MODIFICATION OF TURC METHOD TO DETERMINE THE WATER YIELDS OF SUB-BASINS IN THRACE REGION OF TURKEY

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ABSTRACT

In this research, directly measured flow values in three different basins in Thrace region, that is located in the Northwest Part of Turkey, were compared to the computed ones applying the Turc method to these basins. It is concluded that Turc method with original coefficients, 300 and 0.9, could not be used because of huge discrepancies between the measured and calculated values. Instead, coefficients of 601 and 0.65, respectively, were used after the correction using long term measured flow rates. Employing the modified Turc method for these research basins, reservoirs volume are reduced by 50.7 %. This may decrease the total cost of the reservoirs by about 20-30 % through reducing occupied surface area, embankment and crest height.

KEY WORDS: watershed, reservoir, Turc Method, runoff, water yield

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DETAILED ABSTRACT

Turc method was intended to be modified to determine the water yield of sub-basins in Thrace Region located in Northwest part of Turkey considering 15 years directly measured values.

There were three watersheds located in the European part of Turkey, namely, Edirne Kumdere (EK), Kirklareli Vize Deresi (KVD) and Istanbul-Catalca Damlica Deresi (ICD) watersheds (Figure 1).

The climate in the Region is characterised by cold rainy winters and hot drought-prone summers. Long term annual average temperature and precipitation varied from 12 to 15 °C and from 586 to 649, respectively. Dry farming system without following is practised with wheat - sunflower rotation. The other characteristics of the watersheds are presented in Table 1.

Precipitation is measured using 3 raingauges, placed around the outlet of the watersheds. A triangular weir was constructed at the outlet point to quantify runoff leaving the watersheds. The flow rate against time in the triangular weir was recorded by a stage recording gauge connected to this weir by a channel. To fit the calculated values to the measured values, Turc method was modified through either replacing the coefficient 300 or 0.9 in Turc Equation with the new coefficients for this Region.

Although averages of 609.6, 535.5 and 707.4 mm rainfall were recorded, only 21.30, 6.61 and 43.20 mm runoff were measured in EK, KVD and ICD watersheds, respectively. The magnitude of the measured runoff were too small when compared to the precipitation (Table 2, 3 and 4).

The average annual calculated runoff for EK, KVD and ICD watersheds were 125.4, 101.4 and 178.2 mm, being 5.9, 15.3 and 4.3 times larger than the actual measured values, respectively. The suggested average coefficients instead of 300 and 0.9 are 1026 and 0.39 for EK, 1135 and 0.40 for KVD, and 1035 and 0.19 for ICD watersheds, respectively.

The average of annual rainfall of three watersheds was 617.5 mm while the annual average runoff is 23.71 mm over the period of 15 years. Although 3.84 % of the total annual precipitation was measured as surface runoff, the calculated runoff using original Turc method was 138.0 mm, which is 5.8 times larger that the measured one (Table 5).

The water yields of EK, KVD and ICD watersheds obtained from the directly measured average runoff height were found to be 93 720 m^3/year, 30 607 m^3/year and 356 832 m^3/year, respectively. Using original coefficients, Turc method calculated the water yields as 551 760 m^3/year, 470 496 m^3/year and 1 546 272 m^3/year, respectively.

Average coefficients for Thrace Region were also suggested. These are 1065 and 0.33 instead of 300 and 0.9, respectively. Because these are average coefficients, the likelihood of exceeding the calculated water yields using them in any year is 50% and they are not confident. Therefore, to avoid this and increase the water yield to a secure level that should be considered in investigating the volume of reservoirs and dams, further correction was made by evaluating the findings statistically, and 601 and 0.65 were found finally.

Recalculating the water yields of EK, KVD and ICD watersheds using final coefficient, 279 400 m^3/year, 215 760 m^3/year and 859 886 m^3/year were obtained, respectively.

Application of the modified Turc method for these research basins, reservoirs volume are reduced by 50.7 %. This may decrease the total cost of the reservoirs by about 20-30 % through reducing occupied surface area, embankment and crest height.

INTRODUCTION

Soil and water are very essential natural resources for all livings. Moreover, they are entrusted to us for future generation. To save them was suggested in all holy books. Soil should be protected where it forms whereas water in the place where falls as precipitation. During the period following the precipitation some part of the water percolate deep into the soil profile, some part runs off in control of the surface slope, gets into the river beds and eventually reaches the dams, seas and oceans. Water is salinised or contaminated to different levels during this journey and its usage by living beings is greatly diminished. To prevent this, collecting structures such as ponds and dams on the way of water are necessary to be constructed where the topographic conditions permit.

Dimension of water collecting structures to be built up at the outlet of a watershed are computed according to the total runoff originated from the watershed in consideration. The magnitude of runoff is either measured directly on a single outlet on the main stream or calculated through empirical equations based on important physical properties of a particular watershed.

Using the measured values is, of course, the best way to predict the total runoff, but it takes a long time and investments are delayed. Therefore empirical equations are preferred in application. As in many other countries, the Turc method is used widely in Turkey to investigate the reservoir volume by Turkish General Directorate of Rural Services which is responsible for the investments on agricultural and rural infrastructures [1].

However, the method overpredicts the reservoir volume compared to the actual one for the region in consideration. This increases the cost significantly. Therefore, the method cannot be applied in our conditions without any major modification. This necessitates that this issue should be carefully evaluated in economical and technical aspects.

In this research, the Turc method is intended to be modified to determine the water yield of sub-basins in Thrace Region located in the Northwest part of Turkey considering directly measured values of 15 years.

Figure 1. Location of the Research Areas

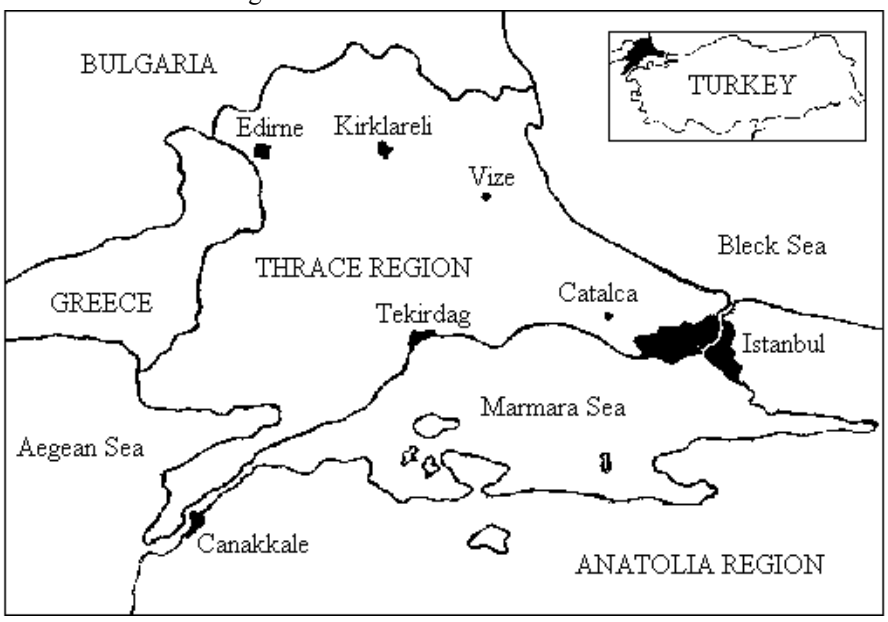

Table 1. Some characteristics of research basins (EK, KVD and ICD represents, Edirne Kumdere, Kirklareli Vize Deresi and Istanbul-Catalca Damlica Deresi watersheds, respectively)

	Name of the basins		
Basin properties	EK	KVD	ICD
North latitude	41° 40' 59"	41° 30' 53"	41° 06' 04"
East longitude	26° 40' 09"	27° 41' 20"	28° 25' 00"
Total area (km^2)	4.40	4.64	8.26
Max. and min. altitude (m)	154-115	244-185	258-110
Length of boundary (km)	9.50	10.55	13.10
Direction	North-South	N.east-S.west	N.west-S.east
Average slope (%)	4.0	3.0	5.9
Compactness constants	1.27	1.37	1.28
Circularity rate	0.61	0.52	0.60
Main stream length (km)	3.55	4.50	4.35
Main stream harmonic slope (%)	0.94	0.59	1.89
Drainage density (m/km^2)	2841	2209	1925
Bifurcation rate	4.4	4.5	4.5
Curve number	77	67	88

MATERIALS AND METHODS

Materials

Investigations were done in three sub-basins located in the European part of Turkey, namely, Edirne Kumdere (EK), Kirklareli Vize Deresi (KVD) and Istanbul-Catalca Damlica Deresi (ICD) watersheds (Figure 1). The watersheds are similar to each other and represent the Region in respect to geological, climatic, soil and vegetation conditions. They are geologically constituted of territorial formation of Pliosen and Miosen period. Non-calcic brown soils are dominant in EK, non-calcic brown forest soils in KVD and vertisols in ICD watersheds [2, 3 and 4].

The climate is characterised by cold rainy winters and hot drought-prone summers. Long term annual average temperature and precipitation varied from 12 to 15 °C and from 586 to 649, respectively [5]. Dry farming system without fallowing is practised with wheat - sunflower rotation [6]. Some characteristic of these three watersheds are presented in Table 1 [2, 3 and 4].

Methods

Precipitation was measured using 3 raingauges, which were placed around the outlet of the watersheds. A triangular weir was constructed at the outlet point to quantify runoff leaving the watersheds. The flow rate against time in the triangular weir was recorded by a stage recording gauge connected to this weir by a channel [7].

The measured values were compared to the ones computed using Turc method as reported by Shaw [8]. The annual water yield expressed in Turc method may be given as:

$$V = h \cdot A \cdot 10 \quad (1)$$

- V: annual water yield of the basins (m^3/year)
- A: area of the basins (hectare).
- h: surface runoff height, that occurred in the basins (mm)

The surface runoff height is calculated as:

$$h = P - E \quad (2)$$

- E: annual actual evapotranspiration (mm);
- P : annual average precipitation(mm).

The rate of annual actual evapotranspiration is defined as:

$$E = \frac{p^2}{\left(0{,}9 + \frac{p^2}{L^2}\right)^{1/2}} \quad (3)$$

in which the correlation parameter L is described as:

$$L = 300 + 25T + 0{,}05T^3 \quad (4)$$

- T: annual average temperature (°C).

First, annual surface runoff (h) values were calculated for each watershed using the above calculation procedure. Then these were compared to

the directly measured ones. To fit the calculated values to the measured values, Turc method was modified through either replacing the coefficient 300 in Eq (4) or coefficient 0.9 in Eq (3) with the new coefficients. Finally, taking the arithmetic mean of the research years for each watershed and their standard deviations into account, new coefficients instead of 300 or 0.9 for research basins and similar sub-basins in the Thrace Region were suggested.

RESULTS AND DISCUSSIONS

The measurements were done during the period between 1982 and 1999, however records for 15 years are available for each basin.

Annual average rainfalls, directly measured runoff heights at the outlet point of the basins, calculated runoff heights using original Turc method and realised water yields were presented in Table 2, 3 and 4 for EK, KVD and ICD watersheds, respectively. New coefficients instead of 300 in Eq (4) and 0.9 in Eq (3) were also suggested in order to realise the actual water yield.

Although averages of 609.6, 535.5 and 707.4 mm rainfall were recorded, only 21.30, 6.61 and 43.20 mm runoff were measured in EK, KVD and ICD watersheds, respectively.

The magnitude of the measured runoff was too small when compared to the precipitation, corresponding 3.5 %, 1.2 % and 6.1% part of the rainfall for EK, KVD and ICD watersheds, respectively. This was because of vegetation, topographic and soil conditions. The curve numbers varied between 67 and 77. The slope along the watershed is not so steep to increase the surface runoff. Soil profile is quite deep and its water holding capacity is considerably high.

The average annual calculated runoff for the EK, KVD and ICD watersheds were 125.4, 101.4 and 178.2 mm, being 5.9, 15.3 and 4.3 times larger than the actual measured values, respectively.

To fit the computed water yield to the long term directly measured values, either coefficient 300 in the Eq. (4) or coefficient 0.9 in Eq. (3) should be modified. However both modifications were done here. One should use only one of these new coefficient. The suggested average coefficients instead of 300 and 0.9 were 1026 and 0.39 for EK, 1135 and 0.40 for KVD, and 1035 and 0.19 for ICD watersheds, respectively.

Table 2. Rainfall, runoff and suggested new coefficients for Edirne Kumdere (EK) watershed during the research years.

	Annual	Total runoff (mm)		Realised	Suggested coefficients	
Year	average rainfall (mm)	Direct measurement	Calculated by Turc Eq.	Water yield rate (%)	instead of 300	instead of 0.9
1985	460.2	31.89	55.1	59.7	476	0.76
1986	454.6	11.57	53.0	21.8	726	0.67
1987	562.2	0.00	100.5	0.0	1341	0.42
1988	668.5	4.77	159.4	3.0	1540	0.19
1989	686.7	11.88	170.5	7.0	1429	0.17
1990	526.5	1.66	83.3	2.0	1178	0.50
1991	537.0	18.82	88.2	21.3	851	0.54
1992	470.6	1.20	59.2	2.0	1015	0.60
1993	438.0	2.33	46.8	5.0	880	0.66
1994	540.7	1.22	73.5	1.7	1122	0.54
1995	864.8	28.71	292.0	9.8	1662	-0.31
1996	635.1	42.80	139.7	30.6	835	0.41
1997	558.8	2.49	98.8	2.5	1256	0.43
1998	880.9	30.09	303.9	9.9	1688	-0.36
1999	895.7	130.40	315.0	41.3	872	-0.11
Average	609.6	21.30	125.4	17.0	1026	0.39

Table 3. Rainfall, runoff and suggested new coefficients for Kirklareli Vize Deresi (KVD) watershed during the research years.

	Annual	Total runoff (mm)		Realised	Suggested coefficients	
Year	average rainfall (mm)	Direct measurement	Calculated by Turc Eq.	water yield rate (%)	instead of 300	instead of 0.9
1985	553.7	0.66	111.1	0.6	1351	0.34
1986	798.9	21.12	270.3	7.8	1650	-0.33
1987	678.0	0.81	185.7	0.4	1740	0.01
1988	610.9	0.12	143.7	0.1	1549	0.19
1989	684.4	0.62	190.0	0.3	1766	-0.01
1990	555.4	0.00	112.0	0.0	1377	0.33
1991	426.2	0.05	51.5	0.1	967	0.61
1992	343.9	0.00	24.1	0.0	709	0.74
1993	266.5	1.12	6.9	16.2	430	0.85
1994	119.5	0.00	0.0	0.0	0	0.97
1995	538.7	2.63	103.1	2.6	1246	0.38
1996	412.9	3.78	46.5	8.1	820	0.65
1997	404.7	3.11	43.5	7.2	812	0.66
1998	848.7	27.96	307.8	9.1	1684	-0.49
1999	789.3	37.24	263.2	14.2	1379	0.13
Average	535.5	6.61	101.4	6.5	1135	0.40

Table 4. Rainfall, runoff and suggested new coefficients for Istanbul-Catalca Damlica Deresi (ICD) watershed during the research years.

	Annual	Total runoff (mm)		Realised	Suggested coefficients	
Year	average rainfall (mm)	Direct measurement	Calculated by Turc Eq.	water yield rate (%)	instead of 300	instead of 0.9
1982	788.2	57.41	240.8	23.8	1110	-0.01
1983	560.2	6.51	101.0	6.5	820	0.43
1984	661.8	25.81	160.4	16.1	1121	0.25
1985	557.7	50.13	100.6	49.8	580	0.65
1986	690.0	74.23	175.1	42.4	731	0.35
1987	935.6	28.66	350.8	8.2	1882	-0.60
1988	708.2	4.35	187.5	2.3	1686	0.06
1989	700.3	41.80	181.6	23.0	1031	0.20
1990	557.8	0.99	100.6	1.0	1307	0.41
1991	901.7	19.50	323.7	6.0	1944	-0.50
1992	610.4	155.08	129.8	119.5	218	1.09
1993	655.8	5.91	155.2	3.8	1481	0.20
1994	601.1	2.06	124.0	1.7	1412	0.32
1995	867.0	103.73	300.3	34.5	962	-0.14
1996	814.7	71.79	260.5	27.6	1055	-0.06
Average	707.4	43.20	178.2	23.1	1035	0.19

CONCLUSIONS AND RECOMMENDATION

The summary of the results obtained in three different watersheds located in Thrace Region of Turkey is presented in Table 5. The Table shows that the average of annual rainfall of three watersheds is 617.5 mm while the annual average runoff is 23.71 mm over the period of 15 years. Although 3.84 % of the total annual precipitation was measured as surface runoff, the calculated runoff using original Turc method was 138.0 mm, which is 5.8 times larger that the measured one.

Table 5. Average Rainfall, runoff and suggested new coefficients for the watersheds in Thrace Region of Turkey during the research years (EK, KVD and ICD represents, Edirne Kumdere, Kirklareli Vize Deresi and Istanbul-Catalca Damlica Deresi watersheds, respectively)

Name	Annual	Total runoff (mm)		Realised	Suggested coefficients.	
of watershed	average rainfall (mm)	Direct measurement	Calculated by Turc Eq.	Water yield rate (%)	instead of 300	instead of 0.9
EK	609.6	21.30	125.4	17.0	652	0.52
KVD	535.5	6.61	101.4	6.5	609	0.83
ICD	707.4	43.20	187.2	23.1	541	0.61
Average	617.5	23.71	138.0	17.2	601	0.65

The water yields of EK, KVD and ICD watersheds obtained from the directly measured average runoff height were found to be 93 720 m^3/year, 30 607 m^3/year and 356 832 m^3/year, respectively. Using original coefficients, Turc method calculated the water yields as 551 760 m^3/year, 470 496 m^3/year and 1 546 272 m^3/year, respectively. These estimated values, which cannot be acceptable when compared to the measured ones, have been used by the General Directorate of Rural Services responsible for construction of reservoirs and dams. New coefficients were proposed for the watersheds individually in the previous section. Average coefficients for Thrace Region were also suggested. These are 1065 and 0.33 instead of 300 and 0.9, respectively. Because these are average coefficients, the probability of exceeding the calculated water yields using these coefficients in any year is 50 %, and the results are not confident. Therefore, to avoid this and increase the water yield to a secure level that should be considered in investigating the volume of reservoirs and dams, further correction was made by evaluating the findings statistically, and thus the values 601 and 0.65 were found finally as parameters tp the method.

Recalculating the water yields of EK, KVD and ICD watersheds using the finally established coefficient, 279 400 m^3/year, 215 760 m^3/year and 859 886 m^3/year were obtained, respectively. When the calculated values for each year were compared to the measured values of the same year, measured values exceeded the estimated ones only once in EK and ICD watersheds and twice in KVD watershed. Hence calculated values are considered to be quite safe.

Application of modified Turc method for these research basins, may result in the reduction of the reservoir volume by 50.7 %. This may decrease the total cost of the reservoirs by about 20-30 % through reducing occupied surface area, embankment and crest height.

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