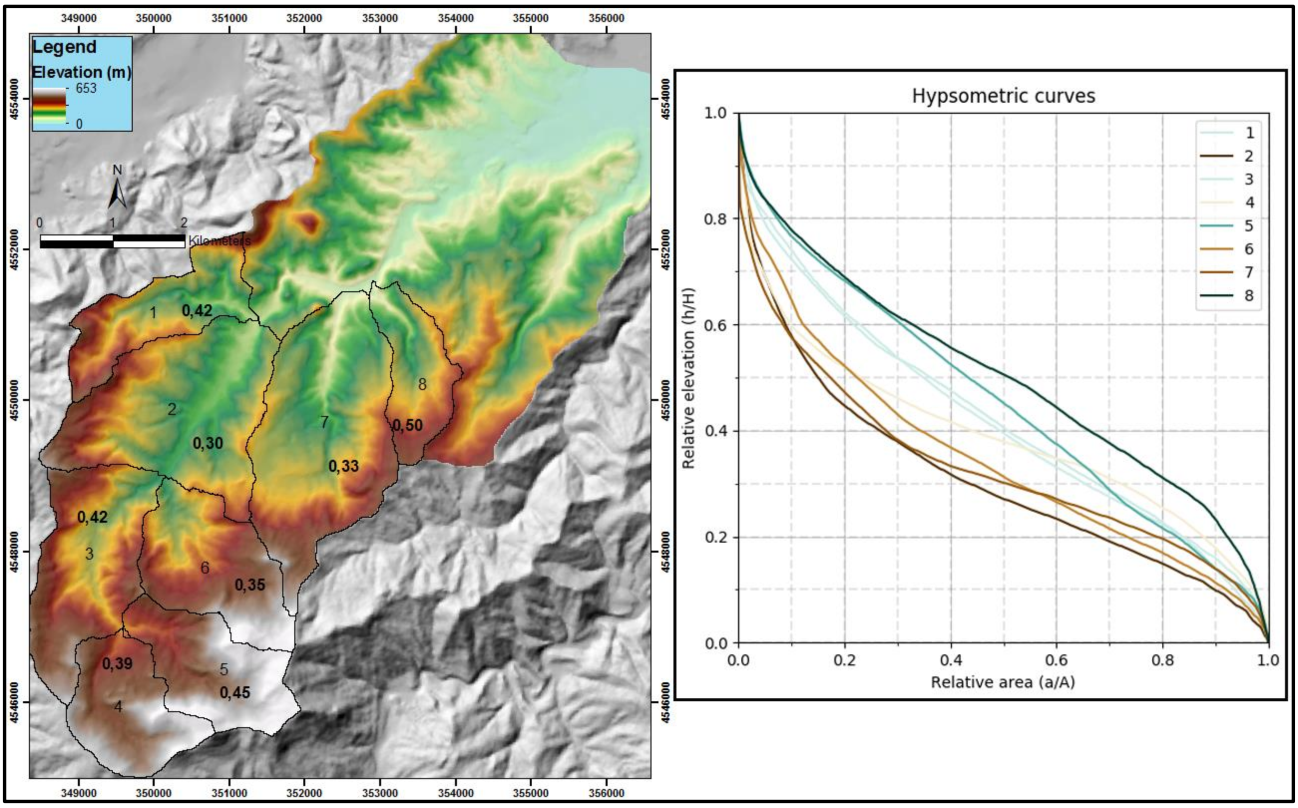

Figure 14. Hypsometric Curves of Micro-Basins (Hypsometrıc Curves Were Drawn With CalHypso Developed by (Pérez-Peña, Azañón, & Azor, 2009)

Conclusion

The characteristics of a basin such as slope, aspect and elevation are deterministic in the formation of flood and overflow. These parameters play a predisposing role in the formation of flood-overflow. In the basins having high slope and facing the sea or maritime air masses, the likelihood of flood and overflow is high. The fact that basins, which have high slope and face the sea, receive abundant rainfall contribute to the occurrence of flooding. In addition, vegetation characteristics of a basin, as well as use of the land by humans also have an effect on the formation of flood and overflow. The spatial or morphometric properties of a basin, which are called 2D and 3D properties, also have a role in the occurrence of flood and overflow. For example, if the drainage density and stream frequency in a basin are high, the hazard of flooding and overflow are high, accordingly. The shape of the basin also affects flood-overflow hazard and duration. For instance, in a basin having an elongated shape, the fact that side streams do not reach the main stream at the same time prevents the flow from rising suddenly. However, in circular basins, simultaneous joining of side streams into the main stream cause a sudden increase in the current. Since the basins that have convex hypsometric curve are in early stage, currents causing flood are more common. In a highly rugged basin, currents causing flood are more common due to the high slope. Since erosion is severe in this type of basins, the material transported to the lower basin reduces the bed capacity and contribute to the occurrence of flood. Relief represents potential energy of the system and directly related to its total erosion intensity. In basins that are small in area, the upstream water reaches the lower basin in a shorter time and collection time of streams is short. Therefore, morphometric properties should be taken into consideration when studying floods and overflows in a basin. In this study, it was aimed to evaluate the areal (two dimensional) and relief (three dimensional) morphometric features of the Tabakhane Stream Basin within the scope of flood-overflow relationship. Accordingly, the values of Dd 2,51, Fs 2,97, Rf 0,31, Re 0,63 and Kg were found as 1,38 in the Tabakhane Stream Basin. According to the results of relief morphometric analysis, the values of Bh were found as 653 m, Rh as 0,05, Rn as 0.31, Tc as 125, 73 minutes and Hi as 0,30. Rn, Fs and Dd values are high in the basins having high potential of flooding. When evaluated from this point of view, Tabakhane Stream Basin shows similarities with basins with high flood-overflow potential. The water carried by tributaries originating from the headspring is collected in the narrow areas of downstream. This is a factor that increases the hazard of flood-overflow. In the basin, where morphometric features increase the hazard of flooding, settlement and agriculture in the stream beds should not be allowed. Stream beds should not be closed or narrowed. Stream beds should be cleaned, bridges and culverts should be built taking into account the hazard of flooding.

References

AFAD. (2020). *Afet Bilgileri Envanteri*. Ankara: Afet ve Acil Durum Yönetimi Başkanlığı.

Altaf, F., Meraj, G., & Romshoo, S. A. (2013). Morphometric analysis to infer hydrological behaviour of Lidder watershed, Western Himalaya, India. *Geography Journal*, 1-14.

Ansari, Z. R., Rao, L. A. K., & Saran, S. (2013). Comparative Study of Morphometric Parameters Derived from Topographic Maps and ASTER DEM. *International Journal of Scientific & Engineering Research*, 4(8), 508-528.

Apaydın, H., Öztürk, F., Merdun, H., & Aziz, N. M. (2006). Determination of the drainage basin characteristics using vector GIS. *Hydrology Research*, 37(2), 129-142.

Atalay, İ. (2016). *Uygulamalı Jeomorfoloji*. İzmir: Meta Basım Matbaacılık Hizmetleri.

Avci, V., & Sunkar, M. (2015). Giresun'da Sel ve Taşkın Oluşumuna Neden Olan Aksu Çayı ve Batlama Deresi Havzalarının Morfometrik Analizleri. *Coğrafya Dergisi,* (30), 91-119.

Avci, V., & Sunkar, M. (2018). Bulancak'ta (Giresun) Sel ve Taşkın Olaylarına Neden Olan Pazarsuyu, İncüvez, Kara ve Bulancak Derelerinin Morfometrik Analizleri. *Fırat Üniversitesi Sosyal Bilimler Dergisi*, 28(2), 15-41.

Babu, K. J., Sreekumar, S., & Aslam, A. (2016). Implication of drainage basin parameters of a tropical river basin of South India. *Applied Water Science*, (6), 67-75.

Baker, V. R., Kochel, R. C., & Patton, P. C. (1988). *Flood Geomorphology*. USA: John Wiley & Sons.

Bastawesy, M. E., Gabr, S., & White, K. (2013). Hydrology and geomorphology of the Upper White Nile lakes and their relevance for water resources management in the Nile basin. *Hydrological Processes*, 27(2), 196-205.

Batista DA Silva, L. D., & Carvalho, D. F. (2006). *Apostila de Hidrologia*. UFRRJ.

Bayrakdar, C., Döker, M. F., & Keserci, F. (2020). Polyelerde hatalı arazi kullanımların sebep olduğu afetlere bir örnek: 31 Ocak 2019 Kayaköy Polyesi taşkını. *Coğrafya Dergisi*, (41), 109-128.

Canpolat, E., Dinç, Y., Usun, Ç. F., & Geçen, R. (2020). 25.09. 2014 tarihinde Erzin Ilıcalarda (Hatay) meydana gelen sel ve taşkının oluşumunda coğrafi faktörlerin değerlendirilmesi. *Coğrafya Dergisi*, (41), 129-146.

Carter, R. V. (1961). *Magnitude and frequency of floods in suburban areas*. U.S. Geological Survey, Paper 424-B, B9-B11.

Deju, R. A. (1971). *Regional hydrology fundamentals*. Newark: Gordon and Breach Science Publishers

Dölek, İ. (2010). Bolaman Çayı Havzasının Doğal Afet Kaynakları. *Hikmet Yurdu Düşünce-Yorum Sosyal Bilimler Araştırma Dergisi*, 3(6), 107-121.

Devlet Su İşleri Genel Müdürlüğü (DSİ). (2018). *Ordu Büyükşehir, Ünye, Perşembe, Fatsa, İkizce, Çaybaşı İlçelerinde 08-09-10 Ağustos 2018 tarihlerinde meydana gelen taşkın ve taşkın zararlarına ilişkin rapor*. Samsun: Devlet Su İşleri Genel Müdürlüğü 7. Bölge Müdürlüğü.

Farhan, Y., Anaba, O., & Salim, A. (2016). Morphometric Analysis and Flash Floods Assessment for Drainage Basins of the Ras En Naqb Area, South Jordan Using GIS. *Journal of Geoscience and Environment Protection*, 4(6), 9-33.

Google Earth Pro (2022). Satellite images of the study area were downloaded.

Gönençgil, B. (2016). Ordu İlinin İklim Özellikleri. *Memleket Pusulası Ordu*. İstanbul: Eski Babil Yayınları.

Görcelioğlu, E. (2003). *Flood and Avalanche Control*, Istanbul University, Faculty of Forestry Publications. Istanbul University Publications.

Görüm, T. (2016). Ordu İlinin Doğal Afetleri. Memleket Pusulası Ordu. İstanbul: Eski Babil Yayınları.

Gravelius, H. (1914). *Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde. Compendium of Hydrology I. Rivers*. German.

Gregory, K. J., & Walling, D. E. (1976). *Drainage basin form and process: A geomorphological approach*. New York: Edward Arnold (Publishers) Ltd.

Grimaldi, S., Petroselli, A., Tauro, F., & Porfiri, M. (2012). Times of concentration: A paradox in modern hydrology. *Hydrological Sciences Journal*, 57(2), 217-228.

Günal, N. (2016). Ordu İlinin Biyocoğrafyası. *Memleket Pusulası Ordu*. İstanbul: Eski Babil Yayınları.

Hadley, R., & Schumm, S. (1961). *Sediment Sources and Drainage Basin Characteristics in Upper Cheyenne River Basin.* US Geological Survey Water-Supply Paper, 1531-B, 137-146.

Hakyemez, H. Y., & Papak, İ. (2002). *1/500000 ölçekli jeoloji haritaları Samsun Paftası*. Ankara: MTA Genel Müdürlüğü (MTA).

Harita Genel Komutanlığı (HGK). (1978). 1/25.000 ölçekli topoğrafya haritaları F 38 d3, F 38 c1, F38 c4 paftaları, Harita Genel Komutanlığı, Ankara.

Horton, R. E. (1932). Drainage-basin characteristics. *Eos, transactions american geophysical union*, 13(1), 350-361.

Horton, R. E. (1945). Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. *Geological society of America Bulletin*, 56(3), 275-370.

Hoşgören, M. Y. (2004). *Hidroğrafyanın Ana Çizgileri-1*. İstanbul: Çantay Kitabevi.

Işık, F., Bahadır, M., Zeybek, H. İ., & Çağlak, S. (2020). Karadere Çayı Taşkını (Araklı -Trabzon). *Mavi Atlas*, 8(2), 526-547.

Jenson, S. K. (1991). Applications of hydrologic information automatically extracted from digital elevation models. *Hydrological processes*, 5(1), 31-44.

Kabite, G., & Gessesse, B. (2018). Hydro-geomorphological characterization of Dhidhessa River basin, Ethiopia. *International Soil and Water Conservation Research*, 6(2), 175-183.

Karakuyu, M. (2002). Şehirleşmenin küresel iklim sapmaları ve taşkınlar üzerindeki etkisi. *Marmara Coğrafya Dergisi*, 6, 97-108.

Keller, E. A., & Pinter, N. (2002). *Active tectonics: Earthquakes, uplift, and landscape*. Prentice-Hall, Upper Saddle River.

Kirpich, Z. P. (1940). Time of concentration of small agricultural watersheds. *Civil Engineering*, 10(6), 362.

Koç, G., Petrow, T., & Thieken, A. H. (2020). Analysis of the most severe flood events in Turkey (1960–2014): Which triggering mechanisms and aggravating pathways can be identified? *Water*, 12(6), 1562.

Kopar, İ., Polat, S., Hadimli, H. & Özdemir, M. (2011). 4-6 Mart 2004 Pulur Çayı (Ilıca-Erzurum) Sel-Taşkın Afeti. *Doğu Coğrafya Dergisi*, 10 (3), 187-218.

Kumar, V. (2011). Elongation Ratio. In: *Encyclopedia of Snow, Ice and Glaciers (*(Edts. Singh, V. P and Singh, P.). *Encyclopedia of Earth Sciences Series*. Dordrecht: Springer.

Langbein, W. B. (1947). *Topographic characteristics of drainage basins*. United States Department Of The Interıor J. A. Krug, Geologıcal Survey, Water-Supply Paper, 968-C, 125-158.

Li, J. & Wong, D.W.S. (2010). Effects of DEM sources on hydrologic applications Computers. Environment and Urban Systems, 34 (3), 251-261.

Malik, M. I., Bhat, M. S., & Kuchay, N. A. (2011). Watershed based drainage morphometric analysis of Lidder catchment in Kashmir valley using geographical information system. *Recent Research in Science and Technology*, 3(4), 118-126.

Melton, M. A. (1957). *An analysis of the relations among elements of climate, surface properties, and geomorphology*. Columbia Univ, Department of Geology, Technical Report, New York.

Mesa, L. M. (2006). Morphometric analysis of a subtropical Andean basin (Tucuman, Argentina). *Environmental Geology*, 50, 1235-1242.

Miller, V. C. (1953). *A Quantitative Geomorphic Study Of Drainage Basin Characteristic in The Clinch Mountain Area, Virginia and Tennesse*. Columbia Univ. Department of Geology, Technical Report, New York.

Moore, I. D., Grayson, R. B., & Ladson, A. R. (1991). Digital terrain modelling: A review of hydrological, geomorphological, and biological applications. *Hydrological processes*, 5(1), 3-30.

Morisawa, M. E. (1959). *Relation of quantitative geomorphology to stream flow in representative watersheds of the Appalachian Plateau Province*. Columbia Univ, Department of Geology Technical report, New York.

Najar, Gh. N., & Pandey, P. (2018). Drainage Morphometric Analysis of Watershed Basin of River Beas at Harike Pattan, Punjab-Using Remote Sensing and GIS Approach. *International Journal of Advance Research in Science and Engineering*, 7(4), 641-653.

Ocak, F., & Bahadır, M. (2020). Örnek taşkın risk modeli oluşturulması ve Ünye şehrindeki derelere ait taşkın risk analizleri. *The Journal of Academic Social Science Studies*, (80), 499-524.

Oruonye, E. D. (2016). Morphometry and flood in small drainage basin: Case study of Mayogwoi River Basin in Jalingo, Taraba State Nigeria. *Journal of Geography, Environment and Earth Science International*, 5(1), 1-12.

Önsoy, H. (2008). Kentleşmede hidrolojinin önemi, 5. Dünya Su Forumu Bölgesel Hazırlık Süreci Türkiye Bölgesel Su Toplantıları: *Sel, Taşkın ve Heyelan Konferansları Bildiriler Kitabı*, 38-42.

Patel, A., Katiyar, S. K., & Prasad, V. (2016). Performances evaluation of different open source DEM using Differential Global Positioning System (DGPS). T*he Egyptian Journal of Remote Sensing and Space Science*, 19(1), 7-16.

Patton, P. C., & Baker, V. R. (1976). Morphometry and floods in small drainage basins subject to diverse hydrogeomorphic controls. *Water resources research*, 12(5), 941-952.

Pawar-Patil, V. S., & Mali, S. P. (2013). Watershed characterization and prioritization of Tulasi subwatershed: A geospatial approach. *Int J Innov Res Sci Eng Technol*, 2(6), 2182-2189.

Peltier, L. C. (1962). Area sampling for terrain analysis. *The Professional Geographer*, 14(2), 24-28.

Pérez-Peña, J. V., Azañón, J. M., & Azor, A. (2009). CalHypso: An ArcGIS extension to calculate hypsometric curves and their statistical moments. Applications to drainage basin analysis in SE Spain. *Computers & Geosciences [Comput. Geosci*.]., 35(6), 1214-1223.

Rai P K., Chandel, R. S., Mishra, V. N., & Singh, P. (2018). Hydrological inferences through morphometric analysis of lower Kosi river basin of India for water resource management based on remote sensing data. *Applied Water Science*, 8(15).

Rastogi, R. A., & Sharma, T. C. (1976). Quantitative Analysis of Drainage Basin Characteristics. Journal Soil and *Water Conservation in Indi*a, 26(1&4), 18-25.

Reddy, G. P. O., Maji, A. K., & Gajbhiye, K. S. (2004). Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India–a remote sensing and GIS approach. *International Journal of Applied Earth Observation and Geoinformation*, 6 (1), 1-16.

Ritter, D. F., Kochel, R. C., & Miller, J. R. (1995). *Process geomorphology*. Dubuque: W.C. Brown Publishers.

Samal, D. R., Gedam, S. S., & Nagarajan, R. (2015). GIS based drainage morphometry and its influence on hydrology in parts of Western Ghats region, Maharashtra, India. *Geocarto International*, 30(7), 755-778.

Scheidegger, A. E. (1961). *Theoretical Geomorphology*. Berlin: Springer.

Schumm, S. A. (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin*, 67(5), 597-646.

Sharma, T. (2013). Relief analysis of the Tangri watershed in the lower Shivalik and Piedmont zone of Haryana and Punjab. *Indian Journal of Spatial Science*, 4(1), 9-20.

Singh, O., Sarangi, A., & Sharma, M. C. (2008). Hypsometric Integral Estimation Methods and its Relevance on Erosion Status of Northwestern Lesser Himalayan Watersheds. *Water Resources Management*, (22), 1545-1560.

Singh, S., & Singh, M. B. (1997). Morphometric analysis of Kanhar river basin. *National geographical Journal of india*, 43(1), 31-43.

Strahler, A. N. (1952). Hypsometric (area-altitude) analysis of erosional topography. *Geological society of America bulletin*, 63 (11), 1117-1142.

Strahler, A. N. (1964). Quantitative geomorphology of drainage basins and channel net work. In: Chow, V., Ed., *Handbook of Applied Hidrology*, McGraw Hill Newyork, 4-76.

Sujatha, E. R., Selvakumar, R., Rajasimman, U. A. B., & Victor, R. G. (2015). Morphometric analysis of sub-watershed in parts of Western Ghats, South India using ASTER DEM. *Geomatics, Natural Hazards and Risk*, 6(4), 326-341.

Summerfield, M. A. (1997). *Global Geomorphology: An Introduction to the study of landforms*. Longman Scientific & Technical.

Thomas, J., Joseph, S., Thrivikramji, K. P., & Abe, G. (2011). Morphometric analysis of the drainage system and its hydrological implications in the rain shadow regions, Kerala, India. *Journal of Geographical Sciences*, 21(6), 1077-1088.

Topal, S. (2018). Quantitative analysis of relative tectonic activity in the Acıgöl fault, SW Turkey. *Arab J Geosci* 11, 198, 1-10, https://doi.org/10.1007/s12517-018-3545-z

Topal, S. (2019). Evaluation of relative tectonic activity along the Priene-Sazlı Fault (Söke Basin, southwest Anatolia): Insights from geomorphic indices and drainage analysis. *J. Mt. Sci*. 16, 909–923. https://doi.org/10.1007/s11629-018-5274-x

Turkish Statistical Institute (TSI). (2021). Address Based Population Registration System.

Turoğlu, H., & Aykut, T. (2019). Ergene nehri havzası için hidromorfometrik analizlerle taşkın duyarlılık değerlendirmesi. *Jeomorfolojik Araştırmalar Dergisi*, (2), 1-15.

Usul, N. (2008). *Mühendislik Hidrolojisi*. Ankara: ODTÜ Yayıncılık.

Uzun, A. (1995). Erzurum Çevresindeki Sellere Bir Örnek: 16 Ağustos 1994, Rize Kent Seli. *Ondokuz Mayis University Journal of Education Faculty*, 9, 246-260.

Verstappen, H. T. (1983). *Applied geomorphology*: *Geomorphological Surveys for Environmental Development* Amsterdam: Elsevier.

Vincy, M. V., Rajan, B., & Pradeepkumar, A. P. (2012). Geographic information system–based morphometric characterization of sub-watersheds of Meenachil river basin, Kottayam district, Kerala, India. *Geocarto International*, 27(8), 661-684.

Wise, S. (2000). Assessing the quality for hydrological applications of digital elevation models derived from contours. *Hydrological processes*, 14(11-12), 1909-1929.

Yalçın, M. (2013). Sel ve Taşkına Duyarlı Alanların CBS ile Belirlenmesi: İstanbul Avrupa Yakası Örneği. Program adı: 18.Esri Kullanıcılar Konferansı, Ankara.

Yılmaz, C. (2005). Ordu İlinin Nüfus Özellikleri. *Orta Karadeniz Kültürü*, Editörler: B.Yediyıldız - H.Kaynar - S. Küçük), Siyasal Kitabevi, 253-278, Ankara.

Zeybek, H. İ. (2009). 2-3 Mart 2005 Turhal Sel Afeti ve Sonuçları. *Doğu Coğrafya Dergisi*, (21), 233-248.

https://land.copernicus.eu/pan-european/corine-land-cover Data of Access, 10/01/2021

https://tr.climate-data.org/ Data of Access 15/02/2021

https://earthexplorer.usgs.gov/ Data of Access 10/01/2021

https://gisgeography.com/ndvi-normalized-difference-vegetation-index/ Data of Access 10/02/2021