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Analysis of Surface Runoff Per Capita in Türkiye-Thrace Region

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Abstract In a settlement, in addition to social and economic planning, in all physical infrastructure and superstructure works, the amount of surface runoff capita resulting from precipitation falling on the area where that settlement surfaces, under conditions where there is no nourishment other than precipitation, is an important indicator of water scarcity. In this study, it is aimed to calculate the amount of surface runoff per capita in the districts of the Thrace Region of Turkey, which has high industrial and agricultural potential and dense human presence. Multi-year average total precipitation amounts representing these places were taken from the meteorological stations of the General Directorate of State Meteorological Affairs. The population of each district was taken from the 2022 year-end results of the Address-Based Population Registration System of the Turkish Statistical Institute (TUIK). The Basin Water Yield Equation method developed by M.Turc was used to calculate the surface runoff amount. According to calculations made using the annual total precipitation amounts of approximately a century between 1929-2023 for the provinces in the Thrace Region, the annual surface runoff amount was obtained as an average of 116.9 (±10.4) mm. This amount corresponds to 19.2% of the total rainfall. There is a serious water scarcity in the Thrace Region, especially in Istanbul. Istanbul is followed by Tekirdağ, Edirne, Kırklareli and Çanakkale, respectively. The unsustainable water scarcity for the European side of Istanbul is prevented from becoming noticeable by the intense use of bottled water in the market and the city network supported by water transferred from Anatolia. As obtained from multi-year total precipitation data, the total surface runoff amount throughout the Thrace Region varies between 2.54 and 3.04 km3, although it varies from year to year.

Keywords Thrace Region, İstanbul, Water scarcity, Precipitation, Surface runoff.

1. Introduction

Water is an essential resource for human life and the entire ecosystem. With each passing year, the increasing population and the accompanying water demand continue to be important for economic, social, and environmental development in many settlements.

The world population is approximately 7.8 billion people. The world population, which was 2 billion two hundred years ago, has increased the most in its history in the last 100 years. Despite this, the world's water resources remain unchanged at 1.4 billion km3, and its per capita amount is decreasing rapidly every year [1].

In addition, when the potential of world water resources is examined, it is seen that their distribution on earth varies greatly. There are serious inequalities in different countries within and between continents. Access to water becomes more difficult every year. According to UNICEF, 2.1 billion, people do not have access to clean drinking water in the world. Approximately twice these numbers of people are deprived of daily hygiene opportunities [2].

The amount of water per capita in Türkiye is decreasing every year. While the amount of water per capita was approximately 8,500 m3 in the founding years of the Republic, it has decreased to around 1,300 m3 today. This amount is much lower for Istanbul, which is a metropolitan city [3].

In the physical infrastructure and superstructure works to be built in settlements, the amount of surface runoff per capita is considered an important indicator of water scarcity [4]. The amount of surface runoff is calculated by subtracting the amount of evaporation and infiltration from the precipitation value. The amount of surface runoff per capita is obtained by dividing the amount of surface runoff determined by the total population in that area.

The goal of this study is to determine the surface runoff per capita in each district of Turkey's Thrace Region, which has a dense population and significant industrial and agricultural potential. This information has grown increasingly significant as the region's population grows annually. Water data would thus be ascertained and disseminated for development to related institutes.

2. Material and Method

The Thrace Region is situated between 41º13' and 42º05' northern latitudes and 26º54' and 28º06' eastern longitudes on the European continent of Turkey. 23,859 km2 make up its surface area (Kirsac, 2003). 25 districts on Istanbul's European side, 11 districts in Tekirdağ, 9 districts in Edirne, 8 districts in Kırklareli, and 2 districts in Çanakkale were all covered in the study. The General Directorate of State Meteorological Affairs' meteorological stations provided the multi-year average total precipitation quantities for these locations [5]. The Turkish Statistical Institute's Address-Based Population Registration System year-end figures for 2022 were used to determine each district's population [6].

Different types of precipitation fall on the ground and are either kept on the surface, evaporated or returned to the atmosphere through plant transpiration. A portion of it percolates deeply into the soil, feeding the soil water and groundwater in the saturated environment it reaches. A portion of it flows straight to the surface.

Surface runoff is used for industrial processes, energy production, agricultural irrigation, and drinking water supply. for this reason, it is crucial to understand the runoff rate on the surfaces. The Basin Water Yield Equation, created by M. Turc and frequently used to examine the link between rainfall and runoff, was applied to determine the surface runoff [7].

In the M.Turc method, which was developed based on observations of basins in different climatic conditions of the world, the surface runoff equation is expressed as

$$h = P - E \qquad (1)$$

In equation; h, amount or height of surface runoff from the basin, mm; P is the total annual precipitation amount falling into the basin, mm, and E is the total annual real evapotranspiration amount of the basin, mm. Determining the actual amount of evapotranspiration is determined by obtaining the parameter $L = A + 25\,t + 0.05\,t3$, then evapotranspiration is calculated with the help of the following equation (Chow, Maidment, and Mays, 1988).

$$E = \frac{P}{\sqrt{0.9 + \left(\frac{P}{L}\right)^2}} \qquad (2)$$

In equation, L is the parameter and t is the basin's yearly average temperature, expressed in °C. After accounting for latitude and altitude, each district's temperature value is rectified. Once more, the value of the main river basin that includes each district was utilized to calculate the L parameter's A coefficient.

Following the calculation of the surface runoff amount for each district, the prospective surface runoff amount was obtained by multiplying this value by the district's surface area. The yearly surface runoff amount per capita was then computed by dividing it by the district's population.

3. Results and Discussion

The per capita amount of surface runoff resulting from falling precipitation is a significant indicator of water shortage in situations where the only source of recharge is precipitation. It's critical to understand the runoff rate in the region because the amount of surface runoff serves as the foundational data for all physical infrastructure and superstructure projects that need to be constructed inside a settlement, particularly to produce energy, industrial processes, agricultural irrigation, and drinking water supplies.

Physical elements such the location, terrain, soil composition, and vegetation have an impact on surface runoff, which is the quantity of precipitation that remains after evaporation, retention, and infiltration. Greater surface area results in increased surface runoff. Lower values are calculated in tiny regions since there is less space to runoff. Surface runoff increases when precipitation falls on rough terrain because it enters the stream before it has a chance to infiltrate. Precipitation can stay on the surface and leak out without flowing in a mostly flat topography. Dense vegetation traps precipitation, which reduces surface runoff in the affected area. When there is no vegetation, precipitation instantly penetrates the surface.

Table 1 shows the surface runoff amounts per capita for the European side of Istanbul, Table 2 shows Tekirdağ, Table 3 shows Edirne, and Table 4 shows Kırklareli. These figures are produced on a district basis for the provinces in the Thrace Region. Table 5 gives it for the European side of Çanakkale.

When considered more broadly, the average yearly surface runoff amount for the provinces in the Thrace Region was calculated using the total amount of rainfall for about one century between 1929 and 2023, and came out to be 116,9 (±10.4) mm. The total value represents 19.2% of the precipitation that fell.

According to data from the General Directorate of State Hydraulic Works (DSI), this value is found to be 27.8% in the Marmara basin and 22.6% in the Meriç-Ergene basin. The same source states that Turkey has an annual surface runoff quantity of 30.0% (Karşılı, 2011). The fact that the Thrace Region's average surface runoff value is lower than Turkey's average is highly noteworthy. The primary causes of the lower surface runoff than in Turkey overall are the limited, gently sloping river rainfall zones in the region, the clayey, deep soil structure, and the year-round vegetation that covers the soil.

Table 1. Surface runoff amounts per capita for the districts of İstanbul province

Districts	Surface runoff (mm)	Surface area (1.000 m^2)	Potential surface runoff (m^3)	Population (The year 2022)	Surface runoff amounts per capita (m^3/year)
Arnavutköy	127,4	478.518	60.963.193,2	362.452	168
Avcılar	124,3	52.174	6.485.228,2	452.132	14
Bağcılar	124,0	22.496	2.789.504,0	740.069	4
Bahçelievler	120,9	16.537	1.999.323,3	594.350	3
Bakırköy	119,2	29.409	3.505.552,8	226.685	15
Başakşehir	126,3	105.969	13.383.884,7	514.900	26
Bayrampaşa	122,4	9.663	1.182.751,2	275.314	4
Beşiktaş	119,4	17.992	2.148.244,8	175.190	12
Beylikdüzü	127,8	37.729	4.821.766,2	412.835	12
Beyoğlu	122,4	8.969	1.097.805,6	225.920	5
Büyükçekmece	125,1	161.067	20.149.481,7	277.181	73
Çatalca	130,4	1.136.737	148.230.504,8	77.468	1.913
Esenler	123,9	18.306	2.268.113,4	445.421	5
Esenyurt	123,9	42.920	5.317.788,0	983.571	5
Eyüpsultan	123,1	230.449	28.368.271,9	422.913	67
Fatih	121,8	16.507	2.010.552,6	368.227	5
Gaziosmanpaşa	125,5	11.635	1.460.192,5	495.998	3
Güngören	120,9	7.305	883.174,5	282.692	3
Kâğıthane	118,6	15.601	1.850.278,6	455.943	4
Küçükçekmece	122,4	44.832	5.487.436,8	808.957	7
Sarıyer	148,3	174.241	25.839.940,3	350.454	74
Silivri	119,4	870.009	103.879.074,6	217.163	478
Sultangazi	122,5	37.227	4.560.307,5	542.531	8
Şişli	125,5	10.904	1.368.452,0	276.528	5
Zeytinburnu	117,9	11.362	1.339.579,8	292.616	5
General	124,1	3.568.558	451.390.403,0	10.277.510	44

Table 2. Surface runoff amounts per capita for the districts of Tekirdağ province

Districts	Surface runoff (mm)	Surface area (1.000 m^2)	Potential surface runoff (m^3)	Population (The year 2022)	Surface runoff amounts per capita (m^3/year)

Çerkezköy	121,3	117.749	14.282.953,7	206.829	69
Çorlu	119,5	410.133	49.010.893,5	290.155	169
Ergene	119,2	416.693	49.669.805,6	67.038	741
Hayrabolu	117,1	1.005.960	117.797.916,0	30.521	3.860
Kapaklı	121,9	194.466	23.705.405,4	137.514	172
Malkara	119,3	1.190.241	141.995.751,3	50.988	2.785
M.Ereğlisi	103,4	193.850	20.044.090,0	29.549	678
Muratlı	115,8	395.481	45.796.699,8	30.067	1.523
Saray	123,7	939.232	116.182.998,4	50.766	2.289
Süleymanpaşa	102,8	1.074.152	110.422.825,6	215.558	512
Şarköy	98,6	517.083	50.984.383,8	33.466	1.523
General	114,8	6.455.040	739.893.723,1	1.142.451	648

Table 3. Surface runoff amounts per capita for the districts of Edirne province

Districts	Surface runoff (mm)	Surface area (1.000 m^2)	Potential surface runoff (m^3)	Population (The year 2022)	Surface runoff amounts per capita (m^3/year)
Enez	97,6	445.899	43.519.742,4	10.488	4.149
Havsa	110,4	602.175	66.480.120,0	17.969	3.700
İpsala	101,5	743.889	75.504.733,5	26.148	2.888
Keşan	109,5	1.123.702	123.045.369,0	83.874	1.467
Lalapaşa	117,6	539.839	63.485.066,4	6.225	10.198
Meriç	105,6	390.301	41.215.785,6	12.841	3.210
Merkez	113,8	812.072	92.413.793,6	191.470	483
Süloğlu	125,2	330.174	41.337.784,8	6.348	6.512
Uzunköprü	105,4	1.213.989	127.954.440,6	59.351	2.156
General	109,6	6.202.040	674.956.835,9	414.714	1.628

Table 4. Surface runoff amounts per capita for the districts of Kırklareli province

Districts	Surface runoff (mm)	Surface area (1.000 m^2)	Potential surface runoff (m^3)	Population (The year 2022)	Surface runoff amounts per capita (m^3/year)
Babaeski	105,4	666.543	70.253.632,2	46.357	1.515
Demirköy	112,6	866.897	97.612.602,2	8.961	10.893
Kofçaz	130,4	547.925	71.449.420,0	2.125	33.623
Lüleburgaz	94,0	1.040.779	97.833.226,0	153.903	636
Merkez	111,6	1.545.544	172.482.710,4	108.550	1.589
Pehlivanköy	93,0	93.742	8.718.006,0	3.380	2.579
Pınarhisar	107,3	557.606	59.831.123,8	17.402	3.438
Vize	110,6	1.079.583	119.401.879,8	28.669	4.165
General	108,1	6.398.619	691.770.696,6	369.347	1.873

Table 5. Surface runoff amounts per capita for the districts of Çanakkale province

Districts	Surface Runoff (mm)	Surface area (1.000 m^2)	Potential surface runoff (m^3)	Population (The year 2022)	Surface runoff amounts per capita (m^3/year)
Ecebat	103,2	432.013	44.583.741,6	8.684	5.134
Gelibolu	107,3	803.194	86.182.716,2	43.984	1.959
General	105,3	1.235.207	130.766.457,8	52.668	3.547

The Thrace Region, particularly Istanbul, is severely short of water. Tekirdağ, Edirne, Kırklareli, and Çanakkale come after Istanbul, in that order. The population density of Istanbul's European side is 2,880 persons per km2. In general, 110 persons per km2 are found in Turkey. Once more, if a settlement's daily drinking water use is estimated to be 200 liters per person, the total annual water requirement is 73 m3. Except for Istanbul's Çatalca and largely Silivri districts, there is an extreme lack of water. The Tekirdağ neighborhood of Çerkezköy presents a same circumstance.

The neighborhood in Istanbul with the most inhabitants per square kilometer is Gaziosmanpaşa. With a population density of over 40,000 persons per km2, this district is followed by those with over 30,000 in Bahçelievler, Güngören, Bağcılar, Kağıthane, and Bayrampaşa districts. In these districts, the annual surface runoff resulting from precipitation is around 3–4 m3/person. This is not enough to give those districts enough monthly drinking water. The surface runoff per capita in the over 20,000-person districts of Zeytinburnu, Şişli, Beyoğlu, Esenler, Esenyurt, Fatih, and Küçükçekmece is approximately 5-7 m3/year, however, not significantly different. The remaining districts face similar circumstances. Nonetheless, there is enough surface runoff because the Silivri and Çatalca districts have greater surface areas and fewer inhabitants. It is possible to supply nearby regions with water by building water storage buildings there. The market uses a lot of bottled water, and the municipal network is bolstered by water moved from Anatolia, to lessen the effects of unsustainable water scarcity on Istanbul's European side.

After Istanbul, Tekirdağ is another province in Europe experiencing water scarcity. The province boasts a thriving industrial sector in addition to its agricultural economy. Significant water scarcity exists in the districts of Çorlu and Kapaklı, particularly in Çerkezköy. The source of pollution in all the region's rivers, big and small, is the wastewater from the industrial enterprises located in these districts. The districts of Hayrabolu, Malkara, and Saray are in the Thrace Region; these areas are known for their heavy animal farming and agriculture, as well as their partial water scarcity. Water scarcity is partially experienced in several districts, including the major district of Süleymanpaşa and the tourist district of Marmara Ereğlisi, which has many summer residences. All these districts heavily rely on groundwater due to the absence of large rivers in the area. Overuse of groundwater is one of the major issues facing the area.

Other than the Lüleburgaz district of Kırklareli and the Central district of Edirne, there isn't a noticeable water deficit in any other district. Important water resources are the streams that run into the Black Sea at Kırklareli and the Meriç River in Edirne. The Meriç River is a vital supply of water for the area. It gathers water from a region twice the size of Thrace, or from Greece and Bulgaria, and flows into the Aegean Sea to form the border between Greece and Turkey. Even though the river basin is transboundary and has global issues, the Republic of Turkey currently produces more than half of its paddy in an area of about 500 km2 that is irrigated by the river's waters. Despite the pollution in the river, issues with flooding, and challenges with irrigation techniques, the river is a vital source of water for the socioeconomic advancement of the area.

Situated on the Gelibolu peninsula in the Thrace Region, the districts of Ecebat and Gelibolu in Çanakkale province have a high concentration of agricultural activity but a low population density. It is noted that population mobility and water supply issues will arise after the building of the Çanakkale bridge in the area where water scarcity is not an issue. The total surface runoff volume in the Thrace Region varies from year to year, although it generally ranges between 2.54 and 3.04 km3, according to multi-year total precipitation statistics.

4. Conclusion

The Thrace Region, particularly Istanbul, is severely short of water. Tekirdağ, Edirne, Kırklareli, and Çanakkale come after Istanbul, in that order. The neighborhood in Istanbul with the most inhabitants per square kilometer is Gaziosmanpaşa. Following this district with more than forty thousand residents are the districts of Bahçelievler, Güngören, Bağcılar, Kağıthane, and Bayrampaşa, each with more than thirty thousand residents. In these districts, the annual surface runoff resulting from precipitation is around 3-4 m3/person. This is not even enough to give those districts enough drinking water for a month. The remaining districts face comparable circumstances, albeit not significantly different. Nonetheless, the surface runoff volume was determined to be sufficient because the Silivri and Çatalca districts have bigger surface areas and fewer inhabitants. It is possible to supply nearby regions with water by building water storage buildings there. The extensive use of bottled water in the market and the municipal network that is fueled by water transported from Anatolia, however, avoid unsustainable water scarcity for Istanbul's European side.

Tekirdağ is the second European province suffering from water scarcity, after Istanbul. The province's Çerkezköy, Çorlu, and Kapaklı districts - which have a sizable industrial sector in addition to agriculture - have a serious water scarcity. The source of pollution in all the region's rivers, big and small, is the wastewater from the industrial enterprises located in these districts. All these districts heavily rely on groundwater due to the absence of large rivers in the area. Overuse of groundwater is one of the major issues facing the area.

Other than the Lüleburgaz district of Kırklareli and the Central district of Edirne, there isn't a noticeable water deficit in any other district. Situated on the Gelibolu peninsula, the districts of Çanakkale province - Ecebat and Gelibolu - have a high concentration of agricultural activity but a low population density. It is noted that population mobility and water supply issues will arise after the building of the Çanakkale bridge in the area where water scarcity is not an issue.

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