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Research Article

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Tekirdağ-Süleymanpaşa Kayi Creek Basin Morphology and Flood Flow

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Abstract Kayi Creek, located in the Süleymanpaşa district of Tekirdağ province in Türkiye, is an important creek basin in the district center with an area of 49.53 km^2. Kayi Creek reaches the sea by passing through Değirmenaltı neighbourhood, which is a dense settlement in the center of the district. The creek, whose flow rate decreases a lot in summer, has a significant flood potential. For this reason, knowing the morphological characteristics of the creek, the water yield of the basin and the flood flows that various repeated torrential rains will create in the creek bed is of great importance in terms of preventing the loss of property and life to be experienced. The morphological characteristics of the basin, which are one of the important elements in determining the precipitation-flow relationships, were calculated using the QGIS computer software program within the Geographical Information Systems. The specific flow rate in the basin, whose direction is northeast-southwest, was 0.000003 m^3/s (0.26 m^3/day) and the coefficient of surface runoff for the average amount of precipitation for many years was 17.4%. The annual water yield of the basin has been calculated as 5 007 483 m^3/year for the amount of surface flow of 101.1 mm. The maximum flood flow rates generated by various recurrent torrential rains in the creek bed in the basin determined as surface flow curve number 82 were 80.23 m^3/s for 6-hour rainfall surplus repeated for 100 years, and 112.48 m^3/s for 6-hour rainfall surplus repeated for 500 years.

Keywords Tekirdağ-Süleymanpaşa, Kayi Creek, Basin morphology, Basin water yield, Basin flood flow

1. Introduction

It is estimated that the world population will reach 9 billion in 2050s. Although the World Food and Agriculture Organization (FAO) has declared that the production of agricultural products currently produced in the world will be sufficient for today's population and the population that will increase to 9 billion tomorrow, it is foreseen that a climate crisis will occur in the future with global warming that has not been on the agenda for many years. Again, FAO data states that 690 million people in the world suffer from hunger. According to the same data, 3 billion people do not have healthy eating conditions. The population of those suffering from hunger in the world has been increasing for the last five years. Added to all this is the Covid-19 pandemic, which emerged in Wuhan, China in 2020 and changed our lives completely [1].

This epidemic, which deeply affected the agricultural sector, has increased the importance of self-sufficiency in the field. Not only that, but also, protectionism in agricultural products has come to the fore. Countries have restricted their foreign trade. Even if you have money, it was not possible to reach some products. All these events, as well as the war between Russia and Ukraine, once again showed how important the supply of agricultural products is.

For this reason, all countries are trying to create a management model that emphasizes the ecological balance with basin management, which is accepted as one of the necessary application tools in their own areas, especially in the basins formed by water resources. Thus, it is aimed to use the existing water resources in the most efficient way.

Because water resources are an indispensable resource for people and all other living things to continue their existence, and it is a resource that cannot be replaced with any other value. In addition to being the most important vital resource for sustainable development, it is also one of the basic tools of civilization. The protection and use of water resources and making land use plans accordingly require planning and management on a basin basis [2].

Basin management plan with the development of the concept of basin management, targets for protecting water resources and quality, increasing efficiency and productivity, and management plans are created as a means of implementation of these targets. The creation of applicable plans is effective in the success of basin management. Because in basin planning, the objectives can be extremely diverse. Depending on the physical, human and economic environment conditions of the basin, some of the stated purposes may precede the others. In other words, the unique characteristics of the basins can also determine the objectives of the planning. Just as the objectives and their priority levels in basin planning are different, the risks of the basins may be different and varied.

Within this, it is necessary to define the creek basins, each of which has different characteristics, and to reveal all the characteristics of the basin. These characteristics are unique to the basins due to their different physical conditions. The transformation of the precipitation falling on the basin into the observed flow at the exit point by changing it over time depends on these characteristics. These can be geological characteristics such as basin area, shape and slope, as well as hydrogeological characteristics such as creek shape, seepage capacity, soil physics (pedological character) and vegetation [3].

In this research study, a creek basin in the Thrace Region of Türkiye, which is located in an important geography due to its geographical location and strategic location, with a high industrial and agricultural potential, has been discussed. It is aimed to provide data for infrastructure investments related to life and property safety in the near future by determining the morphological characteristics of the basin of Kayi Creek, which reaches the sea by passing through the densely populated Değirmenaltı neighbourhood in the Süleymanpaşa district of Tekirdağ province. The annual water yield in the basin and the flood flow rates of the different recurrence times that the torrential rains will create in the creek bed were calculated.

2. Material and method

2.1. Basin description

The research area is the Kayi Creek basin, located between 27º30'-27º35' east longitudes and 41º00'-41º05' north latitudes in the Süleymanpaşa district of Tekirdağ province at Thrace Region in Türkiye. The basin, which has a very young geological structure, is a 49.53 km^2, slightly sloping topographic area. The soils are generally composed of clay-containing and cemented grays. A part of the basin, where cultivated dry farming is common, is used as natural pasture [4].

2.2. Conditions of climate

The basin is under the influence of the Mediterranean climate seen along the coastline of the Marmara Sea. Winters are cool and rainy, summers are dry and hot. Almost all of the precipitation is in the form of rain, and according to the multi-year averages, the number of days with snow does not exceed 5-6 and the number of days covered with snow does not exceed two weeks. The first frost occurs in the second week of November and the last frost in the last week of March [5].

The multi-year monthly average temperature, humidity, wind speed and direction, precipitation and evaporation amounts of the Tekirdağ province Süleymanpaşa State Meteorology Affairs Branch Observatory Station located near the research area are given in Table 2.1.

Table 2.1: The multi-year monthly average some climatic parameters of Tekirdağ Süleymanpaşa Meteorology Observation Station

Months	Average temperature (°C)	Average humidity (%)	Wind speed (m/s)	Wind direction	Precipitation amount (mm)	Evaporation amount (mm)
January	4.7	82.7	3.1	N	68.8	25.3
February	5.4	80.7	3.0	S	54.1	17.8
March	7.3	79.7	2.9	N	54.4	29.7
April	11.8	77.0	2.3	S	40.9	69.1
May	16.8	76.4	2.2	E	36.7	119.4
June	21.3	72.4	2.3	E	37.9	148.2
July	23.8	68.8	2.7	E	22.8	187.0
August	23.8	69.3	2.9	E	13.3	178.5
September	20.0	73.2	2.7	E	33.6	116.5
October	15.4	78.4	2.8	N	62.4	68.2
November	11.0	82.1	2.7	N	75.4	20.6
December	7.1	82.8	3.0	N	81.5	10.8
Annual	14.0	77.0	2.7	N	581.8	987.3

2.3. Method

In the research, primarily the basin morphological characteristics of Kayi Creek located in Tekirdağ province Süleymanpaşa district; basin form coefficient, basin form factor, basin aspect ratio, basin shape index, basin Gravelius and Schumm coefficients, basin equivalent rectangular dimensions, basin slope index, basin circularity ratio, basin average slope, main creek slope, area-elevation distribution curve, basin mean (median), maximum and minimum heights, basin relative relief, valley maximum lateral slope, basin direction, basin creek and drainage density, basin creek grade and basin branching (bifurcation) ratio were determined [3], [6].

In order to reveal all these hydromorphometric features of the Kayi Creek basin and to extract the basin characteristics, 1/25000 scaled digital topography maps and 10 m resolution DEM (Digital Eleavation Model) were used. Geometric corrections of the topography and geological maps to be used as a base were made, and the digitization and analyzes were made in the GIS (Geographic Information Systems) environment. As a satellite image, Landsat 8 OLI image with 174-35 Path-Row index was downloaded from the web environment and 2D modeling was made by using it in QGIS software [7].

Then, the annual water yield from the basin and the flood flow rates of the different recurrence times that the torrential rains will create in the creek bed were calculated. L. Turc method was used to calculate the water yield of the basin. The method is a widely used method for the determination of runoff losses from a basin [8].

$$h = P - E$$

Here; h is the runoff height from the basin, (mm); P is the amount of precipitation falling on the basin, (mm) and E is the amount of actual evapotranspiration from the basin, (mm). The determination of the amount of actual evapotranspiration was calculated with the following equation.

$$E = \frac{P}{\sqrt{0.9 + \frac{P^2}{L^2}}} \qquad L = 300 + 25\,t + 0.05\,t^3$$

Still; L, is the parameter and t, is the average temperature of the basin, °C. This value is the corrected value considering the latitude and altitude differences between the basin and the observation station. The water yield of the basin was calculated by multiplying the resulting runoff height with the basin area.

$$V = h * A * 10^3$$

Here; V is the basin water yield, (m^3/year) and A is the basin area, (km^2). Since it is important to precisely determine the precipitation in the method, Tekirdağ Süleymanpaşa Meteorology Observation Station data, which best represents the basin, was used.

The Synthetic Dimensionless Unit Hydrograph method used by the State Hydraulic Works (DSI) in Turkey was used to calculate the flood flow rate of Kayi Creek. This method was developed by the United States Soil Conservation Service (SCS) [9].

A dimensionless unit hydrograph is a unit less hydrograph obtained by dividing the flow rates of a flood hydrograph at certain times by the maximum flow rate (Q/QP), and their times by dividing their times by the occurrence time of the largest flow (T/TP). In the method, the flood peak of the two-hour excess precipitation was calculated with the following equation.

$$Q_P = A * ha * q_P * 10^3$$

Here; Q_P, peak flood flow rate of two-hour excess precipitation, (m^3/s); A is the basin area, (km^2) and ha, the runoff height from the basin, (mm). The runoff height was found as a result of the runoff curve number, which was determined by considering the soil, land use, vegetation, planting method and soil protection measures of the basin. q_P is the flow rate from each square kilometer of the basin (L/s km^2 mm) when the flood flow reaches its highest value, after an excess of precipitation that lasts for two hours and is accepted to generate 1 mm flow over the basin.

$$q_P = \frac{414}{A^{0.225} * E^{0.16}}$$

Here, the value of E is a coefficient and is calculated by $E = \frac{L * Lc}{\sqrt{S}}$ equation. L is the length of the main creek path in the basin, (km); Lc is the distance between the projection of the basin formal center of gravity on the main creek path and the point where the main creek road leaves the basin, (km).

3. Results

3.1. Basin topographic characteristics

The topographic characteristics of the basin are important factors in determining the precipitation-flow relationships of that basin. Characteristics such as basin area, shape and slope directly affect basin water yield, collection time, flood peaks and hydrograph durations. Basin creek length and branching ratio are the characteristics used to provide the necessary data for dimensioning all structures and facilities to be built in a basin. Reliability in their acquisition is important. In this study, all basin characteristics were obtained using the QGIS.324.4 computer program, accompanied by satellite images [10], [11], [12].

3.1.1. Basin area

The basin area (A) is the size of the precipitation area, and the water yield from the basin is directly proportional to the collection time and the time to reach the peak. The Kayi Creek basin has an area of 49.53 km^2, the outlet of which reaches the Sea of Marmara in Fig 3.1.

3.1.2. Basin perimeter

The basin perimeter (P) is the length starting from the basin outlet and forming a boundary with neighbouring basins. The measured perimeter of the Kayi Creek basin is 45.2 km.

3.1.3. Basin shape

Creek basins can take different shapes. This makes the collection time of the runoff and the time to reach the peak different even if the basin water yield is the same. The shape of the basin can be calculated using different data. These are the shape coefficient, 4.60; shape factor, 0.46; the shape index was 0.22 and the shape aspect ratio was 0.47, while the compaction and Schumm coefficients were 1.80 and 0.53, respectively.

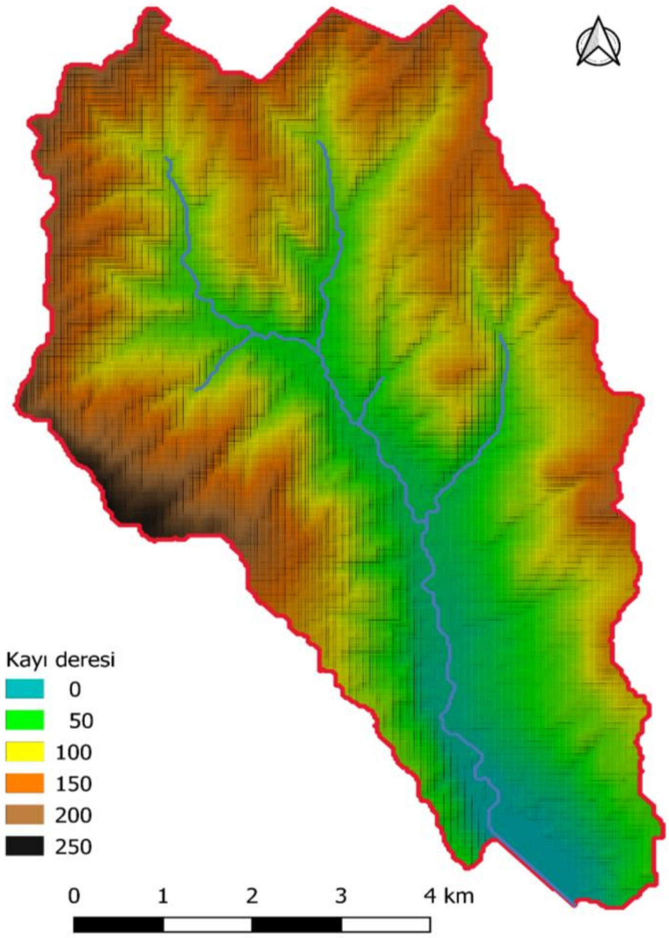

Figure 3.1: Tekirdağ-Süleymanpaşa Kayi Creek basin

3.1.4. Basin equivalent rectangular dimensions

The basin-equivalent rectangle dimensions are the side lengths of the basin and a rectangle whose area and perimeter are the same. For this basin, the L_a side length of the rectangle was 20.17 km and the L_b side length was 2.45 km.

3.1.5. Basin slope index

The basin slope index (Ip) was obtained from the equivalent rectangle and hypsometric curve concepts and was found to be 3.35. The advantage of this index is that the hypsometric distribution of the basin is not considered on a topographic map, but on a simple geometric figure in Table 3.1.

Table 3.1: Area and distribution ratios between basin contours

Height (m)	Area (km^2)	Cumulative area (km^2)	Ratio (%)	Cumulative rate (%)	Xi
0 – 10	0.611	0.611	1.23	1.23	0.25
10 – 20	1.230	1.841	2.48	3.71	0.50
20 – 30	1.602	3.443	3.23	6.94	0.65
30 – 40	1.905	5.348	3.85	10.79	0.78
40 – 50	2.069	7.417	4.18	14.97	0.84
50 – 60	2.414	9.831	4.87	19.84	0.98
60 – 70	2.755	12.586	5.57	25.40	1.12
70 – 80	2.946	15.532	5.95	31.35	1.20

80 – 90	3.317	18.849	6.70	38.05	1.35
90 – 100	3.354	22.203	6.77	44.82	1.37
100 – 110	3.490	25.693	7.05	51.87	1.42
110 – 120	3.600	29.293	7.27	59.14	1.47
120 – 130	3.623	32.916	7.31	66.45	1.47
130 – 140	3.166	36.082	6.39	72.84	1.29
140 – 150	2.998	39.080	6.05	78.89	1.22
150 – 160	2.488	41.568	5.02	83.91	1.01
160 – 170	2.167	43.735	4.38	88.29	0.88
170 – 180	1.769	45.504	3.57	91.86	0.72
180 – 190	1.212	46.716	2.45	94.31	0.49
190 – 200	0.882	47.598	1.78	96.09	0.36
200 – 210	0.533	48.131	1.08	97.17	0.22
210 – 220	0.393	48.524	0.79	97.96	0.16
220 – 230	0.505	49.029	1.02	98.98	0.21
230 – 240	0.245	49.274	0.50	99.48	0.10
240 – 250	0.256	49.530	0.52	100.00	0.11
Total	49.530		100.00		20.17

3.1.6. Basin circularity ratio

The basin circularity ratio (Do) is the ratio of the basin area to the area of the circumference equal to the basin circumference. This ratio was calculated as 0.31 for the Kayi Creek basin.

3.1.7. Basin average slope

The average slope of the basin (S) is obtained by multiplying the total lengths of the contour lines within the basin boundaries by the elevation difference between the two contours and dividing by the entire basin area and calculated as 10.2% in Table 3.2.

3.1.8. Main creek tributary length

It is the length of the longitudinal main creek tributary at the point where it leaves the basin with a larger flow or longer length or higher source. The measured length of the main creek tributary of the basin (L) was found to be 15.1 km.

3.1.9. Main creek tributary slope

The curve obtained by processing the slope of the main creek tributary (Sa), the lengths of the water tributaries at the intersections of the main creek tributary and the contour lines, on the horizontal axis (apse axis), and the land heights at the intersections with the contour curves on the vertical axis (ordinate axis); It was obtained by dividing the readings at the 10% and 85% points to the main creek tributary. It was calculated as 1.0% for Kayi Creek.

Fig 3.2: Contours of Tekirdağ-Süleymanpaşa Kayi Creek basin

3.1.10. Basin hypsometric curve

The basin hypsometric curve shows the elevation distribution of an area. While determining the hypsometric curves; the hypsometric curve is considered separately from the size and height of the basin, as area and height are considered as a function of total area and total height. Therefore, comparisons can be made between basins of different sizes by means of hypsometric curves. The hypsometric curve (in the form of a convex, concave "S" curve) shows the erosional effect of the basin.

Table 3.2: Lengths of contour lines in the basin

Height (m)	Within the borders of the basin length of contour lines (m)
10	3 106
20	8 681
30	9 703
40	13 716
50	16 674
60	21 219
70	24 552
80	30 772
90	35 167

100	38 591
110	39 836
120	41 597
130	39 380
140	36 419
150	31 699
160	28 530
170	25 147
180	19 007
190	14 379
200	9 539
210	5 243
220	3 866
230	2 717
240	1 999
250	1 283
Total	502 872

3.1.11. The distance of the projection of the shape center of gravity of the basin area on the main creek tributary to the basin outlet

The basin area is the distance between the projection of the shape center of gravity on the main creek tributary and the point where the main creek tributary leaves the basin. The measured (Lc) value of the basin is 7.8 km.

3.1.12. Basin average height

Basin average (median) height (H_m) is the height corresponding to 50% of the basin area on a hypsometric curve. In addition, the average height of a basin above sea level can be obtained by dividing the sum of the elevations of the highest and lowest points of the basin by two. For Kayi Creek, this height was 45.4 m.

Table 3.3: Main creek length distribution of the basin area

Height (m)	Creek length (m)	Cumulative creek length (m)	Area (km^2)
0 – 10	1 841	1 841	0.611
10 – 20	2 348	4 189	1.230
20 – 30	1 501	5 690	1.602
30 – 40	1 807	7 497	1.905
40 – 50	1 124	8 621	2.069
50 – 60	1 322	9 943	2.414
60 – 70	1 058	11 001	2.755
70 – 80	785	11 786	2.946
80 – 90	1 033	12 819	3.317
90 – 100	235	13 054	3.354
100 – 110	299	13 353	3.490
110 – 120	208	13 561	3.600
120 – 130	409	13 970	3.623
130 – 140	165	14 135	3.166
140 – 150	114	14 249	2.998
150 – 160	195	14 444	2.488
160 – 170	162	14 606	2.167
170 – 180	127	14 733	1.769

180 – 190	113	14 846	1.212
190 – 200	56	14 902	0.882
200 – 210	105	15 007	0.533
210 – 220	71	15 078	0.393
220 – 230	19	15 097	0.505
230 – 240	2	15 099	0.256
240 – 250	1	15 100	0.245
Total	15 100		49.530

3.1.13. Basin maximum and minimum height

These are the highest and lowest points of the basin relative to the sea level. The highest measured point of the basin is 250 m, and the lowest point is zero elevation, which is the exit to the sea.

3.1.14. Basin relief and relative relief

The basin relief (r) is the difference between the maximum and minimum heights of the basin and is 250 m. Relative relief (r_n) is calculated as the ratio of the maximum and minimum height difference of the basin to the basin perimeter, where it is 0.55.

3.1.15. Basin direction

The basin direction (aspect or orientation) is generally the flow direction of the main creek tributary. It shows the disease characteristic of the basin and is closely related to wind direction, intensity and freeze-thaw. The determined direction of the basin is in the northeast-southwest direction.

3.1.16. Basin creek density

Basin creek density (frequency) is the ratio of the number of all tributaries, including those that dry up throughout the year, to the basin area. The basin creek density for Kayi Creek was 19.4.

3.1.17. Basin drainage density

The basin drainage density (D_d) is the ratio of the total length of all creek tributaries in the basin in Table 3.4 to the basin area and was 4.0. The large drainage density increases the severity of the floods as it will accelerate the arrival of the precipitation to the main creek.

Table 3.4: The degree, number and lengths of the creek tributaries of the basin

Creek grade	**Number of creek**		**Creek length (km)**
Nu	Nu	log Nu	**Lu**
1	523	2.7185	108.2
2	236	2.3729	50.4
3	147	2.1673	26.1
4	55	1.7404	8.2
5	1	0.0000	7.4
15	962	8.9991	200.3

3.1.18. Basin creek degree

It is the degree of each tributary in the basin, and the creek degree of the highest-grade creek basin in the basin determines. The creek degree of the mentioned basin was calculated as five.

3.1.19. Creek concentration time

The creek concentration time is the time it takes for the runoff to reach its exit point from the farthest point of the basin. Although there are different equations developed by scientists, it is determined as 3.14 here.

3.1.20. Basin bifurcation rate

Basin bifurcation ratio is the ratio of the number of creeks of a certain degree to the number of creeks of a higher degree. Here the bifurcation ratio (R_b) was calculated as 4.05.

3.1.21. Basin specific flow

The basin specific flow rate is the ratio of the flow measured at the basin outlet to the basin area. The specific flow rate determined for the said basin was 0.000003 m^3/s (0.26 m^3/day).

Table 3.5: The points where the basin contour lines intersect the main creek tributary

Contour curves number of crossings of the main creek tributary (n)	Main creek of contour lines height of the point where he cut his tributary (h)
1	10
2	20
3	30
4	40
5	50
6	60
7	70
8	80
9	90
10	100
11	110
12	120
13	130
14	140
15	150
16	160
17	170
18	180
19	190
20	200
21	210
22	220
23	230
24	240
25	250
Total	3 250

3.2. Basin flood flow

If precipitation and flow records are not available in a basin area, it is possible to produce a flood unit hydrograph with many synthetic methods developed depending on the physical characteristics (size, main creek length and slope) of that basin. In the Kayi creek, first the surface flow curve number of the precipitation basin and then the flood flow rate were calculated using the SCS dimensionless unit hydrograph method.

In the Kayi creek basin, dry farming is commonly practiced with levelling curved fallow wheat-sunflower binary alternation. Good quality wheat is cultivated in half of the basin, and Sunflower with good characteristics is cultivated in 40% of the basin. 5% of the remaining area is medium-featured natural pasture and 5% is various residential areas and roads. Using all these, the weighted runoff curve number 82 for the Kayi Creek basin was calculated.

By using the precipitation heights determined according to different recurrence years and different hour durations and the weighted runoff curve number, the runoff amounts for various recurrences were calculated. Taking into account the floods experienced in recent years, the Q_{100} and Q_{500} values of the basin were determined by using the rainfall intensities with 100 and 500 years. These values were 80.2 m^3/s for 6-hour excess precipitation with 100 years of recurrence, and 112.5 m^3/s for 6-hour excess precipitation with 500 years of recurrence.

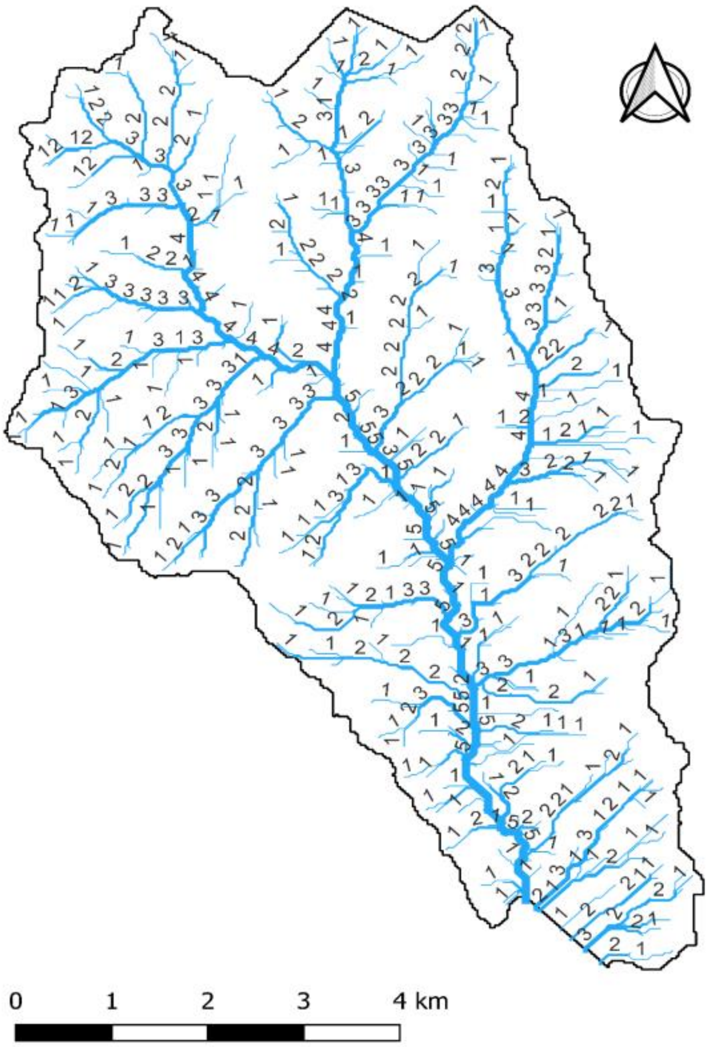

Figure 3.3: Basin main creek tributary curve

3.3. Basin water yield

Basin water yield is usually defined as the total annual water volume or the average flow for long time periods. The annual average flow for a creek is expressed in m^3/s and for a basin, as in precipitation, the water height is expressed in mm. The amount of precipitation and water yields, on which the hydrological characteristics of the basin are effective, should be known in the design of various water structures. According to the Turc method, which was developed for this purpose and used extensively in practice, the surface runoff amounts, the basin flow coefficient and the basin water yields are given in Table 3.6.

Table 3.6: Multi-probable basin flow coefficients of long-term averages

Precipitation amount (mm)	Runoff amount (mm)	Basin runoff coefficient	Basin water yield (m^3/year)
582.1	101.1	0.174	5 007 483
549.8	85.7	0.156	4 244 721
515.2	70.5	0.137	3 491 865
474.8	54.4	0.115	2 694 432
418.7	35.2	0.084	1 743 456

4. Conclusion and recommendations

4.1. Conclusions

Kayi Creek, located in Tekirdağ province Süleymanpaşa district, is an important river basin in the district center with an area of 49.53 km^2. The basin is within the Marmara large river basin. Kayi Creek reaches the sea by passing through Değirmenaltı Neighbourhood, which is a dense settlement in the district center. The creek, whose flow rate decreases in summer months, has a significant flood potential. For this reason, knowing the morphological characteristics of the creek, the water yield of the basin and the flood flow rates that will be caused by various recurrent torrential rains in the creek bed are of great importance in terms of preventing the loss of life and property.

The morphological characteristics of the basin, which are important elements in determining the rainfall-runoff relations, were calculated using the QGIS computer software program within the Geographical Information Systems. From here, the average slope of the basin is 10.2% and its height is 45.4 m, the length of the main creek is 15.1 km and the slope is 1.0%. In the basin, whose direction is northeast-southwest, the specific flow rate was 0.000003 m^3/s (0.26 m^3/day) and the runoff coefficient for the average precipitation amount for many years was 17.4%.

4.2. Recommendations

The management of water resources should be handled with an integrated basin planning, taking into account the river precipitation areas. Because, independent of administrative and political borders, more profitable use of water resources will be ensured in river basins whose borders are drawn completely in accordance with geographical conditions.

The use of satellite images to provide the necessary basic data in the management of river basins and the determination of the morphological characteristics of each basin are important in terms of more accurate planning.

Basin management is important in order to minimize/prevent a flood risk that will cause loss of life and property in the down of Kayi Creek, which passes through the settlement. In this sense, a water storage structure/small soil earth dam should be constructed in the basin.

In order to minimize soil and water losses in wheat-sunflower bilateral alternation, which is widely cultivated as dry agriculture, it is necessary to plow and plant parallel to the levelling curves.

It should be aimed to prevent erosion damages by giving importance to afforestation in the high areas of the basin and improvement works in the existing pastures. In this regard, training and demonstration activities should be carried out for the farmers and residents in the settlements located in the basin.

Information meetings and conferences on integrated basin planning and management should be held for Tekirdağ Namık Kemal University students located in the basin.

Again, the State Hydraulic Works (DSI) Branch Directorate, located in the settlement within the basin, should continue to play an active role in the bed cleaning works of Kayi Creek, which sometimes require it.

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