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PERFORMANCE INDICATORS FOR IMPROVING IRRIGATION MANAGEMENT IN AEGEAN DISTRICT

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Abstract: Water is vital for agriculture and its effective use has become imperative. The largest share of freshwater use in the world is in the agricultural sector with a rate of approximately 70%. Therefore, the evaluation of irrigation schemes is of great importance. In Türkiye, irrigation schemes are managed and distributed by organizations such as water user associations, municipalities, and irrigation cooperatives. In Türkiye, irrigation schemes with a service area of 500 ha or more are managed by water user associations. In this study, Ahmetli, Salihli and Menemen water user associations' irrigation schemes, where the Gediz River is used as a water source, were chosen as materials. The selected irrigation schemes service area constitutes 60% of the total service area in the region (DSI (General Directorate of State Hydraulic Works) 2nd Region (Aegean region)). The service area of Ahmetli irrigation scheme is 50,532 ha, 22,797 ha in Salihli and 22,865 ha in Menemen. The main crop pattern of the irrigation area is vineyards, corn and cotton. These irrigation schemes were evaluated using performance indicators such as water supply, irrigation rate, and amount of irrigation water used per unit area. The raw data sets obtained from DSI cover the years 2007 and 2021. As a result, when looking at the average performance, relative water supply, irrigation rate and amount of irrigation water used per unit area were found to be 0.70, 57.99 and 7682.45 m^3 ha^{-1}, respectively. Although 70% of the irrigation water need can be met with the water diversion to the system, the irrigation ratio was approximately 58% indicating the problems in transferring water to the system and the irrigation techniques used by farmers on the field are not modern. In addition, the main reasons for the unirrigated areas, are social and economic reasons (137 ha in the Menemen WUA) and the lack of water supply in the Salihli and Ahmetli WUAs, 2319 ha and 11320 ha cannot be irrigated, respectively. Modernization seems inevitable for more effective use of our water resources. The most effective techniques in this modernization are land consolidation, renewal of irrigation channels, extension and consultancy services to farmers, and making water fees according to volume can be counted.

Keywords: Gediz River, Performance assessment, Irrigation rate, Water user associations

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1. Introduction

Water is one of the fundamental components of life and an indispensable resource for the survival of all living beings. Constituting a large part of the human body, water is also the most crucial element for the functioning of ecosystems (Akın and Akın, 2007; Özsoy, 2009). Factors such as global warming, drought, and population growth have made the sustainable management of water resources more important than ever (Karaman and Gökalp, 2010). In this context, the conservation and efficient use of water are critical not only for environmental sustainability but also for economic development and social welfare.

One of the sectors where water resources are most intensively used is agriculture. Agriculture accounts for approximately 70% of global water consumption (Dorak et al., 2019), necessitating careful management of water resources. The sustainability of agricultural production depends on the efficient use of water resources. Particularly, incorrect or excessive use of water (Çakmak and Gökalp, 2011; Kartal, 2018) can lead to the depletion of water resources and a reduction in soil fertility. Therefore, the more careful and conscious use of water in agricultural activities (Kartal et al., 2020) is of paramount importance for preventing future water crises (Turan and Bayraktar, 2020) and ensuring food security (Kırtorun and Karaer, 2018).

Although Türkiye is not a country rich in water resources, it uses a significant portion of its existing water resources for agricultural irrigation (Kartal, 2018). In this context, the management of agricultural irrigation plays a vital role in the sustainability of water resources. In Türkiye, the majority of agricultural irrigation management is carried out by irrigation unions. These unions are local organizations formed by local farmers to organize and manage agricultural irrigation activities. They are responsible for the planning, maintenance, and fair and efficient distribution of water in irrigation systems (Kaya and Çiftçi, 2016).

Evaluating the performance of water user associations is

of critical importance in terms of effective use of water and increasing agricultural productivity (Arslan and Değirmenci, 2018; Kartal and Arslan, 2021). The performance of the networks managed by irrigation associations stands out as an important indicator in determining how efficiently water is used, what the level of water losses is and what impact it has on agricultural production. These evaluations also contribute to determining the measures that need to be taken to protect water resources and avoid facing water scarcity in the future. Therefore, regular examination and improvement of the performance of water user associations managed by irrigation unions is an inevitable necessity for both environmental sustainability and agricultural production.

The Gediz River, as one of the most important water resources in the Aegean Region, plays a vital role in the region's agricultural production and ecosystem. However, in recent years, severe droughts have occurred in the river due to human-induced interventions such as climate change and dam construction (Koçman and Sütgibi, 2013). Additionally, problems related to the water use efficiency of irrigation unions are negatively impacting agricultural irrigation management in the region (Akkuzu et al., 2003; Ünal et al., 2004; Akçay and Tunalı, 2016; Akçay, 2018). The decrease in the water level of the river poses a threat to the region's biodiversity and creates significant problems in securing water for agricultural irrigation. The irrigation unions that draw water from the Gediz River are among the most affected stakeholders and play a critical role in the sustainable management of the river. The impacts of these unions on the river and their roles in its conservation carry significant strategic value not only for the continuity of agricultural production but also for the future of the region's water resources.

The purpose of this study is to thoroughly evaluate the irrigation performance of three irrigation unions that use the Gediz River as a water source and to determine the measures that can be taken in terms of water management and agricultural productivity based on the findings of this evaluation. The study aims to analyze the current practices of the irrigation unions, water distribution efficiency, water losses, and their impacts on agricultural production. This analysis seeks to identify the challenges faced by the irrigation unions and define the necessary improvement strategies for the sustainable use of the Gediz River. Additionally, it will focus on the measures that need to be taken in irrigation management by considering the future effects of factors such as climate change and increasing water demand. In this way, the study's results are expected to contribute to enhancing agricultural sustainability in the Gediz River basin.

2. Materials and Methods

This study aims to evaluate the irrigation performance of three water user associations (Menemen, Ahmetli, Salihli) located along the Gediz River between the years 2007 and 2021. The selected water user associations directly utilize the Gediz River as their water source for irrigation, a factor of significant importance for the sustainability of the region's water resources. The selection of these water user associations was influenced by factors such as the increasing risk of the Gediz River drying up, the impacts of climate change, and the rising drought in the region. These factors heighten the challenges in irrigation management and underscore the importance of performance evaluation. Within the scope of the study, the efficiency of water distribution systems, water losses, farmers' water usage habits, and the impacts on agricultural production in the areas managed by the Menemen, Ahmetli, and Salihli water user associations will be examined. The geographical locations of the relevant water user associations are shown in Figure 1.

The irrigation areas, plant patterns, water resources, water supply methods, water transmission channels and irrigation methods used in the irrigation areas of the relevant water user associations are presented in Table 1 in order to understand the scope and methods of the study in more detail. Table 1 contains information about the dimensions of the agricultural areas under the management of Menemen, Ahmetli and Salihli water user associations and the plant species grown in these areas.

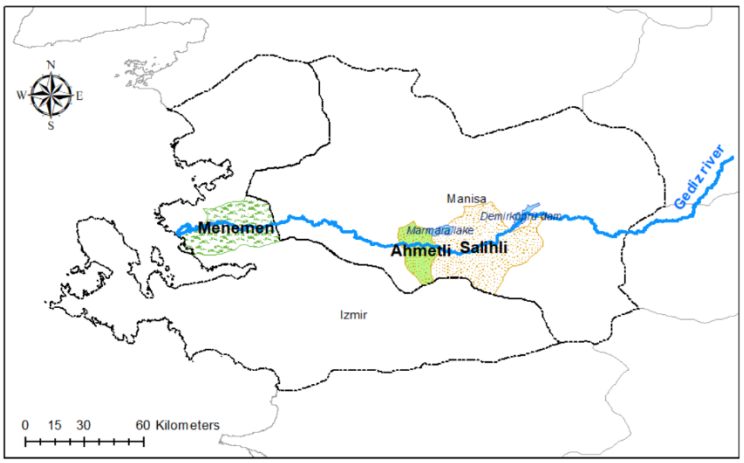

Figure 1. Location of the study area.

Table 1. Main attributes of water user associations

Irrigation Scheme	Menemen	Ahmetli	Salihli
Service area (ha)	22,865	50,532	22,797
Main crops	cotton (65%), corn (14%)	corn (46%), vineyard (43%)	vineyard (52%), corn (32%)
Water resources	gediz river	gediz river, marmara lake	gediz river, marmara lake
Water supply	surface (90%), pump (10%)	surface (100%)	surface (95%), pump (5%)
Water distribution (km)	lined, canalette	lined, canalette, earth lined	lined, canalette, earth lined
Irrigation methods used by farmers	Surface (100%)	Surface (100%)	Surface (99%), drip (1%)

Table 2. Calculation of the indicators (Malano et al. 2004; Kartal et. al. 2021)

Indicators	Formula	Unit	Optimum value
Relative water supply (RWS)	$\frac{\text{total water supply}}{\text{water needed for production}}$	no unit	1
Irrigation ratio (IR)	$\frac{\text{irrigated area}}{\text{servis area}} \times 100$	%	100
Annual amount of water used per unit irrigated area (WIRR)	$\frac{\text{total water supply}}{\text{servis area}}$	$m^3\ ha^{-1}$	-

Table 3. Descriptive statistics of the indicators for the study period

Irrigation scheme	RWS			IR			WIRR		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Menemen	0.80 (0.37)*	0.27	1.53	82.48 (5.14)	71.95	90.48	6281.27 (2165.64)	2437.54	8831.47
Ahmetli	0.56 (0.31)	0.16	1.24	37.76 (7.58)	20.28	53.73	8208.96 (1815.52)	4930.87	11018.51
Salihli	0.74 (0.38)	0.21	1.38	53.73 (9.02)	37.33	66.60	8557.12 (2250.45)	4172.03	11676.74

In the evaluation of water user associations, basic performance indicators such as water supply rate, irrigation rate and the amount of irrigation water distributed per unit irrigated area were used. These indicators are important criteria to determine the effectiveness of water user associations in water management and to what extent water resources are used efficiently. While the water supply rate reveals how much of the existing water resources are used for irrigation purposes, the irrigation rate shows the ratio of the irrigated area to the total irrigation area. The amount of irrigation water distributed per unit irrigated area is used to calculate how much water is consumed per certain area.

Data such as the total amount of irrigation water used, irrigation water need, irrigated area and total irrigation area required for accurate and reliable calculation of these indicators were obtained from the Monitoring and Evaluation Reports published by the State Hydraulic Works (DSİ). These reports contain the most up-to-date and comprehensive data used when evaluating the performance of water user associations and form the basis of the calculations and analyzes made within the scope of the study. The data obtained in this way is used to better understand how Water User Association manage water resources and the effects of this management on agricultural production. Formulas for calculating irrigation performance indicators are given in Table 2. We used SPSS statistics package program for analysis and figures.

3. Results and Discussion

In the evaluation of Menemen, Ahmetli and Salihli water user associations, the minimum, maximum, average and standard deviation values of the water supply rate, irrigation rate and the amount of irrigation water distributed to the unit irrigation area are given in Table 3. Additionally, the data were visualized with biplot graphs (Figure 2).

The water supply rate, calculated by dividing the amount of irrigation water diverted into the water user associations by the irrigation water need, was the lowest at 0.27 and the highest at 1.53 in the Menemen water user association between 2007 and 2021. The average value of this indicator in the relevant water user association was calculated as 0.80. The average values of water supply rates in Ahmetli and Salihli water user associations are 0.56 and 0.74. In all water user associations, the water supply rate is lower than the optimum value during the operating years.

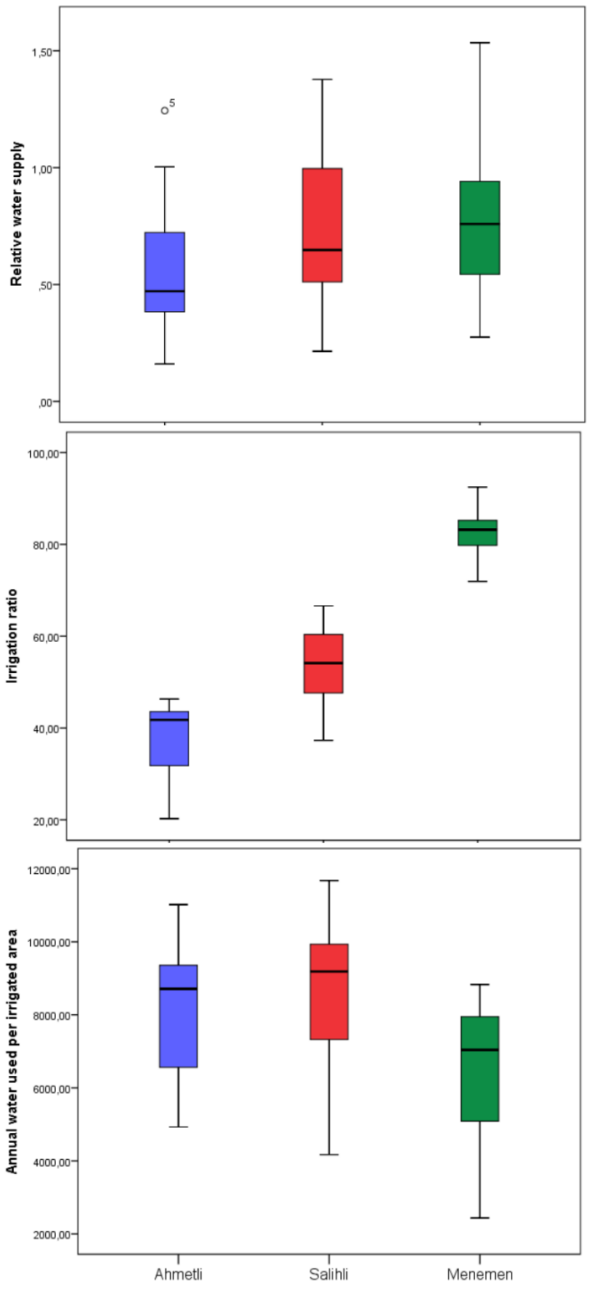

Figure 2. Boxplot graphs of the indicators.

When the irrigation rate indicator, which is calculated by dividing the irrigated area to the service area, is examined, the average value of Menemen water user association is calculated as 82.48%, while this rate in Ahmetli and Salihli water user associations is 37.76% and 53.73%, respectively. In this case, the irrigation rates of Ahmetli and Salihli water user associations are lower than the average irrigation rate of Türkiye.

When the amount of irrigation water distributed per unit irrigated area is examined, the average value in Menemen water user association is 6281.27 m3 ha^{-1}, while this value is higher in Ahmetli and Salihli water user association and is calculated as 8208.96 m^3 ha^{-1} and 8557.12 m^3 ha^{-1} respectively. When standard deviation values, minimum and maximum values are examined, it is understood that water user association have shown inconsistent performance over the years.

The Mediterranean Region is among the sensitive regions that will be most affected by climate change and drought. For example, in regions where water resources are limited, such as Türkiye, Spain and Italy, re-evaluation and development of water management strategies is of great importance. In this context, changes to be made in agricultural irrigation systems will play a critical role in using water more efficiently and disseminating sustainable agricultural practices. These changes can not only ensure the protection of water resources but also increase the efficiency of agricultural production (Arslan et al., 2023).

First of all, structural measures to reduce water use require taking concrete steps to save water. Modernization of irrigation systems at the field level is one of the important steps that can be taken in this direction. Converting surface irrigation or sprinkler systems to drip irrigation systems enables a more controlled and efficient use of water (Çetin et al., 2010). Similarly, replacing open surface channels with pressurized pipelines can further increase water savings by preventing water from being lost through evaporation and infiltration (Kurtulmuş, 2021).

In addition, a pricing system that encourages the use of water needs to be developed. Pricing systems traditionally determined according to the area of use of water or crops are not effective enough in saving water. Instead, a pricing system based on the volume of water delivered could encourage farmers to use water more efficiently. By reflecting the true cost of water, such a system can reduce water waste and contribute to the adoption of sustainable agricultural practices (Arslan, 2023).

Another important point is the structural reorganization of Water user associations (WUA). Dividing Turkish WUAs into smaller associations may help provide more effective control over water management (Arslan et al., 2023). Smaller associations can enable better monitoring of the structural condition of water networks, allowing water distribution to be managed more regularly and effectively. This will prevent water from being wasted and enable more efficient use of water resources.

Restructuring SUs can also contribute to reducing maintenance, operation and management costs. Carrying out more regular and planned maintenance activities, instead of large-scale and expensive restoration works, both reduces costs and makes it possible to better protect water networks in the long term. This offers a significant advantage in terms of water management, especially in regions where economic resources are limited (Arslan and Değirmenci, 2018).

4. Conclusion

The data obtained throughout the study clearly reveals that Water User Association cannot demonstrate the expected performance in water management and distribution. This result questions the effectiveness of

existing irrigation systems and raises the need for urgent modernization. Efficient use of water resources should be supported not only by improving existing systems but also by structural changes.

First, it is of great importance to convert existing water distribution systems from open channels to pressurized pipelines. Open channels cause water losses through evaporation and seepage. This situation not only prevents the efficient use of water, but also threatens sustainable agricultural practices. Pressurized pipelines will ensure that water reaches targeted areas in a more controlled manner, minimizing water losses and providing a significant improvement in water management.

In addition, modern irrigation methods need to be adopted at the farm level. Encouraging methods that use water more efficiently, such as drip irrigation, will increase efficiency in agricultural production and contribute to the protection of water resources. Since such methods ensure that water is delivered only to the root area of the plant, they prevent water waste and make it possible to use water more effectively.

Additionally, water measurement systems need to be established to monitor and manage water consumption. By making water use more transparent, water measurement systems will contribute to the prevention of water waste and ensure a more sustainable management of water resources. These systems will help farmers monitor their water consumption and optimize their water use according to their needs.

In this regard, organizing all changes and supports for the modernization of water management and irrigation systems should be carried out within a plan. In this process, it is important that both public institutions and the private sector work in cooperation. In order for modernization efforts to be successful, in addition to financial support, farmers need to be trained to adapt to these new systems. Training programs will raise awareness about the proper use of water and the adoption of modern irrigation techniques and support sustainable agricultural practices in the long term.

Modernization of irrigation systems is an inevitable necessity in order to increase the performance of Water User Association and ensure the sustainability of water resources. Steps to be taken in this context will ensure more efficient use of water, increasing efficiency in agricultural production and contributing to the protection of water resources. In this process, effective planning and implementation of modernization studies are critical for sustainable success in water management.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	F.A.	D.A.Z.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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