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Determination of Ayancık Stream Basin and its morphometric parameters

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Abstract

As a result of the increase in the negative effects of climate change, many natural disasters such as drought, forest fires, and floods are experienced all over the world. In Türkiye, especially in the Black Sea region, floods and overflows are frequently seen due to excessive precipitation. The use of current data obtained from the land management information system in the disaster management information system increases the accuracy of the predictability of disasters and ensures their sustainability. For this reason, the accuracy and up-to-date data obtained from the land management information system are important. Storage, modeling, querying, analysis, and tracking model has created for local and private administrations thanks to the acquisition of data by remote sensing and photogrammetry methods and their integration with GIS. Thus, natural disasters caused by the negative effects of climate change can be prevented. It is necessary to model the basin in terms of geological, geomorphological, and hydrographic and to create a basin management model, especially to predict, monitor, and take precautions for flood and overflow events. In this study, the boundaries of the Ayancık Stream Basin, which is located on the Sinop Plateau and flows into the Black Sea by mostly flowing in the north-south direction, were determined and morphometric analyses of the basin were made. With the help of morphometric analysis, the hydrographic features of the Ayancık Stream Basin were determined.

1. Introduction

When the floods and overflows caused by heavy rain, snowmelt, ice, rain, tropical storm, or tropical surge and dam around the world are investigated, according to a study conducted on the global flood database site, 913 floods occurred in 169 countries between 2000 and 2015 and that 255 million people suffered from disasters has been reported to be affected (Figure.1) [1].

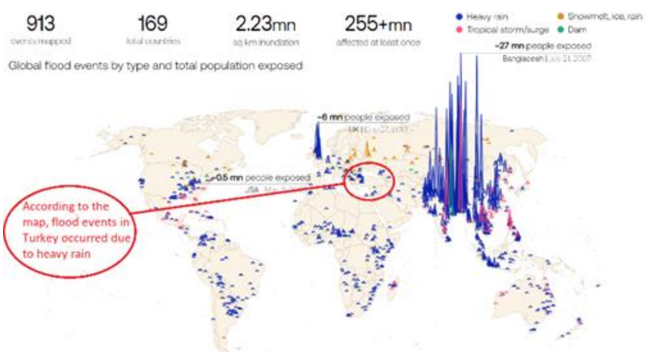

Figure 1. Flood disasters around the world between 2000 and 2015. Adopted from [1].

Within the scope of disaster management published by Disaster and Emergency Management Presidency (AFAD), in the 2019 year overview and nature-based event statistics report; it is stated that flood events increase as one goes from west to east and from south to north throughout Türkiye. In the report, the number of flood events that took place in Türkiye between 1950 and 2019 and their distribution by provinces were mapped [2]. In Figure 2, the number of floods/flood events that occurred in Türkiye between 1950 and 2019 are given on a provincial basis. In addition, Figure 2 shows that there were 31 floods in Sinop between 1950 and 2019.

Considering the available data, forecasting, monitoring, and analysis of flood and flood events is a multidisciplinary study. Therefore, watershed management prefers remote sensing and photogrammetry methods to save time and reduce costs by storing, querying, and analysing the geographical data of the region in a short time. By using the advantages of this method, it is ensured that the data is obtained up-to-date and with high accuracy in certain processes and that the change processes are analyzed and evaluated correctly. With the disaster information system to be

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established for this purpose, the geological, geomorphological, and hydrographic features of the basin are evaluated in a fast, accurate, and up-to-date manner.

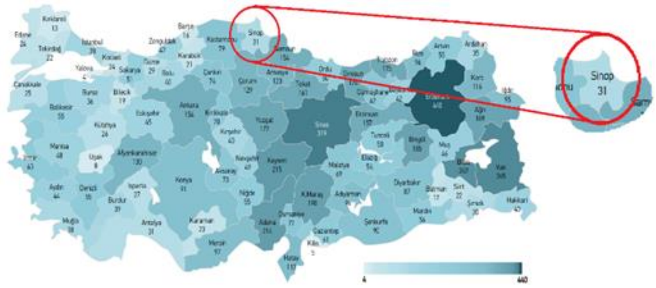

Figure 2. 1950-2019 Number of flood events in Türkiye on a provincial basis. Adopted from [2].

Conditions such as the increase in temperature due to climate change and the melting of glaciers; natural processes such as precipitation amount and evaporation are affected. This situation causes irregular stream flow and varying drainage densities in stream basins. In such a case, it is necessary to determine and interpret the hydrographic characteristics of the basin to prevent natural disasters such as floods and overflows.

Morphometric analyses of the basin, such as; drainage network and density, the minimum and maximum height of the basin, the length of the stream, and its frequency that is the information used in determining the areas to be taken precautions in case of flood, choosing suitable regions for settlement, and making disaster planning. Morphometric analyses are examined in 3 groups: Linear Morphometry, Relief Morphometry, and Aerial Morphometry. In Table 1, the studies in which morphometric analyses were first published in the literature, and the author information are given.

By performing the basin boundary and morphometric analyses of the Sabuncular Stream in Rize province, Çayeli district, Ödeker B. and Türkoğlu N. (2020) determined that the basin has a high drainage density, causes the water to flow to the surface without being able to seep into the ground, the risk of surface erosion increases, and therefore the flood risk is high [10].

The flood disaster, which occurred due to heavy rain on August 11, 2021, in the Ayancık Stream, which is located in the Ayancık district of Sinop province in the Black Sea Region of Türkiye, caused many logs and vehicles to drift, damaged structures in the settlement, 47 buildings collapsed and 6 people died. It was seen that the most affected region in the flood disaster in Ayancık was the village of Babaçay. However, when the literature was examined, no study was found in which morphometric analyses of the basin area of the region were made.

In this study, ASTER GDEM data collected before the flood is utilized. The boundaries of the Ayancık Stream Basin, basin morphometric analyses, and hydrographic features were determined and performed. Thus the predictability of the flood disaster was investigated.

Table 1. Morphometric Parameters

Class	Morphometric Parameters	Formula	Author/Year
LINEAR	Stream Order (Nu)	Determined from Stream To Feature Vector data	First Horton, 1945 [3] As a Hierarchical Order Strahler, 1964[4]
	Stream Length (Lu)	Length of the stream	Horton, 1945 [3] Strahler, 1964 [4]
	Mean Stream Length (Lsm)	Lsm = Lu/Nu Lu: Mean Stream Length of a given order (km) Nu: Number of Stream segment	Horton, 1945[3]
	Stream Length Ratio (Rl)	Rl = Lu/Lu-1 Lu = total stream length of order Lu-1 = The Total Stream length of its next lower order	Horton, 1945[3]
	Bifurcation Ratio (Rb)	Rb= Nu/Nu+1 Nu = Number of stream segments present in the given order Nu+1 = Number of segments of the next higher order	Schumn, 1956 [5]
RELIEF	Basin Relief (Bh)	Vertical distance between the lowest and highest points of basin	Schumn, 1956 [5]
	Relief Ratio (Rh)	Rh = Bh/Lb Bh = Basin Relief, Lb = Basin length	Schumn, 1956 [5]
	Hypsometric Curve (Hc)	Relative height/Relative area	Strahler, 1952 [8]
	Hypsometric Integral (Hi)	(Mean height - Minimum height)/(Maximum height - Minimum Height)	Strahler, 1952 [8]
	Ruggedness Number (Rn)	Rn = Bh*Dd Bh=Basin Relief, Dd=Drainage density	Schumn, 1956 [5] Strahler, 1958 [9]
AREAL	Drainage Density (Dd)	Dd=L/A ; L=Total length of stream (km), A= Area of basin(km²)	Horton, 1945 [3]
	Stream Frequency (Fs)	Fs=Nu/A Nu=Total number of stream A= Area of basin	Horton, 1945 [3]
	Texture Ratio (T)	T=N1/P N1=Total number of first order stream P=Perimeter of basin	Horton, 1945 [3] Smith, 1950 [7]
	Form Factor (Rf)	Rf=A/(Lb)² A= area of basin, Lb=Basin length	Horton, 1945 [3]
	Circulatory Ratio (Rc)	Rc=4πA/P² ; π=3.14 A= Area of basin , P=Perimeter of basin	Miller, 1953 [6]
	Elongation Ratio (Re)	Re=√(Au/π)/Lb , π=3.14 The length of circle's diameter with the area of the basin / The maximum length of the basin	Schumn, 1956 [5]
	Length of Overland Flow (Lg)	1/2Dd; Dd=Drainage density	Horton, 1945 [3]
	Constant Channel Maintenance (C)	Lof = 1/Dd; Dd=Drainage density	Horton, 1945 [3]

2. Study area

Ayancık, a district of Sinop province, was established at the foot of Ayancık Hill, where Ayancık Stream empties into the sea, facing the open sea. In the study area, the elevation increases towards the south, and the residential areas are gathered around the Ayancık stream and its tributaries. The maximum height of the basin area is 1869 m. In Figure 3, the study area and the Ayancık Stream Basin boundary are given.

3. Material and Method

The United States National Aeronautics and Space Administration (NASA) and the Ministry of Economy, Trade, and Industry (METI) of Japan jointly released Version 3 of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) on August 5, 2019 Also, ASTERGDEMV3 data were provided as free satellite images. By using Digital Elevation Model (DEM) data, the watershed boundary was determined and morphometric analyses were made.

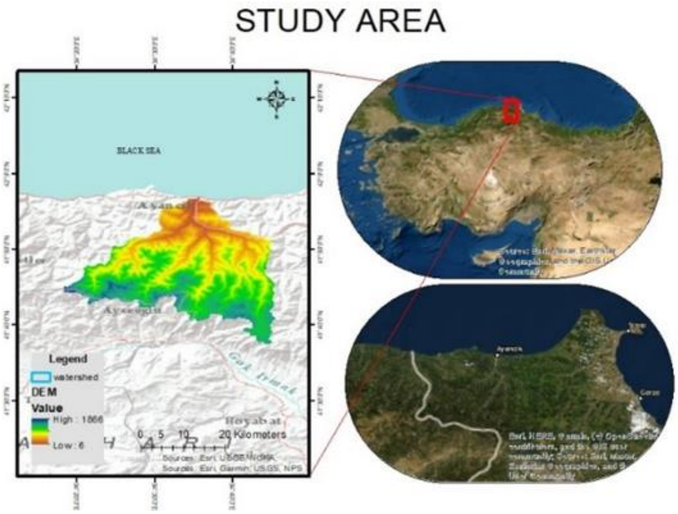

Figure 3. Study area and Ayancık Stream Basin Boundary

The improved Aster GDEM V3 adds additional stereo-pairs, improving coverage and reducing the occurrence of artifacts. The refined production algorithm provides improved spatial resolution and increased horizontal and vertical accuracy. The ASTER GDEM V3 maintains the GeoTIFF format and the same gridding and tile structure as V1 and V2, with 30-meter postings and 1 x 1-degree tiles [11].

In the first step, DEM data was transferred to geographic information systems and base maps were produced. In the DEM data transferred to the GIS software, firstly, the pixels without height information in the data were completed with the iteration method, which is the function renewal process. In the second step, flow direction, flow accumulation, watershed, and pressure are calculated. Stream Order stream indexes were calculated using the Strahler method with flow direction and Flow Accumulation obtained in the third step. In the next step, stream raster data is converted to vector data by calculating Stream to Feature using the calculated Stream Order. At this stage, the origin of the Ayancık Stream was determined as a point. By using the Flow Direction and the exit point of the Ayancık Stream, the water collection area-Basin area of the Ayancık Stream was determined by using the Watershed method.

The Basin boundary was obtained by converting the calculated Basin area from raster data type to vector data. According to the obtained basin boundary, Flow Direction, Flow Accumulation, Stream Order, and Stream to Feature analyses were mapped by mask. In addition, Stream Density was calculated using the line density method with Stream to Feature vector data. In Figure 4 workflow diagram is given.

Data such as basin area, length, and bifurcation rate required in morphometric analyses were obtained by using raster and vectorial data from the stream to feature, watershed and Fill-DEM.

3.1. Fill

In order to ensure the continuity of the drainage network to be created, the pixels in the data that do not contain height information are filled by iteration, which is a function iteration method, up to all pixels containing the determined z limit height value. In the study, the Z-limit value was chosen as 1m. With this correction, the discontinuities that may occur while determining the Flow Direction are prevented.

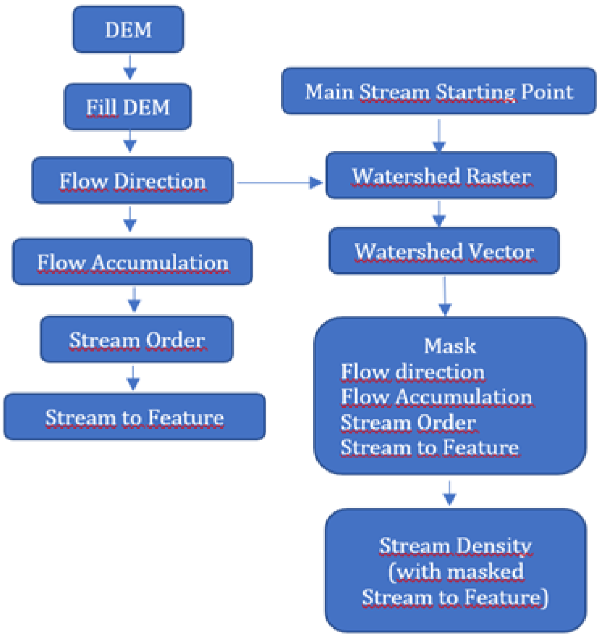

Figure 4. Flowchart

3.2. Flow Direction

By using the Digital Elevation Model, the transport movements of water channels and streams and materials can be calculated by using the flow directions in hydrology research. Each grid cell with a height value on the DEM moves towards one of the neighbouring grid cells that are lower than its own value in 8 possible directions: down, up, right, left, up right, up left, down right, and down left (Figure 5). Thus, the flow direction of the stream is determined by the 8-way flow model and numerical values are used to show the flow direction.

North-West	North	North-East	32	64	128
West		East	16		1
South-West	South	South-East	8	4	2

Figure 5. Flow Direction theory

3.3. Flow Accumulation

By using the determined flow direction, the collection areas of water are determined from the highest elevation value to the lowest elevation value. Flow Accumulation; It is calculated by the accumulated weight of all cells flowing to each low slope value in the Flow Direction, which is a raster image. Therefore, the cellular values of the flow network in the raster image obtained as a result of Flow Accumulation are the number of cells flowing into that cell (Figure 6). A threshold value can be selected to create a flow network by selecting cells with a high accumulated flow. Here, the threshold is the number of cells with the minimum flow and can be determined by examining the histogram of the raster data. If the threshold value is selected low, the density of the river network will be high, and if high, the density of the river network will be low.

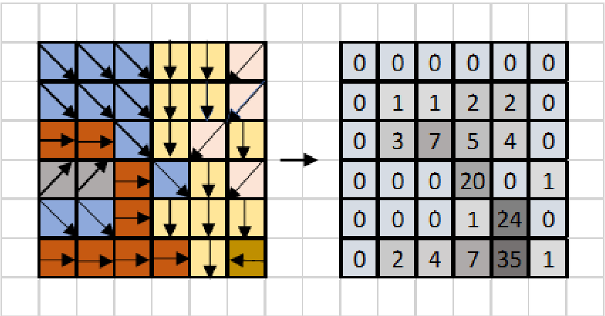

Figure 6. Flow Direction to Flow Accumulation

3.4. Stream Order and Feature

With the help of the flow density of the stream network determined by the selected threshold value and the flow direction of the stream, the main streamline and branches are found using the Strahler method. The found streamline and its branches are divided into indexes and numbered from smallest to largest. Since the obtained data is raster data and is defined with the stream line in the GIS environment, the raster data is converted to vector data and the necessary information for morphometric analyses such as the number of indexes and length of the stream is obtained.

The grading of stream tributaries was carried out for the first time by Horton's work. Horton's technique was developed with Strahler's work. While the tributaries are graded by the Strahler method, a stream bed with a small flow forms the 1st index. When two 1st directories merge, it creates the 2nd directory, when two 2nd directories merge, it creates the 3rd directory, and so on (Figure 7). In this case, an increase in index ranking is seen only when the same indexes are merged. There is no increase in index value when a smaller index is merged with a larger index [13].

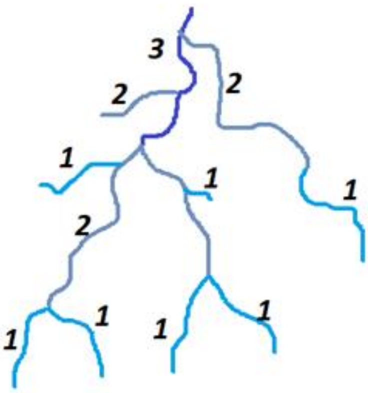

Figure 7. Strahler Method

3.5. Watershed

The lowest point along the basin boundary is the basin outlet. Therefore, the starting point of the Basin should be determined first. The basin boundary is obtained by determining the total flow area of the basin with the data of the basin starting point and the river flow direction.

3.6. Morphometric Parameters

The morphometric parameters that form the basis of the hydrological examination of the basin and provide the numerical expression of the ground surface consist of 3 groups: Linear Morphometry, Relief Morphometry, and Areal Morphometry. Table 2 includes morphometric parameters and their formulas.

Table 2. Formulas used in the calculation of morphometric parameters

Class	Morphometric Parameters	Formula
LINEAR	Stream Order (Nu)	Determined from Stream To Feature Vector data
	Stream Length (Lu)	Length of the stream
	Mean Stream Length (Lsm)	Lsm = Lu/Nu Lu: Mean Stream Length of a given order (km) Nu: Number of Stream segment
	Stream Length Ratio (Rl)	Rl = Lu/Lu-1 Lu = total stream length of order Lu-1 = The Total Stream length of its next lower order
	Bifurcation Ratio (Rb)	Rb= Nu/Nu+1 Nu = Number of stream segments present in the given order Nu+1 = Number of segments of the next higher order
RELIEF	Basin Relief (Bh)	Vertical distance between the lowest and highest points of basin
	Relief Ratio (Rh)	Rh = Bh/Lb Bh = Basin Relief, Lb = Basin length
	Hypsometric Curve (Hc)	Relative height/Relative area
	Hypsometric Integral (Hi)	(Mean height - Minimum height)/ (Maximum height - Minimum Height)
	Ruggedness Number (Rn)	Rn = Bh*Dd Bh=Basin Relief, Dd=Drainage density
AREAL	Drainage Density (Dd)	Dd=L/A ; L=Total length of stream (km), A= Area of basin(km²)
	Stream Frequency (Fs)	Fs=Nu/A Nu=Total number of stream A= Area of basin
	Texture Ratio (T)	T=N1/P N1=Total number of first order stream P=Perimeter of basin
	Form Factor (Rf)	Rf=A/(Lb)² A= area of basin, Lb=Basin length
	Circulatory Ratio (Rc)	Rc=4πA/P² ; π=3.14 A= Area of basin , P=Perimeter of basin
	Elongation Ratio (Re)	Re=√(Au/π)/Lb , π=3.14 The length of circle's diameter with the area of the basin / The maximum length of the basin
	Length of Overland Flow (Lg)	1/2Dd; Dd=Drainage density
	Constant Channel Maintenance (C)	Lof = 1/Dd; Dd=Drainage density

Basin linear morphometric parameters are, the number of streams, length, basin perimeter, basin length (L), basin width (B), Bifurcation Ratio (Rb), Length Ratio (RL), Surface Flow Length (Lo), and Texture Ratio (T) is [13].

The morphometric parameters formed by the spatial characteristics of the basins have a very important effect on the collection of precipitation falling into the basin and the accumulation of surface runoff. These parameters are; Drainage Density (Dd), Stream Frequency (Fs), Basin Shape (RF), and Length Ratio (Re) [13].

Relief morphometry of the landforms of the basin consists of features. These features are elevation, slope aspect, Basin Relief (Bh), Relief Ratio (Rh), Roughness Value (Rn), Flow Collection Time (Concentration Time) (Tc), Hypsometric Curve (Hc), and Hypsometric Integral (Hi) [13].

4. Results

4.1. Determination and analysis of the basin area

ASTER GDEM V3 raster image covering the study area; the elevation limit value (z-limit) is selected as 1 and iteratively corrected by filling the pixels that do not contain elevation information. The maximum elevation of DEM within the basin boundary was found to be 1869m and the minimum elevation of 10.7m by performing the mask operation with the basin boundary obtained by calculating the watershed. The Digital Elevation Model obtained by this process and the minimum and maximum elevation values of this model are shown in Figure 8.

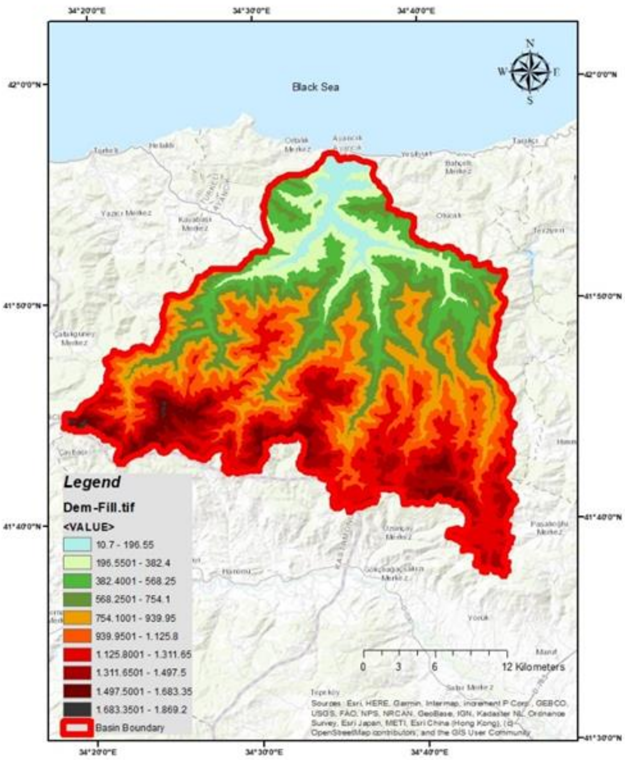

Figure 8. DEM Map

Flow direction was determined using the D8 (directional flow model) method on the obtained DEM. Flow Direction map created in 8 directions is shown in Figure 9.

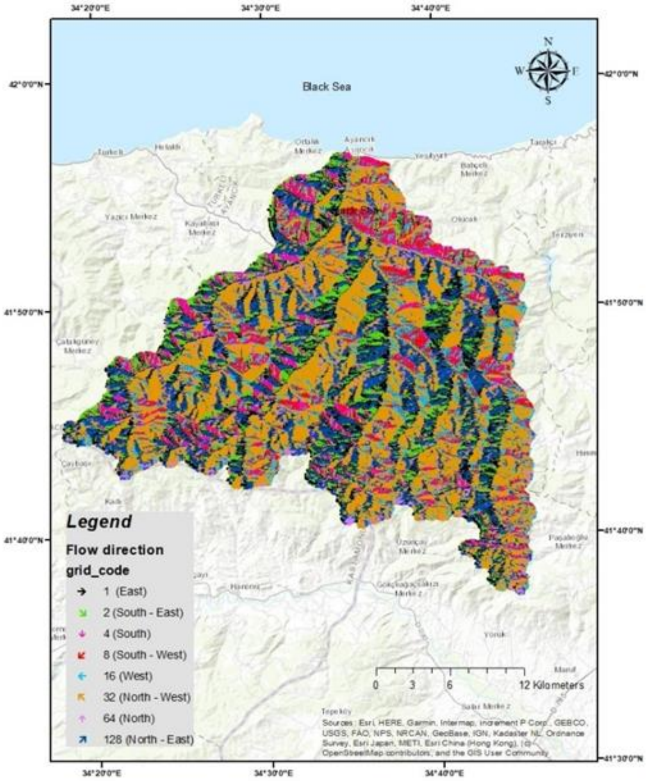

Figure 9. Flow Direction Map

In this study, drainage networks defined by the streams in the Ayancık Stream Basin were obtained and graded using the Strahler method (Figure 10). The drainage network of Ayancık Stream is divided into 5 indices. In this way, water collection areas and areas with drainage density could be determined (Figure 11). The pink areas formed on the river network in Figure 11 show that there are areas where the drainage density is high and that first of all precautions should be taken in case of a possible flood.

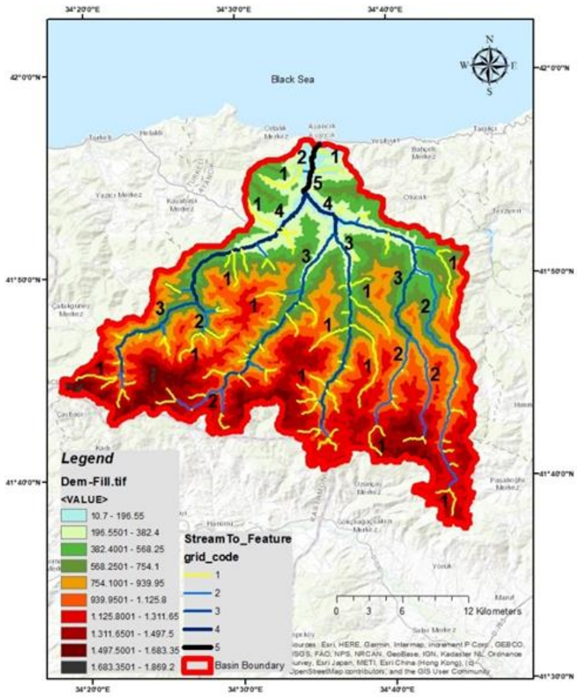

Figure 10. Stream Order Map

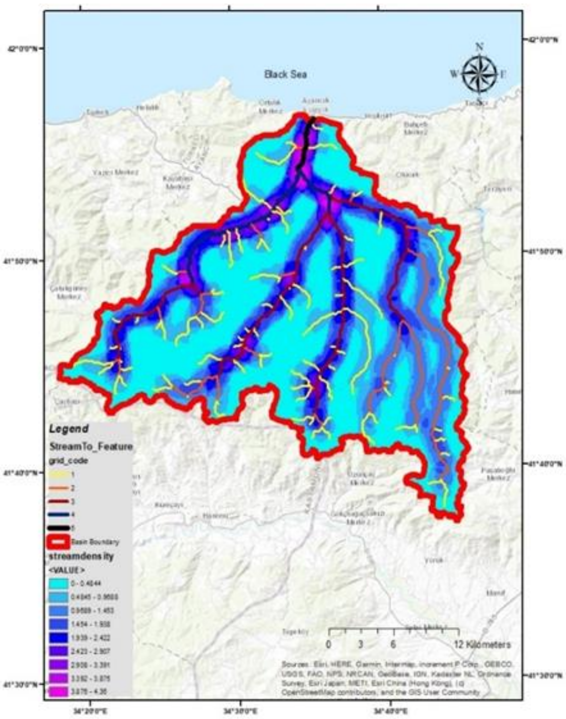

Figure 11. Drainage Density Map

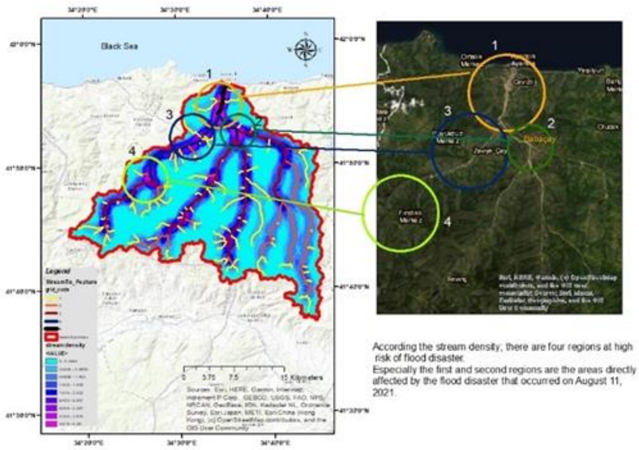

Figure 12. Drainage Density Map and Regional Comparison

In the drainage density map, 4 regions with high flood risk were determined (Figure 12). Since the Aster GDEM V3 raster data we used that was before the flood disaster on August 11, 2021, the flood events; in the 1st and 2nd regions, which are especially high risk, were checked from the news sources. Photographs showing the condition of the 1st and 2nd regions at the time of the flood are shown in Figure 13.

4.2. Calculation and Interpretation of Morphometric Parameters

4.2.1. Linear Morphometry

The basis of the linear morphometric features of the basin is the number and length of the stream sequences.

As shown in Figure 10, the number of indexes of the river network of the Ayancık Basin is 5, and by converting the raster data into vector data, it is possible to query the stream indexes as polylines. The length (Lu) and Frequency values (Fs) of the Ayancık Basin river sequences are shown in Table 3.

Figure 13. Photos showing the situation of the 1st and 2nd regions during the flood on August 11, 2021, in the Ayancık district. a-c-h [15], b [16], d [17], e[18], f [19], g [20], I [21]

Table 3. Ayancık Basin's Length of Stream Orders and Count of Stream Orders

Ayancık Basin		
Stream Orders	**Length of Stream Orders (km)**	**Count of Stream Orders**
1. Stream Order	160	95
2. Stream Order	73	34
3. Stream Order	71	42
4. Stream Order	23	14
5. Stream Order	5	4
Total	332	189

4.2.1.1. Mean Stream Length (Lsm)

The mean stream length (Lsm) shows the relationship of the drainage network with the relevant ground surface for each index; It is found by dividing the total stream length of the sequence by the number of streams. The formula for the Mean Stream Length is given in Table 2 and the results for each index are given in Table 4.

Table 4. Mean Stream Length of Stream Orders

Ayancık Basin	
Stream Orders	**Mean stream length of a given order**
1. Stream Order	1.684210526
2. Stream Order	2.147058824
3. Stream Order	1.69047619
4. Stream Order	1.642857143
5. Stream Order	1.25

4.2.1.2. Stream Length Ratio (Rl)

The Stream Length Ratio helps us to analyze whether the lengths of the lower tributaries are sufficient to carry the water coming from the upper tributaries to the stream's lower tributaries which are calculated as the ratio of the mean stream length of a given order to the mean stream length of next lower order.

Table 5. Stream Length Ratio (Rl) of Stream Orders

Ayancık Basin	
Stream Orders	Stream Length Ratio (Rl)
1. Stream Order	-
2. Stream Order	1.274816176
3. Stream Order	0.787345075
4. Stream Order	0.971830986
5. Stream Order	0.760869565

The ratio of the stream index of the 4th stream index is higher than the length ratio of the 5th stream index and the 3rd stream index (Table 5). This situation shows us that the waters accumulating in the 4th Stream index will collect in the 3rd and 5th Stream indexes due to reasons such as heavy rain and that the length of the 3rd and 5th Stream indexes will be insufficient and therefore will cause a flood disaster.

In the flood disaster on August 11, 2021, the bud storage area of the General Directorate of Forestry, located in the region where the 4th Stream index shown on the Stream Order Map in Figure 10, was mixed with the flood and to the 5th Stream index (district) as shown in the photographs in Figure 13. It was observed that it drifted towards the Babaçay village in the center of the river) and the 3rd stream index.

4.2.1.3. Bifurcation Ratio (Rb)

Bifurcation ratio (Rb), which explains the relationship of precipitation occurring in the basin with vegetation surface permeability and topography according to High and Low values; is calculated as the ratio of the number of stream segments present in the given order to the number of segments of the next higher order. The Bifurcation Ratio formula is shown in Table 2 and the calculated bifurcation rates for each index in the study are shown in Table 6.

Table 6. Bifurcation Ratio (Rb) of Stream Orders

Ayancık Basin		
Stream Orders	**Count of Stream Orders**	**Bifurcation Ratio (Rb)**
1. Stream Order	95	2.794117647
2. Stream Order	34	0.80952381
3. Stream Order	42	3
4. Stream Order	14	3.5
5. Stream Order	4	-

Basins with low Rb value have low permeability capacity, high runoff as well as higher and sharper flow hydrograph features. On the other hand, in basins with a high Rb value, it exhibits a hydrograph character with a high rate of infiltration and a less continuous flow. ([4], [12], [14]) In addition, the geology of the basins with an Rb value between 3-5, in general, has a more homogeneous structure [12].

It can be said that the geology of the basin has a homogeneous structure, since the bifurcation ratio values of the stream sequences of the Ayancık basin are between 3-5.

4.2.2. Relief Morphometry

Relief Morphometry is the analysis made with the slope and height values of the basins.

4.2.2.1 Basin Relief (Bh)

Basin relief, which is defined as the vertical distance between the highest value of the basin and the lowest elevation value, is a hydrological parameter. As can be seen on the DEM map shown in Figure 8, the highest elevation value of the Ayancık Basin is 1869.2 m and the lowest elevation value is 10.7 m. The perpendicular distance between these two points, Bh, is 1858.5 m.

4.2.2.2 Relief Ratio (Rh)

The Relief Ratio, which is calculated as the ratio of the vertical distance between the maximum and minimum basin height to the maximum basin length parallel to the mainstream, gives information about the drainage density and slope characteristics of the basin. The formula for Relief Ratio is shown on the map in Figure 14 with the maximum and minimum height values and the maximum basin length in Table 2. Ayancık Basin Relief Ratio (Rh) is 0.0138173.

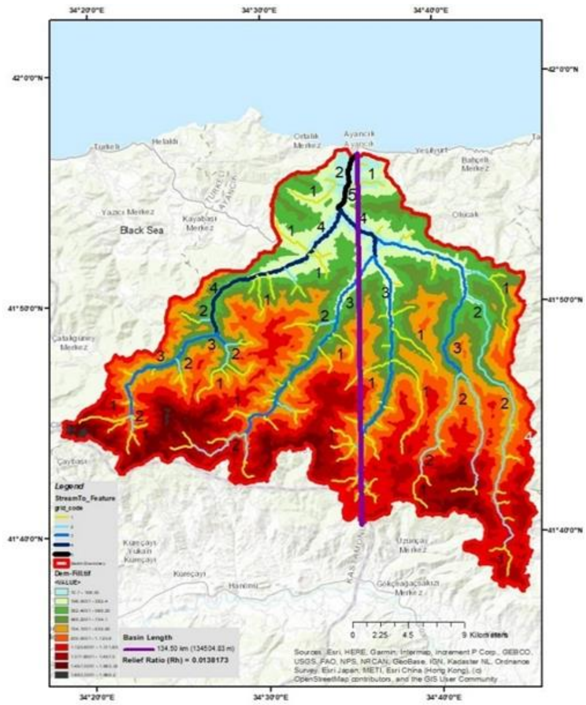

Figure 14. Relief Ratio and Basin Length map

4.2.2.3 Hypsometric Curve (Hc) and Integral (Hi)

The hypsometric curve shows the relationship between the ratio of the basin relative height to the total height and the ratio of the Relative area to the total area; It gives information about the erosion of the drainage network and the structure of the basin. The hypsometric integral is found by dividing the average height value of the basin from the minimum height value to the Basin relief and it shows the area under the hypsometric curve (Table 7). Relative height and relative area values of Hypsometric curve parameters are given respectively in Table 8 and in Figure 15.

Table 7. Hypsometric integral

Ayancık Basin		
Maximum Height	**Minimum Height**	**Average Height**
1869.00	10.00	889.00
Hi	0.47283	

Table 8. Hypsometric curve parameters

Relative Height (h)	Total Height (H)	Relative Area (a)	Total Area (A)	h/H	a/A
10.00	1869.00	674.05	674.05	0.01	1.00
197.00	1869.00	650.90	674.05	0.11	0.97
382.00	1869.00	596.83	674.05	0.20	0.89
568.00	1869.00	518.43	674.05	0.30	0.77
754.00	1869.00	425.03	674.05	0.40	0.63
939.00	1869.00	318.28	674.05	0.50	0.47
1126.00	1869.00	206.86	674.05	0.60	0.31
1312.00	1869.00	102.49	674.05	0.70	0.15
1498.00	1869.00	29.25	674.05	0.80	0.04
1683.00	1869.00	2.12	674.05	0.90	0.00
1869.00	1869.00	0.00	674.05	1.00	0.00

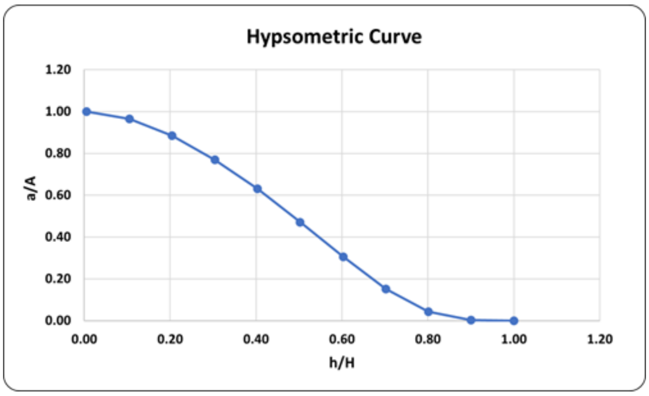

Figure 15. Hypsometric curve (Hc)

Hypsometric integral value and hypsometric curve plot; It shows that the erosion cycle of the Ayancık Basin is between the Young - Mature phase, in other words, the erosion phase is in a trend close to maturity.

4.2.2.4. Ruggedness Number (Rn)

The roughness value of the Basin, calculated by the product of Basin Relief and Drainage Density, gives information about the surface flow and erosion of the basin. The rate of flooding is higher in basins with a high Rh ratio. The Basin Relief Value of the Ayancık Basin is 1858.5m and the Drainage Density Value is 0.492545 (km/km^2). In order to calculate the roughness ratio, the formula which is shown in Table 2, Basin Relief was first converted from m units to km units. The Roughness value of the Ayancık Stream Basin is 0.91539.

4.2.3. Areal Morphometry

Areal Morphometry is the analysis of the basin with area and length information.

4.2.3.1. Drainage Density (Dd)

Drainage Density (Dd), which has a positive relationship with Flood and Flood events; is found by the ratio of the total river length to the basin area. The formula in Table 2 and the total stream index length in Table 3 are shown. The area of the Ayancık Stream basin is 674.05 km^2, and the drainage density is 0.492545 (km/km^2). This value shows that the surface waters infiltrate underground in the Ayancık stream basin and the river intervals are wide.

4.2.3.2. Stream Frequency (Fs)

Stream Frequency value is calculated by the ratio of the total number of stream indexes to the catchment area; if it is high, it indicates non-permeable soil properties and high relief values, if low, and it indicates permeable geological properties and low relief properties. The total number of stream indexes is shown in Table 3 and the Stream Frequency formula is shown in Table 2. The stream frequency (Fs) of the Ayancık Basin is 0.280394.

4.2.3.3. Texture Ratio (T)

Texture Ratio (T), which is calculated by the ratio of the total length of the first stream index obtained by the Strahler method to the perimeter of the basin shows a high value in circular basins and a low value in longitudinal basins. The total length of the 1st stream sequence of the Ayancık stream basin is shown in Table 3, and the Texture Ratio formula is shown in Table 2. The circumference of the basin is 161.33 km. The Texture Ratio value of the Ayancık stream basin is 0.99175.

4.2.3.4. Form Factor (Rf)

Form Factor is calculated by the ratio of the basin area to the square of the maximum basin length and gives information about the circularity of the basin. The formula is shown in Table 2. The Form Factor (Rf) value of the Ayancık basin is 5.0115.

4.2.3.5. Circulatory Ratio (Rc)

Circularity ratio; It is calculated by multiplying the basin area (A) by 4π and dividing by the square of the basin perimeter (P). The closer the value is to 1, the greater the circularity [10]. The circularity map is shown in Figure 16.

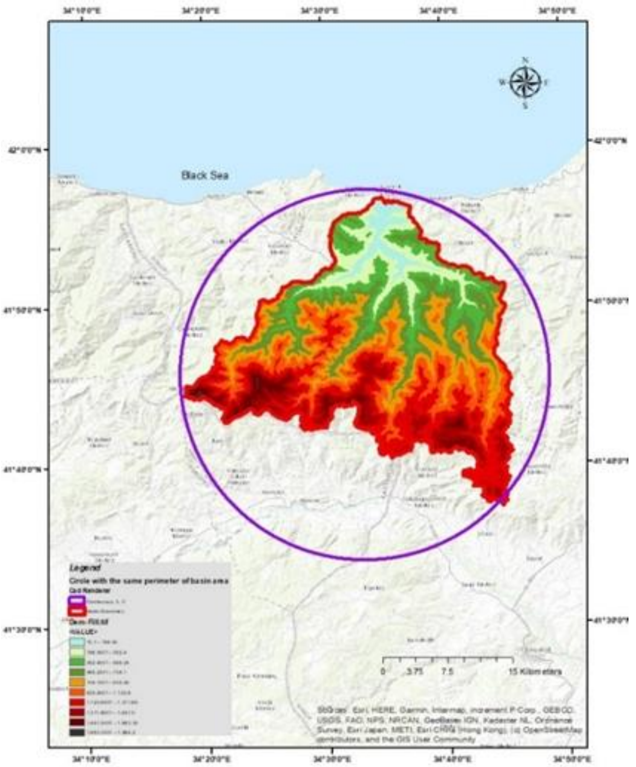

Figure 16. Circulatory Ratio (Rc) Map

The Texture Ratio, Form Factor, and Circulatory Ratio results support each other and show that the Ayancık Stream basin is a basin with circular characteristics.

4.2.3.6. Elongation Ratio (Re)

Elongation Ratio (Re), which is obtained by the ratio of the diameter of a circle with the same area as the basin to the maximum length of the basin, gives information about the infiltration capacity and surface flow of the basin. Ayancık Stream Basin area is 674.05 km2 and the diameter of a circle with the same area as the basin is found from the formula πr^2. The combined version of the formula is shown in Table 2. The Length Ratio of the Ayancık Stream Basin is 0.108969.

4.2.3.6. Length of Overland Flow (Lg)

Length of Overland Flow, which expresses the length of the water on the ground surface before it reaches the flow channel; it is inversely proportional to Drainage Density. Its formula is given in Table 2. The Length of the Overland Flow value of the Ayancık Stream Basin is 0.98509.

4.2.3.7. Constant Channel Maintenance (C)

It is a constant used to determine how many square kilometers of surface area in the basin is required to form a linear foot of the stream channel. The formula is given in Table 2.

A surface area of 2.03 km^2 is required in the basin required for the formation of a linear foot of the Ayancık Stream channel. The C constant of the Ayancık Stream basin is 2.03 km^2.

5. Discussion

The hypsometric curve graph and the integral value showed that the erosion cycle of the Ayancık Basin is in a trend from young to maturity. Since the river valleys show erosion up to the sea level during the maturity stage of the rivers, it is recommended to determine and evaluate the flow and erosion data of the Ayancık Stream over the years while determining the elevation in the creek improvement studies carried out and/or to be made in the region.

Since the Stream Density map obtained was found to be exactly compatible with the areas most affected by the flood disaster that occurred in the Ayancık district on August 11, 2021, it is recommended to perform a flood analysis in the region and to analyze the change in the topography over the years. When the region is examined, it is suggested that settlement maps should be prepared to prevent loss of life and property in case of a possible flood or flood, since the roughness of the land is high.

6. Conclusion

In this study, the boundary and morphometric features of the Ayancık Stream basin were determined by using remote sensing and GIS. In the Stream Density map obtained with the indexes in the drainage networks, areas with a high probability of flooding and flooding were determined. It has been concluded that among these regions, especially the 1st and 2nd Regions are the same as the areas most damaged in the flood disaster on 11 August 2021. For this reason, it has been concluded that these regions are areas where precautions should be taken first.

According to the morphometric characteristics of the basin; Roughness Ratio and Basin relief, it is seen that the basin area has steep slopes and a valley-shaped stream bed is formed. This result supports the difference between the maximum and minimum height in the DEM data.

It has been concluded that the erosional phase of the basin is in a tendency close to maturity and has the characteristic of a circular basin. As a result, it was concluded that there is a flood risk in the Ayancık Stream Basin. The basin model analysis and morphometric parameters obtained as a result of this study have been determined to be a base for flood and flood risk analyses and management plans.

Author contributions

Emine Müjgan ERGENE: Data download, Image processing, calculation, analysis and interpretation, Methodology, Writing, Visualization **Elnaz NAJATISHENDI:** Data curation, Image processing, Software, Validation. **Füsun Balık ŞANLI and Anime Melis Uzar DİNLEMEK:** Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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