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Review Article

The Situation of Water Resources and Agricultural Irrigation in Türkiye

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ABSTRACT
Türkiye's land area is about 78.5 million ha. The population is 84 million, with an annual growth rate of 1.09% in 2020. Türkiye is divided into 25 basins that correspond with its hydrological features. The average yearly flow in the basins is 186 billion cubic meters (BCM). The Euphrates-Tigris River Basin has a water potential of 28.4% and is the largest watershed in Türkiye in terms of water potential and surface area. Türkiye's total usable water potential is 112 BCM, of which 98 BCM is surface water and 14 BCM is groundwater. Approximately 20-25% of Türkiye's irrigable area is irrigated with groundwater. This study discussed the state of Türkiye's water resources and agricultural irrigation.
Keywords: Türkiye, water resources, agricultural irrigation

Türkiye'de Su Kaynakları ve Tarımsal Sulama

ÖZ
Türkiye'nin yüzölçümü yaklaşık 78.5 milyon ha, nüfusu 84 milyon ve yıllık nüfus artış hızı 2020 itibari ile %1.09 olmuştur. Türkiye, hidrolojik özelliklerine uygun 25 havzaya bölünmüştür. Havzalarda yıllık ortalama akış 186 milyar m^3'tür. Fırat-Dicle Nehri Havzası %28.4'lük su potansiyeline sahip olup, Türkiye'nin su potansiyeli ve yüzölçümü bakımından en büyük su havzasıdır. Türkiye'nin toplam kullanılabilir su potansiyelinin, 98 milyar m3'ü yüzey suyu ve 14 milyar m^3'ü yeraltı suyu olmak üzere toplam 112 milyar m^3'tür. Türkiye'nin sulanabilir alanının yaklaşık %20-25'i yeraltı suyu ile sulanmaktadır. Bu çalışmada, Türkiye'deki su kaynaklarının ve tarımsal sulamanın durumu ele alınmıştır.
Anahtar kelimeler: Türkiye, su kaynakları, tarımsal sulama

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Introduction

The situation and management of water in Türkiye is a sensitive and vital issue. According to the climate scenarios adopted by the United Nations Framework Convention on Climate Change (UNFCCC), the temperatures in the region, including Türkiye, will increase significantly, the effects of drought will become evident, the current precipitation will be irregular, and therefore it will be problems in the storage of water. (Muluk et al., 2013).

Although Türkiye is surrounded by water on three sides, it is not a rich country in terms of freshwater. On the contrary, Türkiye is on the way to becoming a "water-poor." There are 25 catchment basins in Türkiye. The average annual precipitation in Türkiye is 643 mm, equal to 501 km^3 of water in volume (Table 1). 37% of the precipitation passes into the flow in Türkiye. In this case, It is accepted that 274 km^3 of the precipitation evaporates from the soil-plant-water surface system and returns to the atmosphere; 41 km^3 feeds the underground water storage, and 186.05 km^3 flows to the sea, lake, and closed basins via rivers (Atçı, 2020).

95 km^3 of this potential can be developed economically (Tekinel, 1999). With the studies carried out on the basin basis, it has been determined that the groundwater potential that can be safely withdrawn is around 12.3 km^3 (Kaya, 1994; DSİ, 1999; Hakyemez, 2019; Atçı, 2020). In this case, Türkiye's total annual usable underground and surface water potential is 107.3 km^3. This value is equivalent to 45.85% of the renewable water potential. Only 37.74% of the usable potential has been developed and put into use.

Table 1. Türkiye's water resources (Atçı, 2020)

Surface water potential, km^3		**Groundwater potential, km^3**	
Annual flow	186.05	Withdrawable annual water potential	12.3
The ratio of annual flow to total precipitation	0.37	Developed water potential	9.0
Usable surface water potential	95.00	Actual annual consumption	6.0
Actual annual consumption	31.49		
Average annual precipitation: 643 mm (501 km^3)			

According to the Falkenmark index (indicator), values above 1700 indicate water richness, values between 1000-1700 indicate water stress, values between 500-1000 indicate water scarcity, and values less than 500 indicate absolute water scarcity (Falkenmark and Rockstorm 1993). Accordingly, water resources and their conditions are given in Table 2.

There is a disproportionate distribution of the amount of water and the population throughout the world. This situation is also valid in Türkiye. There are disproportions between the flow potential of the basins and the number of people benefiting from these basins. In the Marmara Region, where 28% of the total population of Türkiye lives, the basins collect only 4% of the total flow. The use of surface and groundwater in Meriç, Ergene, Gediz, Büyük Menderes, Burdur Lake, Akarçay, Konya, and Asi River basins has exceeded the self-renewal capacity of water resources. This situation increased the pressure on the basins and significantly threatened the natural ecosystem (Öktem and Aksoy, 2014; Atçı, 2020).

Approximately 75 percent of the water resources in Türkiye are used in agriculture (Atçı, 2020). According to scientists, besides providing additional water resources to the basins where agricultural activities are common, it is imperative to take radical measures to plant various crops. Especially; in drought-prone areas, crops such as wheat and barley should be preferred instead of crops that consume a lot of water, such as maize (FAO, 2015).

Table 2. Falkenmayer Indicators (Atçı, 2020)

Basin Name	Population (2015)	Usable Water Potential (billion m³/year)	Falkenmark Indicator (m³/person/year)	Agriculture
Meric Ergene	749 510	0.76	1014	Water Stress
Marmara	17 608 408	2.84	161.06	Absolute Water Scarcity
Susurluk	3 793 746	2.57	677.43	Water Scarcity
North Aegean	1 112 098	0.88	791.30	Water Scarcity
Gediz	1 588 561	0.79	497.31	Absolute Water Scarcity
Küçük Menderes	4 168 415	0.46	109.15	Absolute Water Scarcity
Büyük Menderes	1 346 490	1.70	1262.54	Water Stress
West Mediterranean	908 877	3.87	4258	Water Richness
Antalya	3 341 962	7.03	2103.55	Water Richness
Burdur Lake	680 105	0.17	244.08	Absolute Water Scarcity
Akarçay	709 015	0.31	437.23	Absolute Water Scarcity
Sakarya	7 262 833	4.03	554.88	Water Scarcity
West Black Sea	1 879 209	5.09	2705.93	Water Richness
Yeşilırmak	2 721 221	3.10	1139.19	Water Stress
Kızılırmak	3 715 291	3.95	1063.17	Water Stress
Konya Closed	3 105 368	4.90	1577.91	Water Stress
East Mediterranean	1 745 221	4.80	2747.50	Water Richness
Seyhan	2 183 167	3.55	1626.08	Water Stress
Asi	1 533 507	1.18	769.48	Water Scarcity
Ceyhan	1 609 483	3.81	2367.22	Water Richness
Tigris-Euphrates	12 646 409	37.48	2963.81	Water Richness
East Black Sea	2 404 480	9.36	3892.73	Water Richness
Çoruh	246 920	4.46	18064.15	Water Richness
Aras	584 360	3.28	5609.62	Water Richness
Van Lake	1 096 397	1.65	1504.93	Water Stress
Türkiye (2015)	**78 741 053**	**112**	**1422.23**	**Water Stress**

The Tigris-Euphrates Basin, located between Türkiye and the water-poor Middle East countries and has many important water treatment projects, is Türkiye 's most significant water potential, consisting of many large rivers. Burdur and Akarçay Closed Basins, on the other hand, have the lowest water potential compared to the other 23 basins. It is known that some river basins are "water-rich", and some are "water-poor" (Atçı, 2020).

Susurluk, North Aegean, Sakarya, and Asi are among the basins with Falkenmark Indicator values of 500-1,000 m^3/person/year and famine problems. With the increase in population in these basins, the issue of definite famine is expected. It is seen that 7 of 25 basins are under water shortage. Among these seven basins, there are two big river basins as Kızılırmak and Yeşilırmak basins. Some basins among these basins may reach the "Water Scarcity" level soon due to population growth, like other basins (Hakyemez, 2019; Atçı, 2020). As shown in Table 3, there has been an increase of approximately 50% in water use between 2004 and 2016. If population growth and economic-industry growth continue, it is expected that the pressure on Türkiye's water resources will increase in the future (Hakyemez, 2019; Atçı, 2020).

Table 3. Use of Water Resources in Türkiye

Year	Irrigation (billion m³)	Household (billion m³)	Industry (billion m³)	Total (billion m³)
1990	22.0	5.1	3.4	30.5
2004	29.6	6.2	4.3	40.1
2008	33.8	5.8	6.0	45.6
2010	38.2	5.8	6.0	49.9
2012	41.6	6.0	8.4	56.0
2014	35.9	5.7	9.1	50.7
2016	43.1	6.2	11.1	60.4
2023	72.0	18.0		

Sectoral Use of Water and Per Capita Water Potential in Türkiye

In Türkiye, 74% of the total utilizable water is used for agriculture, 15% for domestic use, and 11% for industry (Muluk et al., 2013). In our country, the surface water potential per capita is about 3300 m³/year, and the amount of usable water per person is around 1550 m³/year. According to the Turkish Statistical Institute (TUIK), if the population of our country reaches 100 million by 2030, the amount of usable water per capita will decrease to 1000 m³ (Atabay et al., 2014; Atçı, 2020). It is stated that the water demand in Türkiye in 2025 is estimated to be 183% of the current consumption. Under these conditions, severe water shortages may be seen in some regions of Türkiye, such as Thrace, Central Anatolia, and Western Anatolia. By 2030, it is predicted that Türkiye will be water scarcity at a rate exceeding 40% in the inner and western regions. This rate is expected to vary between 20 and 40% in Southeast and East Anatolian regions (Muluk et al., 2013).

When Will Water Run Out?

According to scientists' analysis, it is inevitable that we will face 'drought' bulletins such as weather bulletins soon. We need to change our water consumption culture, especially in agriculture. Türkiye ranks 4th in the world in water consumption per capita (Anonymous, 2022). Some mistakes have been made in this regard. In 2021, the Ministry of Agriculture and Forestry pioneered the first Water Council in Türkiye's history regarding detecting errors and taking measures. The Council started on March 29, 2021, and ended on August 25, 2021. In the study, which lasted for about five months, in which 141 scientists and 1631 experts participated, many issues, from efficient water use to basin management, were discussed. The date for the drought at the meeting was given, and the measures that should be taken were discussed and linked to the report. (Anonymous, 2022). As the report mentioned above, the global climate crisis has exposed many countries, including Türkiye, to the threat of 'drought.' Although the measures listed in the said report are tried to be taken, the problem is more significant than it seems. In this context, it is clear that Türkiye, among the countries experiencing 'water stress,' is rapidly advancing towards drought. For example, it is now imperative to change our habits regarding water use, from agriculture to daily lives.

According to water availability reports, Türkiye is one of the countries experiencing water stress, which is the previous phase of 'drought.' For this reason, many international organizations, NGOs, and universities are working on the threat of drought for Türkiye (Anonymous, 2022).

'Grey Water' Proposal for Agriculture

One of the most emphasized issues among the measures that can be taken against excessive water use is to utilize wastewater, which we call greywater, in agricultural irrigation. On the other hand, the need for parks and gardens can be met by building collection pools in big cities.

Türkiye is in the 4th rank among the 'most water consuming' countries globally. Estonia, a European country of 1.3 million, ranks first with 355 liters per day, followed by the USA with 353 liters per day and Greece with 282 liters. The amount of water consumed per person per day in Türkiye is approximately 217 liters. This rate is around 150 liters in European Union member countries on average. The amount of water consumed in the bathroom and toilet constitutes 70 percent of the total water consumed at home. Water in homes; 35 percent is used in the bathroom, 30 percent in the toilet, 20 percent for laundry and dishwashing, 10 percent for cooking and drinking water, and 5 percent for cleaning purposes. In the three big cities of Turkey, it has been determined that the average daily amount of water drawn per person is 189 liters for Istanbul, 227 liters for Ankara, and 173 liters for Izmir (TÜİK, 2016; Muluk et al., 2013).

Approximately 75 percent of the total water consumed in Türkiye is used for irrigation. 35-60% water loss occurs in the surface irrigation method, and 5 to 25% in the sprinkler and drip irrigation. Using sprinkler and drip irrigation methods in agricultural production is recommended to prevent water losses. There are also parks and gardens where water conservation should be done. To irrigate these areas, it is essential to prefer morning or evening hours when evaporation is low. Watering the plants in the morning or evening saves 112 liters of water, and cleaning the parking area with a broom instead of water saves 675 liters of water. Irrigating the grass 1-2 times a week saves 3780 liters of water, the sealing of the sprinkler systems saves 2250 liters per month, and the smart ventilation systems save 180 liters of water per day depending on the weather conditions. (Anonomyous, 2022)

Agricultural Irrigation Problems and Solutions

Türkiye covers an area of 78.5 million hectares. A total of 36 percent of this land is used for agriculture. Irrigation is possible on 92 percent of agricultural land. In this perspective, problems associated with agricultural irrigation, the sector in which our water resources are exploited the most, can be defined as issues that arise in water resource development initiatives. These occur in stages, starting with the development of water resources and ending with water usage in the field. As a result, addressing irrigation issues entails several stages and a complex procedure that spans the project's economic life cycle, behavior, and environmental impacts (Sezginer and Güner 1994). When the lack of funding is neglected, the challenges associated with Türkiye's water resources development can be divided into three categories: The first group is primarily of economic origin. They could be removed if the appropriate financial resources for planning and implementation are available. However, due to limited budgetary resources, the state has been unable to dedicate sufficient resources in recent years. The second category includes issues that develop during implementation (including planning and construction), which are sometimes anticipated but frequently unforeseen. There are factors such as poor selection of priorities, wrong planning, mistakes during construction, wrong operating techniques, inconsistent political, economic, and social approaches, lack of irrigation information, or misdirection of producers. The third category includes problems during water application. Detailed information is given in section III.

(I) Underutilization of Natural Resources

Türkiye's irrigable fields are still unable to be irrigated. Only 53.44 percent (17.57 percent of total irrigable fields) of economically and technically irrigable areas (8.5 Mha) have been irrigated, with 46.56 percent awaiting water. However, considering the newly developed irrigation techniques, Türkiye's economically irrigable areas are directly 25.85 Mha, not 8.5 Mha. For example, threshold lands previously inaccessible to irrigation because of soil topography and drainage issues can now be irrigated using drip, mini sprinkler, and other similar approaches (Kanber and Ünlü, 2006). Problem areas (saline-alkaline areas) can also be irrigated with intermittent furrow (surge) method that can easily convey water in very light-textured soils and drip irrigation method. In this case, updated numbers should be considered instead of old data for determining irrigable areas and irrigation water requirements. This should be considered in the plans and programs that should be done in the future.

Türkiye's water potential is not fully utilized yet. The utilization of 33.15 percent of the usable good quality surface water potential and 48.78 percent of the groundwater potential were actualized. Even though 24.39 percent of the exploitable groundwater potential is suitable for use, it remains unused. According to these data, only 66.85% of the surface water resources potential and 26.83 percent of the groundwater potential have been utilized. Only 34.94 percent of the useable groundwater and surface water potential has been utilized; the remaining 65.06 percent has been unused. Water distribution figures for different sectors are suspect (Kanber and Ünlü, 2006).

The standards for irrigation water quality for irrigation should be revised. Today, the tendency to use approaches considering the plant, region (soil), and climate in classifying irrigation waters predominates. Water regarded unfit in one place and for one plant may be suitable for another. Furthermore, irrigation water of dubious quality can be used with some unique techniques. Türkiye's water potential should be examined and calculated in this scenario. For determining the water potential, all irrigable lands should be considered.

According to the findings, our country's subsurface and surface water reserves are enough under today's conditions because they are not fully utilized. However, some believe that it will not be adequate for future applications. This situation has not yet been sufficiently clarified. On the other hand, detailed scientific studies that give the basins water and soil resources for applying inter-basin water transmission techniques have not been yet encountered. However, several inter-basin water transfer projects, including the Çatalan-İmamoğlu Project and the Ceyhan Project, have been effectively implemented in recent years. Due to the negative effects of inheritance legislation, agricultural estates in Türkiye are divided into small sections, making it impossible to develop lucrative businesses. 67 percent of agricultural enterprises fall into the 1-50 decare category, while 85 percent fall into the 1-100 decare category. The enterprises in both groupings account for 22.1 percent and 42.0 percent of the total cultivated area. The percentage of enterprises greater than 101 decares, on the other hand, is 15.0 percent, and the ratio of the areas in which they operate is 58.0 percent. Although the percentage of enterprises having more than 500 decares of land in Türkiye is just 0.93 percent, the area they operate is roughly 17.13 percent (Kılınçer et al., 2002).

Due to the lack of land use planning and the increase in non-agricultural land use, agricultural areas are shrinking (DPT, 1997). The misuse of agricultural lands has reached significant proportions in Türkiye. Occupation of agricultural lands has become increasingly widespread. It has become a significant problem for the country's agriculture due to factors such as rapid population growth, irregular and uncontrolled migration of the rural population to cities, industrialization, tourism, and large-scale infrastructure investments (Yurdakul et al., 1991). The issue mentioned above is particularly acute in areas where irrigated agriculture has expanded, such as Adana and Bursa. The problem can be solved primarily by preventing internal migration. To integrate the producer into the land, measures should be implemented to raise the producer's income level, and expenditures in the development of water and soil resources should be prioritized. In addition, required in-laws and regulations as susceptible to political influences as possible should be implemented, and their effective application should be ensured.

(II) Problems During the Operation Phase

Due to economic, political, social, and technical factors, Türkiye's expected value-added improvement in irrigated agriculture investments is fairly modest. Even though irrigation increased yield by 7 times, the added value increased by 2.6 times (Sayın et al., 1993). This circumstance considerably diminishes the value of irrigation investments as an incentive.

The vegetation pattern observed in irrigated areas differs greatly from the projected.

Irrigation rates predicted in the project are sometimes substantially below reality. So much so that the profitability of the projects is adversely affected; Producers in the project area are switching from irrigated agriculture to dry agriculture. This is generally due to market conditions, farmer traditions, diseases and pests, fluctuations in prices of agricultural inputs, and especially the inability to implement production planning in our country. In addition, insufficient irrigation water and network (irrigation-drainage) arise due to factors such as; salinity-alkalinity and groundwater problems, the producers' irrigation with their facility, and non-compliance with the right of water passage. To increase irrigation rates, effective production planning should be applied. As in Western countries, the producer should be supported with low-interest loans, and some critical production inputs should be subsidized, particularly in selected strategic products. It is also an important problem that irrigation systems are put into operation before they are fully completed. Because of the system's beneficial appeal, most large irrigation projects have been placed into operation before the main drainage, and irrigation networks have been built until recently. As a result of this practice, for example, infiltration losses are well above the acceptable limits. In a study conducted in Central Anatolia, it was determined that 0.4 to -4.3 percent of the incoming flow is lost by infiltration and evaporation in every 100 m canal length (Öğretir, 1981); in the Aegean, 2.5 to -9.8% (Sezginer, 1976); and in Çukurova, 0.6 to -2.4 percent (Yavuz, 1984) is lost by infiltration and evaporation depending on the channel characteristics. Because much research on the subject has been conducted in Türkiye, the cases presented can be increased.

(III) Problems That Arise During the Application of Water

Soil-plant-water relations in irrigated farming areas and their effects on humans and the environment are not discussed much in Türkiye. As a result, the producer cannot receive proper training; there is a tendency to overuse water, and water losses such as surface flow and deep infiltration increase. As a result, irrigation efficiency decreases; several issues include poor land preparation for irrigation, drainage, high groundwater, and salinity. Irrigation performance measures are the best indicator of water losses in field irrigation applications. According to a recent study, the irrigation performance of several regionally implemented irrigation schemes was relatively poor (Kanber et al., 2004). The research found that irrigation system performance is not acceptable due to infrastructure, operation, water distribution, climate, and some socio-economic problems/deficiencies. Almost all irrigation systems do not have efficient irrigation programming. Therefore, application efficiency is low, and water losses are high (Table 4).

On the other hand, performance indicators for some irrigation systems are given in Table 5. Elements such as irrigation uniformity (CU) and distribution homogeneity (DU), storage efficiency (Es), transmission efficiency (Ec), transmission losses (CL), and drip uniformity (EU) are shown separately by region. Irrigation water is lost in the project regions due to deep infiltration, evaporation, surface runoff, and faulty irrigation system operation. Traditional open channel systems are commonly used in our country. In areas where these systems are dominant, the transmission and distribution efficiency is 60%, the water application efficiency is 50%, and the total project efficiency is around 30%. Leakage can be reduced by adopting advanced modern techniques to build water transmission systems, cover bare channels, and ensure sealing. Establishing downstream controlled open canal systems and pressurized pipe irrigation systems are two examples of improving irrigation efficiency, providing controlled irrigation, and increasing water. Our country's establishment and distribution of these systems are one of the 7th Five-Year Development Plan targets.

Irrigation is a crucial component that promotes agricultural output. Completing and putting physical irrigation facilities into service without implementing cultural and technical safeguards will lead to a slew of significant and impossible issues to solve in the future. It is feasible to use water effectively in irrigated agriculture and boost efficiency by taking technological steps based on basin projects and farms (Hamdy and Lacirignola, 1999).

Table 4. Application Efficiency According to Regions and Irrigation Methods, Ea (%)

Regions	Drip Irrigation	Sprinkler Irrigation	Surface Irrigation
Mediterranean	67-84 (Söğüt,1986) 87-98 (Bilal, 1997)	95-97 (Andırınlıoğlu, 1993)	52-59 (Şimşek, 1992)
Southeast		61 (Oğuzer and Önder, 1988)	86-94 (furrow, Kanber et al., 1996) 60-70 (surge, Kanber et al., 1996) 38 (Oğuzer and Önder, 1988)
Central Anatolia		33.7 (Şimşek, 1992)	48.7 (Balaban and Beyribey, 1991) 29-80 (Ertaş, 1980) 37.9 (Şimşek, 1992) 32-77 (Öğretir, 1981) 23-58 (Oylukan, 1970)
Black Sea			35-94 (Bayrak, 1991) 55-87 (Balçın et al., 2001)

Table 5. Irrigation Performance Indicators in Different Regions (%)

Region	Es	DU	CU	EU	Ec
Mediterranean	56-75 Mini sprinkler (Uçar, 1994)	98-99 Drip (Bilal, 1997) 82-88 Surface Irr. (Şimşek,1992) 87.2 Sprinkler (Andırınlıoğlu, 1993) 12.1 Furrow (Önder et al., 1992)	40 Furrow (Önder et. al., 1992) 97.5 Drip (Oğuzer and Yılmaz,1991)	84 Drip (Söğüt,1986)	
Southeast	24 Furrow, 41 Sprinkler (Oğuzer and Önder, 1988)	85 Sprinkler (Kanber et. al., 1996)	85 Surface and sprinkler (Kanber et al.,1996)		
Central Anatolia	75-80 Sprinkler (Oylukan, 1972)	37-81 Sprinkler (Tarı, 1998)	58-82 Sprinkler (Tarı, 1998)		85 Irrigation channel (Balaban and Beyribey, 1991)
Black Sea	17-90 Surface Irr. (Bayrak, 1991)				

Studies that will eliminate the water shortage, which is expected to occur in the future, provide water increase, should be started now, and scientific projects related to the subject should be supported first. Water can be increased by conserving precipitation in basins, transmitting water across basins, combining low-quality waters, and using seawater, urban wastewater, and drainage water. Making ponds on small dry streams and using precipitation waters for irrigation during the summer is a good example of this situation.

Surface irrigation techniques developed for the effective use and increase of water on a field basis, such as intermittent furrow, reduced flow furrow, cyclic furrow, variable or fixed straight furrow, etc., automation of irrigation and irrigation time, sprinkler irrigation, and the use of modern irrigation techniques with low pressure-low flow In addition to saving water, the inconveniences of traditional irrigation methods can be eliminated. Necessary training activities should be expanded and financially supported to popularise these techniques in Türkiye and adopt them for farmers.

Geographic Information Systems and Remote Sensing Techniques are used in the planning, development, monitoring, and evaluation stages of water resources in the world in the globalization process. In Türkiye, the number of skilled workers and the essential equipment is far from complete. However, as the world changes, it is unavoidable that some measures be taken and appropriate adjustments in the institutional framework for staff training and equipment be made.

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