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Research Article

Evaluation of Irrigation Performance in Boyalıca Pump Irrigation

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Abstract

This study was conducted to evaluate the performance of Boyalıca Pumped Irrigation in Iznik-Bursa between the years 2016-2020. In the performance evaluation, an indicator set recommended by the International Programme for Technology and Research in Irrigation and Drainage was used. According to the average results of water use efficiency indicators, the irrigation ratio was 63.2%, the annual water supply ratio was 0.71 and the annual irrigation water quantity delivered to irrigated or irrigation unit area were 7317 m^3 ha^{-1} and 4644 m^3 ha^{-1}, respectively. When the average results in terms of financial efficiency were examined, the fee collection ratio was 95.5%, the total management-operating-maintenance costs per unit area was 752 TL ha^{-1}, the total cost per person employed on water delivery was 63971 TL $personnel^{-1}$, average revenue per cubic meter of irrigation water supplied 0.104 TL m^{-3}, and the cost recovery ratio was 223% . According to the average results of agricultural production efficiency, the equivalent gross production value (EGPV) of the irrigation area was 3859$ ha^{-1}, the EGPV of the actual irrigated area was 6088$ ha^{-1} and the EGPV for a unit of diverted irrigation water was 0.86$ m^{-3}.

Keywords: irrigation management, performance assessment, economic indicators.

Boyalıca Pompaj Sulamasında Sulama Performansının Değerlendirilmesi

Öz

Bu çalışma 2016-2020 yılları arasında İznik-Bursa'da yer alan Boyalıca Pompaj Sulamasının performansını değerlendirmek amacıyla gerçekleştirilmiştir. Performans değerlendirmesinde Uluslararası Sulama ve Drenajda Teknoloji ve Araştırma Programı tarafından önerilen bir gösterge seti kullanılmıştır. Su kullanım etkinliği göstergelerinin ortalama sonuçlarına göre, sulama oranı %63.2, yıllık su temin oranı 0.71, sulanan birim alana ve sulama birim alanına saptırılan yıllık sulama suyu miktarı sırasıyla 7317 m^3 ha^{-1} ve 4644 m^3 ha^{-1} olarak belirlenmiştir. Finansal etkinlik açısından ortalama sonuçlar incelendiğinde, tahsilat oranı %95.5, birim alan başına toplam işletme-bakım-yönetim masrafı 752 TL ha^{-1}, sulama suyu dağıtımında istihdam edilen kişi başına toplam maliyet 0.104 TL m^{-3} ve yatırımın geri dönüşüm oranı %223 olarak bulunmuştur. Tarımsal üretim etkinliğinin ortalama sonuçlarına göre, sulama alanı eşdeğer brüt üretim değeri (EBÜD) 3859 $ ha^{-1}, fiilen sulanan alan EBÜD 6088 $ ha^{-1} ve saptırılan birim sulama suyuna karşılık EBÜD ise 0.86 $ m^{-3} olarak belirlenmiştir.

Anahtar Kelimeler: sulama yönetimi, performans değerlendirmesi, ekonomik göstergeler.

Introduction

Over the next two decades, many countries are expected to face insufficient water resources to meet current agricultural, domestic, industrial and environmental water demands. It is estimated that the world population will increase by approximately 30% to 8 billion people by 2025. Living standards are also expected to increase as a result of improved communication, globalization and greater urbanization. This means that competition between agricultural, industrial, domestic and other water users will increase to an unprecedented levels (Takeshi and Abdelhadi, 2003).

Since the 1980s, severe financial crises and limited progress in improving economic and social well-being have led to a profound reassessment of the role of the state. As a result, there has been an increase in the adoption of decentralization, with governments ceding certain functions to various social organizations. Many countries around the world are delegating water management responsibilities to participatory, self-sustaining water user organizations that operate independently of government agencies. This trend is especially striking in the field of irrigation. Governments initiated this era of irrigation management primarily due to poor performance in administration, insufficient financial resources for operation and maintenance costs, and extremely low water fee collection rates from farmers (Kloezen and Garces-Restrepo, 1998).

These developments have also had an impact on Turkey's agricultural and irrigation management system. Since 1993, there has been a gradual shift in responsibilities for the management, operation, and maintenance of the 1900000 hectares of irrigated land, which were previously overseen by the State Hydraulic Works (DSI). This transition has predominantly involved transferring these duties to water user organizations, especially locally formed irrigation associations. As a result, approximately 90% of public irrigation scehems are now under the management of farmer organizations (Anonymous, 2023).

In Turkey, the average irrigation rate stands at 65%, with an irrigation efficiency of 45%. A significant factor contributing to this situation is the poor distribution and management of irrigation water. Adequate monitoring and evaluation of performance is required to address this issue and ensure an increase in overall efficiency (Sarma and Rao, 1997).

Poor performance, coupled with rising operating and maintenance expenses, has created a great incentive to transfer the administration of irrigation systems towards user management. The decentralization of water management can yield favorable outcomes for farmers, such as improved irrigation service and maintenance, a heightened sense of ownership of resources, and increased accountability and transparency.

The performance of irrigation systems is evaluated for various management objectives. Numerous researchers have put forth a range of indicators to gauge the effectiveness of these systems. Primarily, these indicators have centered on the internal aspects of management objectives, such as irrigated area, vegetation patterns, and water distribution (Abernethy, 1986; Molden and Gates, 1990). These process indicators are designed to evaluate the quality of business performance. However, it does not provide information for comparative analysis across different systems (Small and Svendsen, 1990).

Molden et al. (1998) proposed a set of nine external comparative indicators that would allow meaningful comparisons across countries, regions, various management approaches, and environmental contexts as well as facilitate the assessment of performance trends within a specific irrigation scheme over time. These comparative indicators have been used by many researchers to evaluate temporal and spatial variations in the agricultural, water use, environmental and financial performance of irrigation systems (Kloezen and Garces-Restrepo, 1998; Molden et al., 1998; Sakthivadivel et al., 1999; Kuşçu et al., 2008, 2009; Kuşçu, 2012; Yürekli and Topak, 2018; Ersöz and Çamoğlu, 2020; Kartal et al., 2020). Ersöz and Çamoğlu (2020) evaluated the performance of irrigation associations operating in Bursa province in 2018 comparatively. According to the results obtained from the performance indicators, Karacabey Irrigation Association was found to be the most successful in terms of physical performance, and Lake Iznik Keramet Irrigation Association was found to be the most successful in terms of economic performance. As a suggestion, they emphasized that the open channel system should be converted into a closed pipe system in order to improve performance indicators.

In the Turkish National Water Plan (2019-2023), the importance of water use in agriculture is emphasized. In this context, it has been stated that the transition to the pressurized irrigation system should be widespread. The plan sets a target to increase irrigation efficiency from the 2018 level of 50% to 55% by 2024. To achieve these objectives, it is important to accurately determine the volume of water used for agricultural purposes and encourage farmers to adopt modern irrigation techniques (Anonymous, 2023). In pursuit of such goals, the performance analysis of irrigation associations is a valuable tool.

This study aims to evaluate the performance status of the Boyalıca Pump Irrigation, operated by the İznik Ova Köyleri Irrigation Association, for the years 2016-2020 using performance indicators related to water usage efficiency, financial efficiency, and agricultural production efficiency.

Materials and Methods

Experimental area

In this study, the Boyalıca Pump Irrigation system, located in İznik, a district of Bursa province, Turkey, and operated by the İznik Ova Köyleri Irrigation Association, was selected. İznik is a district within Bursa and is situated in a fertile basin at the eastern end of Lake İznik, surrounded by hills to the north and south. Irrigation water is sourced from Lake İznik. İznik has a Mediterranean temperate summer climate. The annual average temperature near the lake is 14°C, while in the higher parts of the basin, it ranges from 8 to 10°C. The average annual precipitation is 690 mm in Orhangazi, 485 mm in İznik, and reaches 1200 mm in the highest basin elevations (Akbulak, 2009).

The İznik region has five main soil types. The most common soil type is non-calcareous brown forest soil. Other soil types include brown soils, reddish-brown Mediterranean soils, colluvial soils, and alluvial soils. The majority of Class 1 and 2 agricultural lands are alluvial soils (Anonymous, 2022). İznik Lake is a tectonic origin lake and the sixth largest freshwater lake in the country. The lake area is surrounded by the Samanlı Mountains to the north and the Avdan and Gürle Mountains to the south. The lake's elevation above sea level is 85 meters, with an average water depth of approximately 40 meters. The surface area of the lake is approximately 313 km^2, and its water volume is 12.2 km^3. The main water and sediment inputs come from the Karasu Stream in the northeast and the Koca or Sölöz Stream in the southwest. Additionally, the lake is fed by groundwater sources. The outlet of the lake is the Gölayağı Stream on the western side of the lake, which flows into Gemlik Bay in the Marmara Sea (Roeser et al., 2012).

Over the study period from 2016 to 2020, the region's agricultural landscape encompasses various crops with distinct irrigated land allocations. Vines cover approximately 7.8% of the total irrigated area, olive cultivation extends over a significant 72.2%, fruit and all kinds of saplings occupy about 13.4%, and all kinds of vegetables account for around 7.2%. This allocation of irrigated land contributes to the overall agricultural production, with vines, olives, fruits, and vegetables each playing a crucial role in shaping the region's agricultural output during these five years.

Irrigation system

The İznik Ova Köyleri Irrigation Union comprises two main irrigation areas: Boyalıca Pump Irrigation and İznik Pump Irrigation. This study focuses on the Boyalıca Pump Irrigation system. The Boyalıca pump station, serving as the main pumping facility, is composed of two booster stations (Elbeyli and Orhaniye) and one lift station (Çakırca). The facility, located between İznik center and Boyalıca, was constructed in 1985 with the purpose of irrigating 3190 hectares of land from Lake İznik. Between the lake and the pump suction pool, there exists a soil channel and iron cover. Behind the pump building, two air tanks and two butterfly valves for the lift lines are situated. From the suction pool, five pumps deliver water into the B1 main canal, while six pumps pump water into the B2 main canal. The general characteristics of these pump stations are provided in Table 1.

Table 1. General characteristics of pump stations serving İznik-Boyalıca Irrigation

Characeteristics of irrigation system	**Pump stations**			
	Boyalıca	**Orhaniye**	**Elbeyli**	**Çakırca**
Pump power (kW)	2632	590	740	360
Water resource	İznik Lake	Irrigation canal	Irrigation canal	Irrigation canal
Irrigation area (ha)	3190	447	539	0 (for pressurization)
Year of construction	1985	1999	1999	2011

Method

In this research, an approach recommended by IPTRID, developed by FAO, was used alongside other commonly used indicators to assess irrigation and drainage performance (Malano and Burton, 2001). For this purpose, performance indicators for water use efficiency, financial efficiency, and agricultural production were utilized (Table 2). The data used for performance evaluation were obtained from the records of the İznik Plain Villages Irrigation Association and the State Hydraulic Works (DSİ). Total water required for irrigation was calculated as follows:

$$Total\ water\ reequired\ for\ irrigation\ = ETc - Er + Applied\ irrigation$$

where:

- ETc is the crop evapotranspiration,
- Er is the effective rainfall,
- Applied irrigation is the amount of water applied through irrigation.

During the study, the financial performance indicator results were converted to US Dollars (USD) for comparison purposes on an international basis. Product prices were converted from Turkish Lira (TL) to USD using the Central Bank's exchange rate of the study period in question. In the equations for agricultural production indicators, EGPV (Equivalent Gross Production Value) was given in dollars ($), Ai represents the planted area of crop i (ha), Yi represents the yield of crop i (t ha^{-1}), Pi is the local market price of crop i ($ t^{-1}), Pb is the local price of crop i obtained equivalently ($ t^{-1}), and Pword is the world price of crop i obtained equivalently ($ t^{-1}).

Table 2. The indicators used in the evaluation of irrigation performance

Water use efficiency	**Definition**
Irrigation ratio (%)	$\frac{Irrigated\ area}{Irrigation\ area}$
Annual water supply ratio (AWSR)	$\frac{Actual\ water\ used\ for\ irrigation}{Total\ water\ required\ for\ irrigation}$
Annual irrigation water quantity delivered to irrigated unit area ($AIWQ_{irrigated}$) ($m^3\ ha^{-1}$)	$\frac{Irrigated\ area}{Total\ water\ taken\ from\ the\ network}$
Annual irrigation water quantity delivered to irrigation unit area ($AIWQ_{irrigation}$) ($m^3\ ha^{-1}$)	$\frac{Irrigation\ area}{Total\ water\ taken\ from\ the\ network}$
Financial efficiency	
Fee collection ratio (%)	$\frac{Collection\ amount}{Accrual\ amount}$
Total management, operation and maintenance costs per unit area MOM(TL ha^{-1})	$\frac{Total\ management - operation - maintenance\ expenses}{Irrigated\ area}$
Total cost per person employed on water delivery (TL $personnel^{-1}$)	$\frac{Total\ expenses\ of\ operation\ and\ maintenance\ personel}{Number\ of\ people\ on\ duty\ for\ operation\ and\ maintenance}$
Average revenue per cubic meter of irrigation water supplied (TL m^{-3})	$\frac{Total\ water\ fees\ collected\ from\ users}{Total\ water\ volume\ delivered\ to\ users}$
Cost recovery ratio (CRR)	$\frac{Total\ water\ fees\ collected\ from\ users}{Total\ operation\ management\ maintenance\ expenses}$
Agricultural production efficiency	
Equivalent gross production value (EGPV) ($)	$(\sum_{crop} A_i Y_i * P_i / P_b) * P_{word}$
Annual agricultural production quantity (APQ) (t)	$\{\sum A_i Y_i\ crops\}$
Equivalent gross production value for irrigation area ($EGPV_{irrigation}$) ($ ha^{-1})	$\frac{Equivalent\ gross\ production\ value}{Irrigation\ area}$
Equivalent gross production value for actual irrigated area ($EGPV_{irrigated}$) ($ ha^{-1})	$\frac{Equivalent\ gross\ production\ value}{Irrigated\ area}$
Equivalent gross production for a unit of diverted irrigation water (DIEGPV) ($ m^{-3})	$\frac{Equivalent\ gross\ production\ value}{Total\ water\ supplied\ to\ the\ system}$

Results and Discussion

Water use efficiency

The results of water use efficiency calculated for the research field between 2016 and 2020 are presented in Table 3. It can be observed that in Boyalıca Pump Irrigation, the irrigation ratio reached a maximum of 65% in 2019 and a minimum of 62% in 2016. According to the State Hydraulic Works, irrigation management is considered successful if the irrigation rate is above 60% (Akçay, 2016). As evident from these rates, approximately 40% of the irrigation area was left unirrigated during the period of 2016-2020. Low irrigation ratios may be caused by factors such as inadequate irrigation facilities, insufficient water resources, deficient irrigation infrastructure, drainage problems, inadequate maintenance and repairs, as well as sufficient rainfall and fallow periods. Beyribey and Öğretir (1997) found the country's average irrigation rate to be 66% in a study they conducted to evaluate the performance of government irrigation systems. Diker (2018), in his study assessing the performance of 18 irrigation associations in the Lower Seyhan Plain, identified the highest irrigation rate as 100% in the Seyhan Irrigation Association in 2011, and the lowest irrigation rate as 57% in the Kuzey Yüreğir Irrigation Association in 2014 under the Yüreğir Akarsu Irrigation Association. Gümüş and Tekiner (2023) reported that the irrigation rate varied between 23.2% and 42.1% in their assessment of 84 irrigation networks in Turkey and was comparatively higher in irrigation networks whose management was transferred from DSİ to irrigation associations. The reasons for non-irrigation of the irrigated areas were listed as 25.4% other reasons, 17.9% social and economic reasons, 16.9% fallow, 14.1% adequate rainfall/lack of water demand, 7.9% lack of water supply, 6.4% lack of irrigation facilities, 5.2% maintenance and repair insufficiency, 3.0% salinity/sodium content, 1.7% basewater height and 1.4% topographical insufficiency of the land.

Table 3. Results of water use efficiency indicators for İznik-Boyalica Irrigation

Years	Irrigated area(ha)	Irrigation area (ha)	Total water taken from the network (m^3)	Total irrigation water requirement (m^3/year)	Irrigation ratio (%)	Annual water supply rate	Annual irrigation water quantity delivered to irrigated unit area (m^3 ha^{-1})	Annual irrigation water quantity delivered to irrigation unit area (m^3 ha^{-1})
2016	2515.3	4035	18915000	24273000	62	0.78	7520	4687.7
2017	2534.9	4035	16426800	24696000	63	0.67	6480	4071.1
2018	2551.0	4035	14531000	24974000	63	0.58	5696	3601.2
2019	2636.5	4035	24567000	33464000	65	0.73	9318	6088.5
2020	2542.6	4035	19250000	24771000	63	0.78	7571	4770.8

The maximum annual irrigation water supply ratio was found to be 0.78 in 2016 and 2020, while the minimum was 0.58 in 2018 (Table 3). According to Beyribey (1997), when the ratio equals 1, it indicates that the water supply meets the demand. If it is less than 1, it means that there is insufficient water supply, and if it is greater than 1, it signifies an excess of water provided. In the Boyalıca pump irrigation area, adequate water distribution for meeting the irrigation water demand is not being achieved. Numerous factors contribute to a low annual water supply ratio in irrigation, including climate variability, water scarcity, inefficient water management, groundwater depletion, environmental changes, population growth, inadequate policies, and infrastructure limitations. These challenges, compounded by climate change, highlight the need for a comprehensive approach to improve water management practices, promote sustainable agriculture, and implement effective policies to ensure a reliable and sufficient water supply for irrigation.

In similar studies, irrigation water supply ratios have been reported to vary. For example, Eliçabuk and Topak (2017) reported a range of 0.51-1.04 for the Gevrekli irrigation, Demir and Topak (2014) reported 0.62-1.0 for the Gözlü YAS irrigation operation, Kaya and Çiftçi (2016) reported 2.35-3.45 for the Çumra Irrigation Association, and Turhan (2019) reported values ranging from 2.03 to 3.42 for the years 2015-2017 in the service area of the Develi Ovası Irrigation Association. These variations may be due to the unique dynamics of each irrigation network. For instance, if surface irrigation methods are commonly used, the irrigation efficiency may be low, resulting in a water supply ratio above 1.

In Boyalıca Pump Irrigation, the annual irrigation water quantity delivered to irrigated unit area was calculated to be a minimum of 5696 m³ ha^{-1} in 2018 and a maximum of 9318 m³ ha^{-1} in 2019 (Table 3). According to a study conducted by Anderoğlu (2020), in the Anamur Irrigation Association, the annual irrigation water quantity delivered to irrigated unit area was calculated to be a minimum of 7981 m³ ha^{-1} in 2015 and a maximum of 33650 m³ ha^{-1} in 2017. Eliçabuk and Topak (2017) reported the values ranging from 2577 to 5273 m³ ha^{-1} for Gevrekli irrigation, while Kalender (2017) reported the values ranging from 1428 to 6334 m³ ha^{-1} for Ilgın Pump Irrigation. The variability in the values in different regions is thought to be due to differences in crop patterns, irrigation methods, as well as climate and soil characteristics.

The annual irrigation water quantity delivered to the irrigation unit area reached a minimum of 3601.2 m³ ha^{-1} in 2018 and a maximum of 6088.5 m³ ha^{-1} in 2019 (Table 3). Generally, the lowest amount of water supplied to the network occurred in 2018. This situation led to the lower value for that year. There could be various reasons for this, such as higher-than-average rainfall during the irrigation season of that year. When examining rainfall values for the İznik district, it was found that the long-term average total rainfall in May was 50 kg m^{-2}, but in 2018, it was approximately 100 kg m^{-2}. In a study conducted by Kalender (2017) in the Ilgın Ovası Pump Irrigation Association for the years 2007-2015, the values were reported to range from 967 to 2839 m³ ha^{-1}. The values for 2015 were determined as 5792 m³ ha^{-1} for Keysun irrigation, 7648 m³ ha^{-1} for Göksun irrigation, and 6730 m³ ha^{-1} for Kayacık irrigation (DSİ, 2015). When comparing the the values obtained in the research area with the previous studies mentioned, it is seen that they are within normal levels.

Financial efficiency

The total maintenance- operation-management cost values per unit area determined between 2016-2020 in Boyalıca Pumped irrigation are given in Table 4. If this indicator is low, it may cause low irrigation rate, water supply ratio and production values. It is seen that the total MOM expenses per unit area were lowest at 572 TL ha^{-1} in 2017 and highest at 1382 TL ha^{-1} in 2020 (Table 4). In a study conducted by Akçay (2018), the average value was found to be 58-88 TL ha^{-1} in the irrigation unions located in the Lower Büyük Menderes Basin. In a study they conducted to examine the performance of 23 irrigation networks between 2010 and 2014, Arslan and Değirmenci (2018) reported an average of 123 TL ha^{-1}. Çakmak and Tekiner (2010) stated that the value for the years 2001-2008 in Kepez Irrigation Cooperative was realized between 0.4-193 TL ha^{-1}.

When the total cost values per personnel working in operation and maintenance were examined, it was determined that the lowest was 48323 TL per person in 2017 and the highest was 117120 TL per person in 2020. As shown in Table 4, it is seen that the cost per person is gradually increasing between 2016 and 2020. In a study conducted by Nalbantoğlu and Çakmak (2007) in Akıncı irrigation, they reported that the value was between 1271 and 19987 TL person^{-1} depending on the years.

The fee collection rate results calculated between 2016 and 2020 in Boyalıca Pumped Irrigation are given in Table 4. The maximum collection rate of Boyalıca Pumped irrigation was determined to be100% in 2019 and the minimum was 91.4% in 2018. Beyribey (1997) found an average RO of 36% in irrigation facilities operated by DSI. The study emphasized that after the facilities were transferred to irrigation unions, collection rates increased over 90%. In a study conducted by Kalender (2017), it was reported that the RO for Ilgın Plain Pumped Irrigation Association was between 83.5% and 147%. Molden et al. (1998) stated that collection rates varied between 28% and 139%, and the rate was between 30% and 50% in state-run irrigation systems. The collection rate is an effective parameter for covering total revenue and expenses such as operation, management and maintenance. As the collection rate increases, maintenance and repairs of irrigation and drainage facilities can be carried out on time and the chance of providing a better service increase. In this study, it is seen that the income for Boyalıca Pumped Irrigation in question is at a level that covers its expenses. The average collection rate for the years 2016-2020, when the performance evaluation was made, was 96.6%. In this respect, the Irrigation Association was found successful.

The MOM expense for unit irrigation water diverted to the network is presented in Table 4. The maximum value was recorded in 2020 at 0.182 TL m^{-3}, while the minimum was recorded in 2016 at 0.063 TL m^{-3}. In a study conducted by Kapan (2010) for Asartepe Irrigation, the MOM expense was reported to range from 0.611 to 1.534 TL m^{-3}. Gençoğlu and Değirmenci (2019), in their study on Kırıkhan Irrigation, found the value to be a minimum of 0.011 TL m^{-3} in 2008 and a maximum of 0.006 TL m^{-3} in 2010. Çolak and Çakmak (2018), in their research on DSİ 15th Regional Irrigation Networks in 2016, indicated that the values ranged from 0.100 to 0.290 TL m^{-3}. When compared to other studies, the MOM expense in Boyalıca Pump Irrigation appears to be within normal levels. It's worth noting that these costs can vary based on whether the irrigation water is pumped or gravity-fed. Energy costs are generally expected to be higher in pumping facilities, which can contribute to variations in the MOM expense for unit irrigation water diverted to the network.

The cost recovery ratio values, which are shown as the ratio of user-collected water fees to operation-maintenance-management expenses, are provided in Table 4. According to the research results, in Boyalıca Pump Irrigation, the highest cost recovery ratio value was 286.4% in 2019, while the lowest was 152.1% in 2020.

When examining other studies, it has been reported that cost recovery ratios varied. For example, in the Akıncı irrigation area, it ranged from 2.51% to 10.82% (Nalbantoğlu and Çakmak, 2007), in Konya – Ilgın pump irrigation, it ranged from 42% to 101% (Kalender, 2017), and in Antalya-Aksu plain, it ranged from 59% to 151% (Özbek et al., 2017).

In the context of Boyalıca Pump Irrigation, adherence to the Law on Irrigation Associations No. 6172 in Turkey is crucial. The law specifies that associations managing open irrigation facilities must allocate a minimum of 30% of their income to investment repayments, maintenance, and repair works. Similarly, for associations overseeing pump irrigation facilities, the requirement is at least 15% of the income. This legal framework ensures the financial sustainability of irrigation associations by earmarking funds for essential purposes. Consequently, the case of Boyalıca Pump Irrigation demonstrates compliance with these legal provisions, confirming that revenue generated from water use services is appropriately directed to cover maintenance and repair expenses, as outlined by Law No. 6172.

Table 4. Results of financial efficiency indicators for İznik-Boyalica Irrigation

Years	Total operation, maintenance and management MOM expense (TL)	Number of staff on duty	Fee collection amount (TL)	Accrual amount (TL)	Total MOM costs per unit area (TL ha^{-1})	Total cost per person employed in water delivery (TL $person^{-1}$)	Fee collection ratio (%)	Average revenue per cubic meter of irrigation water supplied (TL m^{-3})	Cost recovery ratio (%)
2016	1520677	30	3136029	3236698	605	50689	96.9	0.080	206.2
2017	1449678	30	3492417	3236848	572	48323	98.5	0.088	240.9
2018	1555856	30	3569295	3905296	610	51862	91.4	0.107	229.4
2019	1555856	30	4456669	4455154	590	51862	100.0	0.063	286.4
2020	3513587	30	5342456	5537254	1382	117120	96.5	0.182	152.1

Agricultural production performance

The total production quantities for the years 2016-2020 in the Boyalıca Pump Irrigation area are provided in Table 5. The highest production quantity in the irrigation area was 30698 tons in 2020, while the lowest production value was 25275 tons in 2016. In a similar study, the annual total agricultural production quantity for the Acıpayam Irrigation Association was reported to be an average of 94078 tons (Cengiz, 2019). Crop patterns, market prices for the years when crops are grown, and yield obtained per unit of irrigated area can all have an impact on agricultural production values.

Table 5. Total annual agricultural production amount

Product	Irrigated area (da)					Yield (kg da^{-1})					Produce amount (ton)				
	Years (20..)					Years (20..)					Years (20..)				
	16	17	18	19	20	16	17	18	19	20	16	17	18	19	20
Vine	1944	1945	1548	1789	1734	2227	2227	2750	2750	2750	4329	4332	4257	4920	4769
Olive	18060	18247	18772	18219	16854	395	395	450	450	450	7134	7208	8447	8199	7584
Fruit + All Kinds of Saplings	3342	3494	3819	4501	4709	2700	2700	2700	2700	2700	9023	9434	10311	12153	12714
All Kinds of Vegetables	1807	1663	1371	1849	2125	2650	2650	2650	2650	2650	4789	4407	3633	4900	5631
Total agricultural production value (ton)											25275	25380	26649	30171	30698

The equivalent gross production values for Boyalıca Pump Irrigation are provided in Table 6. The highest equivalent gross production value was $17643640 in 2018, while the lowest was $13095030 in 2016.

The maximum equivalent gross production value for the irrigation area was $4373 ha^{-1} in 2018, and the minimum was $3245 ha^{-1} in 2016 (Table 6). In a study by Değirmenci (2001) for irrigation systems in Turkey, irrigation area EGPVs were found to be between $1000-$2000 ha^{-1} for 66 irrigation systems, between $2000-$3000 ha^{-1} for 40 irrigation systems, and over $3000 ha^{-1} for 38 irrigation systems. Tanrıverdi et al. (2011) calculated this value to be between $72-$2013 ha^{-1} for some irrigation systems in the country. Nalbantoğlu and Çakmak (2007) reported that the equivalent gross production value for irrigation in the Akıncı irrigation area ranged from $1454 to $2970 ha^{-1}. The focus on high-value crops such as olives, fruits, and vegetables in the study area resulted in higher irrigation area EGPVs compared to the findings of other researchers.

Actual irrigated area equivalent gross production value ranged from a minimum of $5206 ha-1 in 2016 to a maximum of $6916 ha^{-1} in 2018 (Table 6). Tanrıverdi et al. (2011) found the actual irrigated area EGPVs between $449 and $5079 ha^{-1} in various irrigation networks in Turkey. Geçgel et al. (1998) determined that the actual irrigated area EGPV for Alaşehir irrigation ranged from $1675 to $5003 ha^{-1}. The actual irrigated area EGPV obtained from this study isrelatively higher than that reported in other studies.

The results regarding the unit cost of irrigation water delivered to the network in relation to the equivalent gross production values are presented in Table 6. The maximum EGPV for a unit of diverted irrigation water was $1.214 m^{-3} in 2018, while the minimum was $0.676 m^{-3} in 2019. In a study by Tanrıverdi et al. (2011) for some irrigation networks in Turkey, the EGPV for a unit of diverted irrigation water was determined to range from $0.01 to $0.85 m^{-3}. Gençoğlu and Değirmenci (2019) reported that for Kırıkhan irrigation, EGPV for a unit of diverted irrigation water ranged from $0.009 to $0.041 m^{-3} for the years 2009 to 2013. In irrigation systems transferred to associations in Turkey, it has been reported that EGPV for a unit of diverted irrigation water ranged from a maximum of $1.84 to $1.39 m^{-3} and a minimum of $0.20 to $0.80 m^{-3} (Değirmenci, 2001). In Boyalıca Pump Irrigation, the average value of the EGPV for a unit of diverted irrigation water showed a moderate performance at approximately $0.86 per m^{-3}.

Table 6. Indicators regarding equivalent gross production values

Years	Equivalent gross production value (EGPV; $)	Irrigation area EGPV ($ ha^{-1})	Actual irrigated area EGPV ($ ha^{-1})	EGPV for a unit of diverted irrigation water ($ m^{-3})
2016	13095030	3245	5206	0.692
2017	14905184	3694	5880	0.907
2018	17643640	4373	6916	1.214
2019	16605484	4115	6298	0.676
2020	15610641	3869	6140	0.811

Conclusion

The average irrigation rate in Boyalıca pump irrigation was 63.2%. According to DSİ (State Hydraulic Works), irrigation is considered successful if the irrigation rate is above 60%. The average annual water supply rate was 0.71, which indicates that an insufficient amount of water was supplied. The values for annual irrigation water quantity delivered to the irrigated unit area and annual irrigation water quantity delivered to the irrigation unit area are 7317 m^3 ha^{-1} and 4643.9 m^3 ha^{-1}, respectively, and when compared with other studies, they are within normal levels. When examining the financial efficiency averages, the fee collection rate was 95.5%, indicating that during the research period, the income in Boyalıca pump irrigation exceeded the expenses, and the collection was sufficient to cover the operation and maintenance costs. The average operating, maintenance, and management costs per unit area were found to be 751.70 TL ha^{-1}, which are very close to literature values and can be considered normal. The cost recovery rate in the study area was an average of 46.7%, indicating that a significant portion (at least 30%) of the expenses specified in the legislation have been covered. In Boyalıca pump irrigation, the average equivalent gross production value per irrigation area and the average equivalent gross production value per actually irrigated area were 3859 \$ ha^{-1} and 6088 \$ ha^{-1}, respectively. When compared with similar study data, these values are above average in the research area. The average value of equivalent gross production per unit of diverted irrigation water was 0.86 \$ m^{-3}, which is within normal levels compared to the general average of 0.20-1.84 \$ m^{-3} in Turkey.

Research on irrigation performance shows that many irrigation projects in Turkey fail to achieve their set goals, and many facilities are not efficiently operated. As the study results indicate, some performance indicators in the research area did not meet the desired targets. To use water resources more efficiently, activities such as education on water management, crop pattern planning based on market demands, accelerated use of modern technologies in water management, and steps to improve irrigation system performance can be taken. Promoting the cultivation of high-value crops to increase income per unit area and water, proper irrigation scheduling, and selecting a production pattern aligned with market demand are also crucial. Another problem encountered in the research area was the low water supply rate. During periods of inadequate water supply, preference can be given to crops that can rely on natural rainfall in the planned irrigation areas. Regular canal maintenance and the maintenance of damaged irrigation infrastructure can improve the water supply rate. Additionally, moving away from open canal systems in favour of pressurized water distribution networks is the most effective method for water conservation in sustainable irrigation practices. Population growth and climate change are causing water resources to become scarcer, and indiscriminate water use is becoming more common. To address these challenges, government policies and water use should be conducive to water conservation. One practical approach is to analyze the current situation in irrigation systems and take measures accordingly. By evaluating the performance of the systems, the current situation can be determined, and necessary measures can be implemented.

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Author Contributions

All authors have participated in the work and take responsibility for the manuscript content.

Conflicts ofInterests Statement

The authors declare no conflicts of interests.

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