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Research Article

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Groundwater Recharge in Türkiye-Thrace Region: Tekirdag Analysis

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Abstract: In order to cultivate engineering high-quality talents with innovative ability and practical ability, this study explores a new approach to the teaching mode of engineering undergraduates in combination with theoretical practice, aiming to improve students' learning effect and comprehensive ability. Firstly, the problems of the traditional teaching mode are analyzed, based on which the framework of project-oriented learning teaching mode is constructed. The implementation effect of the method in enhancing students' innovation ability, problem-solving ability and teamwork spirit is further explored, and the effect of the teaching mode is evaluated. The teaching mode is of great significance for cultivating high-quality talents and improving the comprehensive ability of engineering undergraduates.

Keywords: Thrace Region, Tekirdag, Curve number, Precipitation, Groundwater

1. Introduction

Water that leaks from the earth's surface into the underground and fills the porous layers or rocks there is called groundwater. It has an important place and importance in the hydrological cycle. Because 97.4% of the water in the world is salty and the remaining 2.6% is fresh water. 2.0% of fresh water is in the poles and 0.6% is underground [1].

Groundwater, which has the most strategic importance among water resources, is used less than surface water due to the difficulties in extracting it from the surface and delivering it to the place where it will be used. However, in recent years, with the increase in technological developments used in its extraction, it has reached half the amount of water used. Although it is, in a sense, the safest resource to be used during war or any natural disaster and in dry years, its increasingly excessive use threatens the future of nature and humanity [2].

More than half of the groundwater is used for agricultural irrigation and a significant amount is used for domestic and industry. Groundwater is a resource that is generally used without requiring treatment, as it is put into operation in a short time.

Groundwater is meteoric water fed by precipitation and located within the hydrological cycle. The quality of meteoric waters varies depending on the minerals it can dissolve as it flows through geological layers. When there is not enough rainfall, the decrease in nutrition and excessive extraction negatively affects the amount of groundwater. The formation of sinkholes in some areas is a result of this. Pollution caused using fertilizers and pesticides in agricultural activities and domestic and industrial wastes are important problems that threaten groundwater [1].

Located in an important geographical location in Turkey, the Thrace Region has approximately 3% of Turkey's land assets and hosts 15% of the population. Its current agricultural and industrial potential and its ever-increasing population put great pressure on water resources. In the region where irrigated agriculture is not

common in the agricultural sector, which requires a great deal of water, domestic and industrial water needs exceed all resources of the region.

In this study, it was aimed to determine the distribution of evaporation, retention, surface flow and groundwater recharge of precipitation in Tekirdağ, one of the important provinces of the region. The amount of groundwater recharge to be determined will provide important data for the planning and management of future investment projects of the provincial administrator and relevant organizations.

2. Material And Methods

Tekirdag is in the Thrace Region, between 40º59' north latitude and 27º31' east longitude. Its surface area is 6,455 km^2. It is under the influence of Black Sea-Mediterranean climates along the Marmara Sea coastline and partially continental climates in the inner parts. Winters are cool and rainy; summers are hot and dry. Almost all the precipitation is in the form of rain, and according to multi-year averages, the number of days with snowfall is 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 occurs in the last week of March

Annual total precipitation data (1950-2022) used in the study were taken from the State Meteorological Affairs (DMİ) Tekirdag - Süleymanpaşa Branch Directorate observation station and are given in Table 1 [3].

The provincial geography has a slightly undulated topographic structure. In general, soils of medium depth and clay-loam texture, without significant erosion and drainage problems, contain low organic matter. The geological structure of the province is quite young. While the provincial area was covered with seas in the I. period, its current appearance is in the IV. received in time. The groundwater basin consists of an upper layer of fine sand, silt and lacustrine limestone, and a lower layer of clay and interlayered gravel, sand and weakly cemented sandstone. Hydrologically, it consists of a single aquifer due to the interrelationships of the upper and lower aquifers. The average thickness of the aquifer, which is generally fed by infiltration from rainfall, is around 600 meters [4].

Table 1. Total annual precipitation amounts of Tekirdağ-Süleymanpaşa Meteorology observation station

Year	Precipitation (mm)	Year	Precipitation (mm)	Year	Precipitation (mm)	Year	Precipitation (mm)
1950	491,6	1969	578,6	1988	625,8	2007	546,5
1951	576,5	1970	578,7	1989	431,7	2008	304,2
1952	604,9	1971	561,9	1990	511,0	2009	816,2
1953	550,0	1972	477,1	1991	504,1	2010	803,9
1954	663,5	1973	410,3	1992	427,0	2011	729,6
1955	705,2	1974	480,0	1993	469,4	2012	670,8
1956	708,8	1975	711,9	1994	578,4	2013	471,7
1957	481,9	1976	569,7	1995	848,1	2014	850,8
1958	663,3	1977	521,1	1996	522,3	2015	515,8
1959	616,1	1978	696,8	1997	796,1	2016	439,4
1960	546,2	1979	534,6	1998	896,3	2017	652,5
1961	405,2	1980	532,7	1999	614,7	2018	675,3
1962	744,0	1981	754,9	2000	410,1	2019	336,4
1963	630,6	1982	478,1	2001	703,9	2020	420,9
1964	525,9	1983	438,8	2002	554,6	2021	614,5
1965	778,9	1984	516,6	2003	572,4	2022	374,5
1966	666,0	1985	483,9	2004	578,8	Avrerage	579,7
1967	511,3	1986	554,6	2005	522,3		
1968	722,3	1987	564,1	2006	491,5		

Provincial land use and vegetation pattern were determined using agricultural reports published by the Tekirdag Provincial Directorate of the Ministry of Agriculture and Forestry and are given in Table 2 [5].

Table 2. Land use, vegetation pattern and surface area values of the districts of Tekirdağ

Districts	Small grains	Order plants	Bait plants	Meadow-pasture	Forest-Shrubbery	Residential locations	Area (da)
Çerkezköy	44,9	18,7	1,0	5,1	10,2	20,1	117.749
Çorlu	37,3	29,2	1,0	3,7	7,3	21,5	410.133
Ergene	39,1	30,0	1,2	4,6	7,9	17,2	416.693
Hayrabolu	41,4	33,0	3,4	9,7	2,2	10,3	1.005.960
Kapaklı	48,7	20,6	0,9	4,6	8,7	16,5	194.466
Malkara	30,9	27,6	3,2	6,7	18,8	12,8	1.190.241
M.Ereğlisi	44,2	24,7	1,2	2,0	8,3	19,6	193.850
Muratlı	42,5	37,0	3,1	4,7	1,0	11,7	395.481
Saray	32,1	21,8	0,9	3,4	28,6	13,2	939.232
Süleymanpaşa	35,6	28,0	1,5	4,2	15,4	15,3	1.074.152
Şarköy	16,4	6,6	0,7	0,8	48,6	26,9	517.083
Average	37,6	25,2	1,6	4,5	14,3	16,8	6.455.040

Some of the precipitation that falls on the earth in the form of rain, snow and other forms is retained on the surface, evaporates or returns to the atmosphere through transpiration by plants. Some of it infiltrates the soil and feeds the soil water and the groundwater in the saturated environment it reaches by percolating deep. Some of it passes directly to surface flow.

The most difficult part of the circulation of water in nature, referred to as the hydrological cycle, is the estimation of groundwater recharge. The fact that the nutrition, which mostly occurs by filtering from the precipitation falling on the area where it surfaces, depends on many factors and is slow, creates a difficulty. This feature also limits the number of methods that can be chosen to calculate the amount of nutrition [6].

Surface Flow Curve Number (CN) developed by the US Soil Conservation Service (SCS) and Basin Water Yield Equation methods developed by M.Turc are widely used to analyze the rainfall-flow relationship. These two methods were used together in this study [7, 8].

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

$$h = P - E.$$

h is the amount or height of surface runoff from the basin, mm; P is the annual total amount of precipitation falling on the basin, mm, and E is the total annual real evapotranspiration amount of the basin, mm.

The determination of the actual evapotranspiration amount is calculated with the equation following the parameter [9].

$$L = A + 25\ t + 0.05\ t3$$

$$E = \frac{P}{\sqrt{0,9 + \left(\frac{P}{L}\right)^2}}).$$

L is the parameter, and t is the annual average temperature of the basin, 0C. The temperature value is the corrected value for each district, considering its latitude and altitude. Again, for the A coefficient in determining the L parameter, the value of the main river basin in which each district is included was used.

Surface Flow Curve Number (SCS-CN) method is based on the principle of continuity as the retention of water in the soil at the beginning of precipitation (P), the amount of water that percolates deep into the soil and feeds the groundwater after the surface flow begins (Fa), and the amount of water passing into the surface flow (Q). Accordingly, it is expressed as P = Ia + Fa + Q. Ia is all the losses before the start of surface flow. It is the amount of water retained in plant branches and leaves, stored in ponds and evaporated directly from the soil surface. According to the data obtained from the studies, Ia = 0.2 * S is recommended. Here, the maximum potential retention (S) value is $S = \frac{25.400 - 254 * CN}{CN}$ and depends on the basin soil type (hydrological soil group), land use, cultural process, soil protection (terracing, etc.) and soil moisture conditions. It depends on the curve

number (CN) value, which varies between 0-100 [10].CN determined for different humidity conditions was evaluated for average conditions in the study. 75 for wheat, 81 for oil crops, and 72 for forage crops, which is widely cultivated in medium-deep, well-drained, moderate water transmission rate and slope-oriented conditions. Values of 79 were taken for medium cover natural pasture, 73 for forest-heathland and 87 for other areas [11].

The amount of precipitation that infiltrates the soil and feeds the soil water and the ground water in a saturated environment where it filters into the depths $Fa = \frac{S * (E - I_a)}{(E - I_a) * S}$ The E value here is the actual evapotranspiration amount obtained from the M.Turc method. The amount of evaporation is obtained by subtracting the amount of actual evapotranspiration (E) from the sum of the amount of water that percolates deep into the soil and feeds the groundwater (Fa) at the beginning of the precipitation (Ia) and after the surface flow begins, and the amount that passes to the surface flow (h) [12].

3. Results And Discussions

Determination of soil type, land use and cover has become extremely important in calculating the surface flow curve number in the area where Tekirdağ province surfaces, including snowfall and melting, in conditions where there is no nourishment other than precipitation. Although the surface flow curve number varies between 77.4 and 79.3 according to districts, the average is calculated as 78.4.

In addition, separate data entries were made for each district and actual evapotranspiration calculations were made. It was determined between 456.0 and 481.1 mm depending on the districts. The data used here, and the values obtained are given in Table 3.

Table 3. Data used and actual evapotranspiration values obtained for each district

Districts	Latitude (Degree)	Altitude (m)	Basin Coefficient	Temperature (ºC)	L Parameter	Evapotraspiration (mm)	Precipitation (mm)
Şarköy	40,61	10	303,7	14,44	815,25	481,1	
Süleymanpaşa	40,96	4	”	14,10	796,36	476,9	579,7
M.Ereğlisi	40,97	10	”	14,05	793,63	476,3	
Muratlı	41,18	95	285,9	13,43	742,51	463,9	
Hayrabolu	41,22	108	”	13,33	737,58	462,6	
Ergene	41,18	145	”	13,18	729,63	460,5	
Malkara	40,89	207	”	13,17	729,12	460,4	
Çorlu	41,14	160	”	13,15	728,35	460,2	
Çerkezköy	41,26	160	”	13,02	721,76	458,4	
Kapaklı	41,32	160	”	12,97	719,24	457,8	
Saray	41,45	160	”	12,84	712,74	456,0	

According to calculations made for the 73-year period between 1950 and 2022 with the help of a simple computer program, the annual average surface flow amount was obtained as 114.8 mm. This amount corresponds to 18.3% of the total rainfall. The least amount of surface flow was in Şarköy, as nearly half of the district's surface area is forest-heathland.

The annual average retention amount throughout the province was 14.0 mm and the evaporation amount was 390.4 mm, corresponding to 2.5% and 68.3% of the total precipitation, respectively. While the highest evaporation was in the districts along the coastline, it was observed to be slightly lower in the inland areas. State Hydraulic Works states that the evaporation amount of the annual water potential throughout Turkey is 55% [14].Again, in a study conducted in Ankara Beypazarı, it was stated that 60% of the total annual precipitation of 331 mm was lost by evaporation [14].Although it varies on a district basis, the average groundwater recharge on a provincial scale is calculated as 60.5 (± 1.63) mm. In other words, 10.9% of the annual precipitation in the

area where the province is exposed feeds the groundwater. For comparison, it is calculated by the State Hydraulic Works that 13.0% of the annual water potential in Turkey feeds groundwater [13].In a study conducted in Ankara Beypazarı, this rate is approximately 10% of the average rainfall in the basin [14].

On a district basis, it is seen that the highest nutrition is 11.4% in Saray district and the lowest nutrition is 10.4% in Çorlu district. In addition, within the 73-year period between 1950 and 2022, although it varied from year to year, the most nutrition occurred in 2008, when 896.3 mm of precipitation fell. This year, 19.2% of the rainfall in Saray district fed the groundwater. At least in Çorlu in 1998, 6.6% of the 304.2 mm rainfall fed the groundwater. The distribution of precipitation in the districts of Tekirdağ within the hydrological cycle is given in Table 4.

As obtained from multi-year total precipitation data, the total groundwater recharge amount across the province varies between 380 and 400 million m3, although it varies from year to year. Additionally, a regression equation that will help in calculating the annual total groundwater recharge amount from the annual total precipitation amount is given in Figure 1.

Table 4. Distribution of precipitation in the districts of Tekirdağ within the hydrological cycle

Districts	Surface Runoff Curve Number	Surface Runoff		Retention		Recharge		Evaporation	
		mm	%	mm	%	mm	%	mm	%
Şarköy	77,7	98,6	15,6	14,6	2,6	62,9	11,3	403,6	70,4
Süleymanpaşa	78,3	102,8	16,3	14,1	2,6	61,0	11,0	401,8	70,2
M.Ereğlisi	78,7	103,4	16,4	13,8	2,5	59,7	10,8	402,7	70,3
Muratlı	78,7	115,8	18,4	13,8	2,5	59,5	10,7	390,5	68,3
Hayrabolu	78,5	117,1	18,7	13,9	2,5	60,1	10,8	388,6	68,0
Ergene	78,9	119,2	19,0	13,6	2,5	58,8	10,6	388,1	67,9
Malkara	78,0	119,3	19,0	14,3	2,6	61,6	11,1	384,5	67,3
Çorlu	79,3	119,5	19,1	13,3	2,4	57,6	10,4	389,3	68,1
Çerkezköy	78,5	121,3	19,4	13,9	2,5	60,0	10,8	384,5	67,3
Kapaklı	78,2	121,9	19,5	14,2	2,6	60,9	11,0	382,6	67,0
Saray	77,4	123,7	19,8	14,8	2,7	63,4	11,4	377,8	66,1
Ortalama	78,4	114,8	18,3	14,0	2,5	60,5	10,9	390,4	68,3

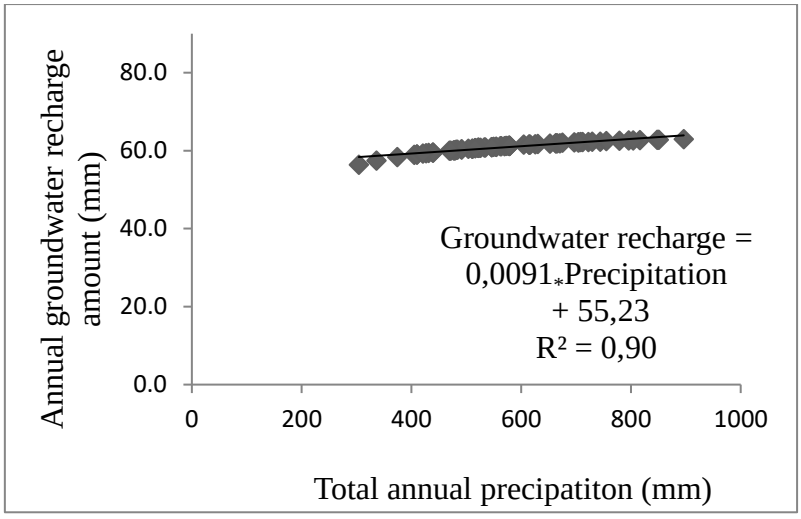

Figure 1. *Relationship between total annual precipitation and total annual groundwater recharge*

4. Conclusion

M. Turc and SCS-CN methods were used together to examine the basin water yield and rainfall-flow relationship formed by the rainfall in the surface area of Tekirdag province. In these methods, snowfall and

melting are not considered and are treated as rain. Additionally, it is assumed that no surface flow enters the surfaced area.

Determining CN values is extremely important in obtaining a reliable result from the combination of methods. Because land use, cover status, cultural processes, hydrological conditions and soil groups are the determining criteria.

As a result of the analyses made using multi-year total precipitation values, the average groundwater recharge at the provincial scale was calculated as 60.5 (± 1.63) mm, although it varies on a district basis. In other words, 10.9% of the annual precipitation in the area where the province is exposed feeds the groundwater.

The annual average surface flow amount was 114.8 mm. This amount corresponds to 18.3% of the total rainfall. The annual average retention amount was 14.0 mm, and the evaporation amount was 390.4 mm, corresponding to 2.5% and 68.3% of the total precipitation, respectively.

On a district basis, it is seen that the highest nutrition is 11.4% in Saray district and the lowest nutrition is 10.4% in Çorlu district. Again, although it varies from year to year, the most nutrition was in 2008, with 896,3 mm of precipitation, and the least was in 1998, with 304,2 mm of precipitation. The total amount of groundwater recharge throughout the province varies between 380 and 400 million m^3.

In addition to all these data, the ease of obtaining it and the low purification cost make it preferred in use. However, excessive water withdrawals, uncontrolled use of pesticides and fertilizers, and problems caused by urbanization pose a great danger for groundwater pollution. In this sense, there is a need for planning in the use of groundwater throughout the province and region.

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