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Production-water user association performance nexus in mediterranean irrigated agriculture: The case of banana in Türkiye

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ABSTRACT

In this study, the relationship between the increasing banana production in the Mediterranean region of Türkiye and the performance of Water User Associations (WUAs) is investigated. The increase in banana production due to economic incentives and nutrient demand has triggered a complex nexus of challenges and opportunities in the context of water resource management. The effect of banana production areas on performance of WUAs has not been studied in the region in terms of statistical evaluation. Principle component analysis sheds light on several critical dimensions, including irrigation water use, methods, management, operation and maintenance costs, production value, and water supply ratio, all of which are affected by the expansion of banana cultivation. The findings underline the urgency of adaptive strategies and sustainable practices within the scope of WUAs to meet the growing demand for irrigation water, promote water-efficient technologies, and mitigate economic and environmental consequences. As a result of the research, it has been observed that increasing banana production areas ensures more efficient use of water, improves performances related to production value, and reduces operating, maintenance, and management costs per unit service area.

1. Introduction

The Mediterranean region, with its different climates and geographical features (Lionello et al., 2006), has long been the cradle of agricultural innovations and adaptations (Abd-Elmabod et al., 2020). Among the many crops grown in this region, banana has emerged as an important player in the field of agriculture (Sgroi et al., 2023). The increase in banana production in the Mediterranean countries (Pinar et al., 2021) has not only provided economic opportunities, but also created significant challenges, especially in the fields of water resource management and irrigation efficiency.

The Mediterranean basin covers a rich tissue of agricultural practices in which ancient traditions are in harmony with modern technologies. Agriculture in this region covers a wide range of ecosystems, from arid coastal plains to fertile valleys, and each of them offers unique opportunities and challenges for planting crop cultivation (Pathirana and Carimi, 2022). The Mediterranean diet, lauded for its health benefits, relies heavily on locally produced fruits and vegetables, with bananas increasingly becoming a staple ingredient. Banana cultivation, although relatively new in the Mediterranean (Fox, 2019), has experienced a significant expansion, changing the agricultural landscape.

Originating from Southeast Asia, bananas found their way to the Mediterranean region during the colonial period (Hancock, 2022). However, in recent years, there has been a significant increase in banana production due to factors such as global demand, advanced varieties, and favourable agricultural climate conditions (Olumba and Onunka, 2020). This increase in banana cultivation has led to an increased dependence on irrigation, the transformation of traditional agricultural practices, and the emergence of multifaceted challenges.

Banana production is important in 130 countries around the world. The main producers of banana producers are India, China, Philippines, and Ecuador; these are the biggest exporters, which provide about 50% of banana fruit to the other countries (Evans and Ballen, 2020; FAOSTAT, 2017). Türkiye is one of the countries where bananas are produced and has a share of 0.02% of worldwide banana production, tries to increase their banana production. The banana harvest area in Türkiye was forecasted to be 9733 ha in 2025 (Eyduran et al., 2020). Banana is mostly cultivated in Anamur, Bozyazı, Alanya, and Gazipaşa besides some towns of Adana, Hatay, Muğla, and Manisa. Climate is an important factor in choosing the crop and its production value.

Irrigation has been the lifeblood of Mediterranean agriculture for thousands of years. The irregular precipitation pattern of the region and

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the hot, dry summer months make irrigation indispensable for crop production (Crovella et al., 2022). Historically, various irrigation systems were developed, including flaps, aqueducts, and terracing, to efficiently use and distribute water. In the modern era, advanced irrigation technologies have been adopted to increase agricultural productivity (Pérez-Blanco et al., 2020). However, the sustainability and performance of irrigation systems are now under scrutiny due to the intensification of agriculture, including banana cultivation.

The intersection of banana production and irrigation (Bridgit and Thomas, 2023) is characterized by a complex network of interdependence. Since banana is a water-intensive plant (Swafo and Dlamini, 2023), it has increased the demand for irrigation water in regions where water resources are mostly limited and exposed to competitive uses. This situation has led to the need for more efficient water management practices and sustainable irrigation methods (Santana Junior et al., 2021) to ensure both agricultural productivity and the protection of water resources. The complex nature of this connection requires a closer examination of the basic dimensions.

Efficient water use in banana cultivation is of vital importance not only in terms of optimizing yield, but also in terms of minimizing environmental impacts. The adoption of precision irrigation methods, such as drip or sprinkler systems, can significantly improve the efficiency of water use (Sekaran et al., 2020; Panigrahi et al., 2021; Yadav et al., 2022). However, the extent to which these technologies are adopted and their effects on banana production need to be investigated in depth.

Banana production in the Mediterranean has socio-economic implications that extend beyond agricultural production. It provides employment opportunities, provides income for rural communities, and contributes to export earnings. Conversely, dependence on irrigation for banana cultivation can strain local water resources, potentially leading to conflicts over water allocation and emphasizing the need for equitable water distribution.

The increase in banana production in the irrigated Mediterranean agriculture (Arslan and Kartal, 2023; Atilgan et al., 2023) has raised concerns about the environmental footprint. Land use changes associated with excessive water use, the application of agricultural chemicals, and banana cultivation can have negative effects on soil health, water quality, and biodiversity. Sustainable agricultural practices and environmental protections (Waseem et al., 2020) are vital to reducing these impacts.

Water User Associations (WUAs) play a pivotal role in Mediterranean irrigated agriculture (Zema et al., 2020; González-Pavón et al., 2020; Alcon et al., 2022), particularly in regions where tropical fruits are cultivated (Arslan and Kartal, 2023). These associations are essential in promoting efficient water management practices that are critical for sustaining the water-intensive cultivation of crops like tropical fruits. The primary purpose of WUAs in this context is to facilitate collective decision-making among water users, which includes farmers, agricultural cooperatives, and other stakeholders (Arslan et al., 2023). By fostering collaboration and communication, WUAs enable the equitable distribution of available water resources, a crucial factor in ensuring the viability of agricultural production.

Moreover, WUAs contribute to sustainable water management by promoting responsible water use practices and the reduction of wastage. They often develop rules and regulations to ensure fair water distribution, maintenance of infrastructure, and monitoring of water consumption. In regions where water resources are limited, effective water management is imperative not only for agricultural production but also for mitigating the environmental impacts associated with excessive water extraction. WUAs help balance the demands of tropical fruit cultivation with the broader ecosystem's need for water, thereby addressing sustainability concerns. WUAs can foster knowledge sharing and capacity building among farmers, providing training and educational resources to enhance water-efficient farming techniques. By disseminating best practices and offering guidance on irrigation scheduling and water-saving technologies, WUAs can empower agricultural communities to adapt to the challenges of a changing climate and evolving water resource constraints.

Performance indicators are essential tools in evaluating the effectiveness and functionality of WUAs within the context of water resource management (Bastiaanssen and Bos, 1999; Rodríguez-Díaz et al., 2008; Ntantos and Karpouzos, 2010; Seyedzadeh et al., 2022). These indicators, whether quantitative or qualitative, are used to systematically assess the performance of WUAs and their ability to fulfil their designated roles. The need for performance indicators arises from several factors. Firstly, they provide a standardized framework for measuring and comparing the achievements and shortcomings of different WUAs, enabling stakeholders, including government agencies and funding organizations, to make informed decisions and allocate resources efficiently. Secondly, these indicators promote transparency and accountability within WUAs, ensuring that their actions are aligned with the expectations of the communities they serve. Lastly, performance indicators facilitate continuous improvement by offering feedback that can guide adaptive management strategies, helping WUAs evolve and enhance their capacity to address the dynamic challenges associated with water resource management.

While the existing literature provides insights into the water management challenges in Mediterranean regions and the role of WUAs, there is a notable gap in the specific examination of how the proliferation of tropical fruit crops, such as bananas, influences water resource management within these associations. Few studies have explored the nuanced interactions between crop patterns, particularly the shift towards water-intensive tropical fruits, and the adaptive strategies adopted by WUAs to cope with increasing water demand in Türkiye (Arslan, 2022; Arslan and Kartal, 2023). As the Mediterranean climate continues to face water scarcity issues aggravated by climate change, understanding the implications of changing crop patterns on water management strategies is essential for ensuring the resilience and sustainability of agricultural practices in the region. Therefore, further research is needed to delve into the intricacies of this dynamic relationship and to provide actionable insights for policymakers, water authorities, and farmers alike.

This study aims to explores the relationship between banana production and irrigation performance in Mediterranean region of Türkiye. It also aims to achieve the following research goals by aiming to reveal the challenges and opportunities posed by the expansion of banana cultivation in the irrigated regions within 3 WUAs. In pursuit of these goals, this research aiming to offer a comprehensive insight into the interplay between banana production and performance, shedding light on the challenges and opportunities related to sustainable agricultural development in this dynamic region.

2. Material and method

2.1. Case study

Anamur, Bozyazı, and Alanya Water User Associations were chosen as material to assess the relation between banana production and performance indicators. The data on WUAs was obtained as the annual reports between 2006 and 2021 from State Hyraulic Works (DSI-Devlet Su İşleri). The region is mostly under Mediterranean Climate (mild winters and hot summers), however, a sub-tropical climate (extremely hot and humid) is dominant in the study area, which is the coastline between Alanya and Anamur. In the area, bananas can be cultivated in the fields and greenhouses. The location of selected WUAs within the region is given in Fig. 1.

The main characteristics of WUAs are given in Table 1. Irrigation methods used and main crops data belong to recent years. Banana production in irrigated areas has increased year by year. Farmers tend to cultivate crops according to their production value a year before in the region (DSI, 2022); therefore, bananas become more popular in the

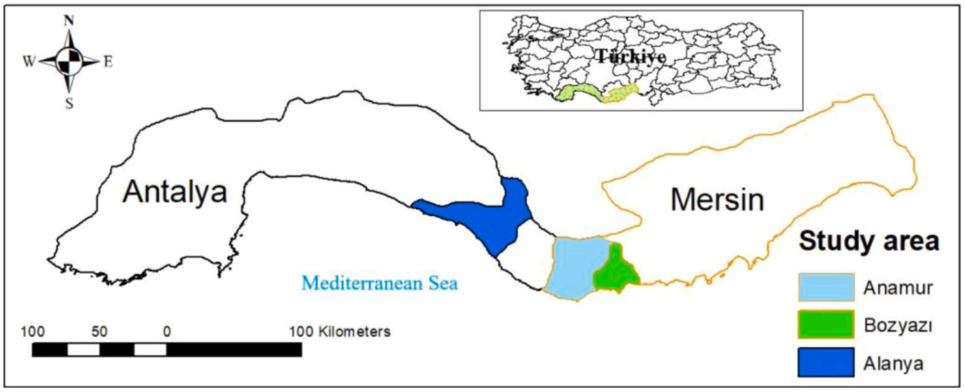

Fig. 1. Study area.

Table 1
Main characteristics of selected WUAs.

WUAs	Anamur	Bozyazı	Alanya
Service area (ha)	3027	1370	1100
Water diversion	Gravity	Gravity	Gravity+pumped
Irrigation method used	Drip (40%), sprinkler (58%)	Sprinkler (70%), drip (16%)	Surface (76%), drip (24%)
Main crops (2021	Banana (54%), strawberry (23%)	Banana (70%), vegetables (15%)	Citrus (56%), Banana (37%)
Water resource	Dragon river	Sini river	Dim river

region year by year. Drip irrigation technology as well as micro-sprinkler irrigation have been adopted by producers for banana cultivation. Farmers more tend to adapt new technologies to increase tropical fruits.

3. Performance indicators

The selected performance indicators showing the performance of water user associations are given in Table 2. The service area shows the total command area of the WUA, and the irrigated area shows the area of irrigation service given. Irrigation ratio shows the ratio of irrigated area to responsible WUA. The ratio may differ according to precipitation conditions in the region. Annual water consumption per unit irrigated area is an important indicator for rapid assessment of the WUA. Another water supply ratio which is unitless, illustrates if the WUA uses more than the total water requirement (evaporation/water efficiency of the system) or not. Evaporation in the field is calculated with the help of CROPWAT by technicians working in the WUA responsible to DSI. Annual operation and maintenance (OM) cost per unit service area may give information on cost modernization, repair, cleaning, distribution of water to farmers expenses etc. Another similar indicator is the annual management, operation and maintenance (MOM) costs per unit area helps researchers to understand the share of management on per unit service area. Annual OM and MOM cost per unit of irrigation water are also indicators that some researchers have been working on and gives information on expenses of per unit water. Output is the annual production value in the irrigated area, is mostly related with crop pattern. The currency changed from Turkish Lira to Euro according to Turkish Central Bank data for each year. And banana production area is the indicator which is the main topic of the study effects on the other indicators. The selection of these indicators is primarily driven by the increase in banana production, impacting various aspects such as water usage, MOM, and production value. This influence underscores the significance of these chosen indicators in our assessment.

Table 2
Calculation of selected performance indicators (Zema et al., 2015; Alcon et al., 2017; Kartal et al., 2020; Alcon et al., 2020).

Indicator	Abbreviation	Formula
Irrigation ratio (%)	IR	$\frac{irrgated\ area}{Service\ area} x100$
Annual volume of water per unit service area (m^3 ha^{-1})	watService	$\frac{annual\ volume\ of\ water\ diverted}{service\ area}$
Annual volume of water per unit irrigated area (m^3 ha^{-1})	watIrrigated	$\frac{annual\ volume\ of\ water\ diverted}{irrigated\ area}$
Water supply ratio	WSR	$\frac{annual\ volume\ of\ water\ diverted}{total\ water\ requirement\ of\ irrigated\ crops}$
Annual OM cost per unit service area (€ ha^{-1})	serviceOM	$\frac{annual\ OM\ cost}{service\ area}$
Annual MOM cost per unit service area (€ ha^{-1})	serviceMOM	$\frac{annual\ MOM\ cost}{service\ area}$
Annual OM cost per unit irrigation water (€ m^{-3})	waterOM	$\frac{annual\ OM\ cost}{annual\ volume\ of\ water\ diverted}$
Annual MOM cost per unit irrigation water (€ m^{-3})	waterMOM	$\frac{annual\ MOM\ cost}{annual\ volume\ of\ water\ diverted}$
Output per unit irrigated area (€ ha^{-1})	outputArea	$\frac{annual\ output}{irrigated\ area}$
Output per unit irrigation water (€ m^{-3})	outputWater	$\frac{annual\ output}{annual\ volume\ of\ water\ diverted}$
Banana production area (%)	bananaArea	$\frac{banana\ production\ area}{irrigated\ area} x100$

4. Statistical assessment

Principle component analysis (PCA) and a correlation matrix were used to investigate the data in terms of statistical relations between banana production and the other performance indicators using statistical package programs. The data were evaluated all together for all WUAs for statistical evaluations (Özdamar, 2010; Alpar, 2017) to assess of the performance indicators. PCA was conducted following the procedure outlined by Còrcoles et al., (2010) and Zema et al. (2015). The steps included standardizing the performance indicators to achieve a zero mean and unit variance in the original data matrix, computing the correlation matrix to assess correlations between the indicators, determining the percentage of variance explained, and selecting the principal components (PCs). The Varimax rotation method (Richman, 1986; Özdamar, 2010; Zema et al., 2015) was then run to compute the rotated component matrix, as it is widely used for its ability to reduce the variance of data projections onto the rotated axes. Finally, we selected the principal components that accounted for at least 70% of the original variance in the study.

5. Result and discussion

5.1. Result

Banana production area has increased in all WUAs by 2021. After 2013, Bozyazı WUA has increased its banana production area more than 50% and Anamur catch the same level in 2020. The result illustrates that banana production increase its popularity in crop pattern chosen by the farmers within WUA' irrigated areas. Banana production in Anamur, Bozyazı and Alanya WUA in years were given in Fig. 2.

Summary statistics of performance indicators for the study period are given in Table 3. The irrigation ratio shows the area which irrigated with WUAs' facilities. In the study period (2006–2021), not-irrigated areas show there is no demand for water in the way that precipitation is considered enough for the crops by farmers.

The annual volume of irrigation water per unit service area (watService) shows if WUA irrigates all area by itself. However, the annual volume of irrigation water per unit irrigated area (watIrrigated) illustrates the water distributed by WUA itself. The mean value of watIrrigated was found to be 14280.71 m^3 ha^{-1} on during the study period. The value reached a maximum value of 37627.91 m^3 ha^{-1} and the min value of 6421.31 m^3 ha^{-1} showed the irrigation supply inconsistency among WUAs. The mean WSR (1.51) indicates water used more than crop water requirement, Bozyazı WUA had the maximum value (6.24) of WSR that shows irrigation water was supplied about 6 times more than crop water requirement. The indicator value decreased by banana production area increased within the years together with irrigation ratio for the WUA.

The mean annual cost of operation and maintenance (serviceOM) is 151.77 € ha^{-1} and the mean annual total cost per unit service area (serviceMOM) is 522.85 € ha^{-1}. The mean operation and maintenance cost per unit irrigation water (waterOM) and the mean total cost per unit irrigation water (waterMOM) were found to be 0.02 € m^{-3} and 0.07 € m^{-3}, respectively.

Table 3
Summary statistics of indicators.

Indicator	Mean	St. Dev.	Min	Max
IR	67.71	11.30	52.41	97.30
watService	9482.92	4323.83	4722.83	26726.13
watIrrigated	14280.79	6421.31	5942.62	37627.91
WSR	1.51	1.25	0.50	6.24
serviceOM	151.77	130.38	20.62	758.70
serviceMOM	522.85	204.58	250.63	1346.72
waterOM	0.02	0.02	0.002	0.08
waterMOM	0.07	0.03	0.01	0.14
outputArea	1714.19	890.50	405.98	3994.97
outputWater	0.13	0.07	0.02	0.28
bananaArea	35.52	19.97	2.00	78.00

The mean output per unit irrigated area (outputArea) and the mean output per unit irrigation water (outputWater) were found to be 1714.19 € ha^{-1} and 0.13 € m^{-3}, respectively. The banana production increased the production value in irrigated areas in all WUAs. The mean banana production in all WUAs was 35.52% and the maximum rate reached the level approximately 78% in Bozyazı WUA.

6. Statistical evaluation

The correlation among indicators is given in Table 4. A negative significant correlation was found between banana production area and water supply ratio (r: −0.61; $p < 0.01$). Banana production is also

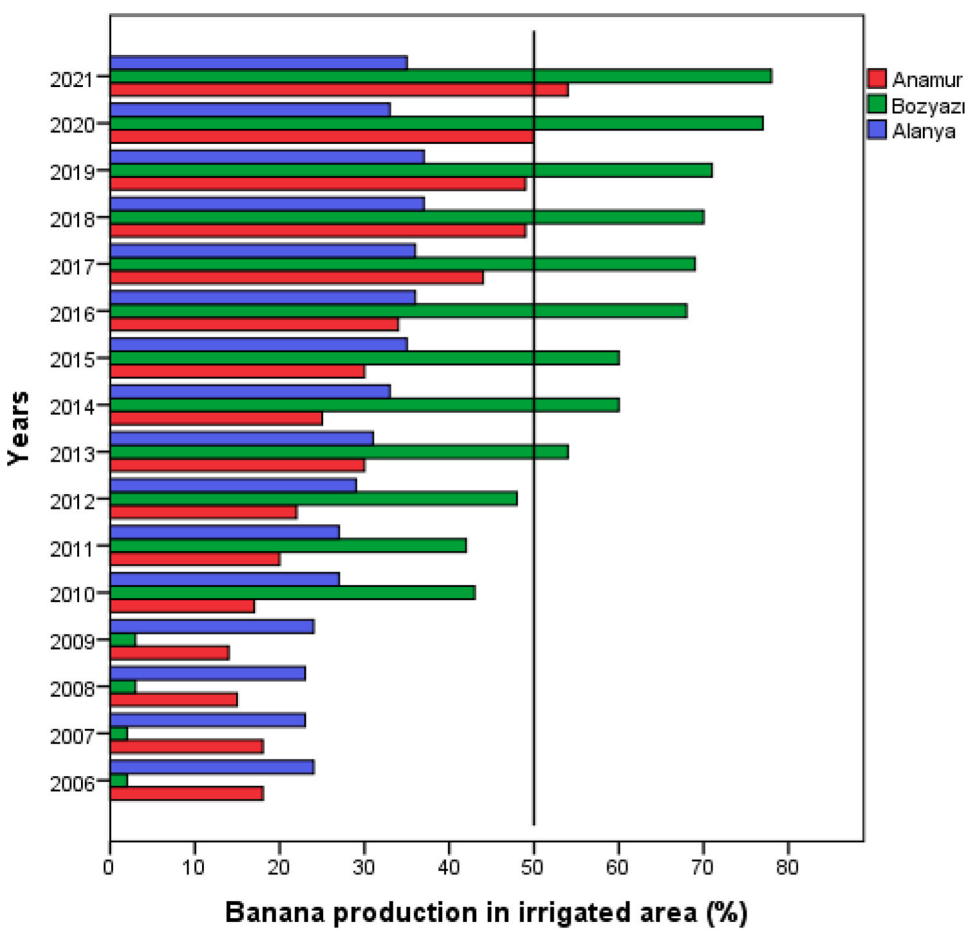

Fig. 2. Banana production area in irrigated area.

Table 4
Correlation among indicators.

	IR	watService	watIrrigated	WSR	serviceOM	serviceMOM	waterOM	waterMOM	outputArea	outputWater	bananaArea
IR	1	.13	-.26	.09	.08	.33*	.107	.26	-.42**	-.09	-.28
watService		1	.92**	.83**	-.19	-.21	-.41**	-.65**	.03	-.46**	-.27
watIrrigated			1	.75**	-.22	-.33*	-.44**	-.73**	.21	-.41**	-.14
WSR				1	-.15	-.22	-.32*	-.53**	-.24	-.56**	**-.61****
serviceOM					1	.82**	.93**	.60**	-.30*	-.24	-.10
serviceMOM						1	.77**	.78**	-.32*	-.07	**-.31***
waterOM							1	.78**	-.39**	-.18	-.06
waterMOM								1	-.36*	.17	-.16
outputArea									1	.73**	**.65****
outputWater										1	**.52****
bananaArea											1

* Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level.

correlated with output per unit irrigated area (r: 0.65; $p < 0.05$) and output per unit irrigation water (r: 0.52; $p < 0.05$).

To test if the data set is applicable for principal component analysis, Kaiser-Meyer-Olkin (KMO) test was run, and the p-value was found to be less than 0.01. The eigenvalues of the correlation matrix show the percentages of the variance, see Table 1 in supplementary material. given in Table. The cumulative percentage of the first two components is 71.10% which was selected to explain variance. According to Özdamar (2010) and Alpar (2017), values of the percentage of variance are above 67% are acceptable.

In principle component analysis, first two components' coefficients were given in Table 2 in supplementary material. According to the first two components, the biplot graph was extracted and given in Fig. 3.

Water User Associations are not located close to the vector endpoints. The WUAs closest to the vector endpoint can be associated with Bozyazı and Anamur, with watService and watIrrigated. The Alanya WUA is grouped together primarily due to similarities in OM and MOM related indicators. Anamur and Bozyazı WUAs exhibit similarities in some years when examining the waterIrrigated and outputArea indicators. Lines drawn from observations (indicators) to any variable at a 90-degree angle provide information about the proximity (or distance) of the indicators at the relevant variable angle. The angle between BananaArea, outputArea, and outputWater indicates a positive correlation among these three indicators. Therefore, considering that the banana production value is high, an increase in outputArea is positively influenced by the increase in BananaArea. On the other hand, the outputWater indicator, while positively correlated with BananaArea, is also related to the amount of water consumed. The angle between bananaArea and WSR being close to 180 degrees indicates a negative correlation. Since the average value of WUAs is greater than 1 in all years, this situation is considered positive.

7. Discussion

In the study, we present the implementation of performance indicators on the irrigation schemes managed by WUAs in a part of the Mediterranean region of Türkiye, where banana production areas are increasing due to the particularly high production value of bananas. In the study area, overall IR has changed from 67.71% to 97.30%. The values show lower performance when compared with the mean Turkish WUAs' IR which is about 70% (DSI, 2022). IR is a ratio that show the service given to farmers and is used to evaluate the efficiency and effectiveness of irrigation schemes. An IR of under 100% doesn't mean all plants are not receiving enough water thanks to precipitation or individual unground water usage.

Banana evapotranspiration is about 9000–12000 m^3 ha^{-1} for all production periods (Agritech, 2023). Water requirements differ from plans; however, average watIrrigated is above the peak irrigation requirement. The Mediterranean climate necessitates extensive irrigation to support agricultural activities especially where tropical fruits are cultivated. The mean water supply ratio (WSR), which is higher than 1 (the optimum value) is another indicator showing water was used more than the water requirement. Achieving this optimum ratio and reduce value of watIrrigated can be accomplished through a combination of

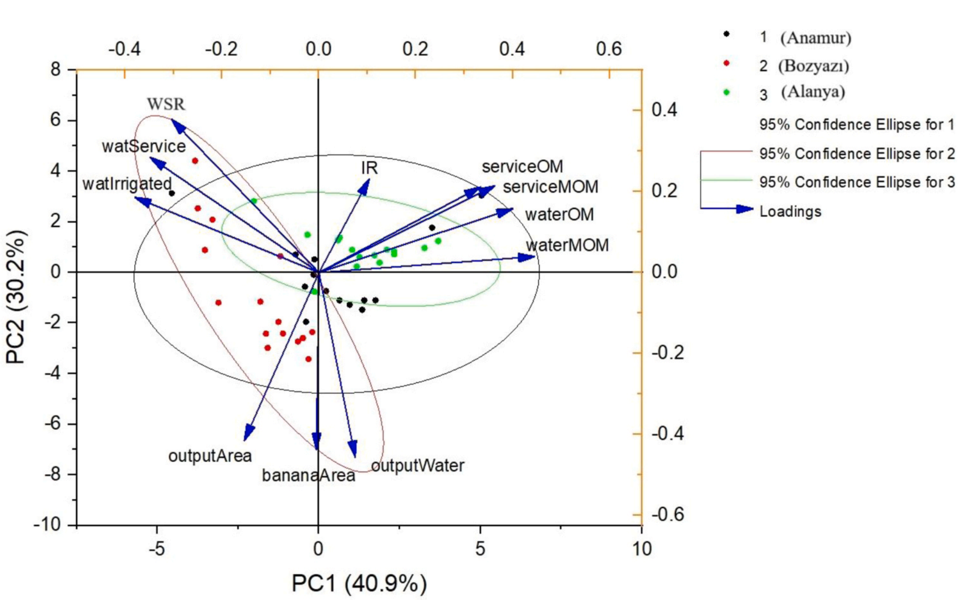

Fig. 3. PCA biplot graph.

technological, agronomic, and policy measures. For example, a WUA uses irrigation water more than 6 times, mangers can focus on the reasons and focus on the problems that can be solved by farmer-oriented management. The education of the farmers is always a key factor adapting the new technologies which can help reduce water usage. The aspect of the value of IR under 100% and the value of WSR above 1 show that water is used excessively, and the mean value of watIrrigated support the phenomenon in the region. Water pricing mechanisms and regulatory frameworks can also incentivize water-saving practices and discourage excessive use. In some countries, irrigation water can be sold with a price gradually increasing to save water by farmers their self.

Statistical analysis reveals a compelling relationship between the increase in banana production and the increased irrigation water use in Irrigation Associations. Since banana cultivation is water-intensive by nature (Ayenew, 2007), it puts significant pressure on existing water resources in the region (van Asten et al., 2011). The findings show that WUAs need to adapt to this increasing demand quickly by implementing efficient water allocation strategies and exploring alternative water sources to ensure fair distribution (Jeyabaskaran and Uma, 2020).

The results highlight a remarkable change in irrigation methods within WUAs as banana production increases. Traditional irrigation methods are increasingly being replaced by more efficient techniques such as drip or sprinkler systems. These modern methods not only save water, but also increase crop yields (Arslan and Kartal, 2023). Setting up modern technology in irrigated areas is not efficient without farmer-oriented management. The study results underline the role of WUAs in facilitating the transition to sustainable irrigation practices to challenge increasing water demand (Kartal and Arslan, 2021; Kartal et al., 2023).

Banana cultivation can affect other agricultural activities and ecosystems by straining local water resources. In order to ensure sustainability and prevent overuse of water resources, WUAs should actively assess and manage these changes in the water supply ratio. It is vital to balance the needs of different crops and sectors (Zema et al., 2020; Rathod and Gavali, 2021).

The swift expansion of crops with high water demand poses a formidable challenge (Kourgialas and Dokou, 2021) for WUAs, necessitating a heightened focus on enhancing the efficiency of irrigation water management in dry areas such as Mediterranean Region. For instance, banana production in certain regions of Türkiye (Arslan and Kartal, 2023), requires substantial water resources, and as the cultivation area expands, it exerts increased pressure on local water sources. In response, WUAs find themselves compelled to implement measures that transcend the boundaries of specific crops, emphasizing the critical importance of devising comprehensive strategies to manage water resources efficiently. Farmer-oriented adaptation strategies play an important role in terms of using modern irrigation techniques. Where WUAs (Ouassanouan et al., 2022) are not developed and farmers (Banerjee, 2015; Dono et al., 2016) are not willing to adapt new technologies are not recommended areas for cultivation of high-water demand crops. The case of banana production in Türkiye exemplifies a larger trend wherein the rapid expansion of water-intensive crops demands a holistic approach to irrigation water management, urging WUAs to adapt and innovate to ensure long-term sustainability.

The recommendation against the widespread adoption of high-water demand crops stems from the inherent strain they impose on water resources, often leading to environmental degradation and exacerbating water scarcity issues (Noto et al., 2023). Such crops not only place stress on local ecosystems but also challenge the resilience of communities dependent on the same water sources for various purposes. Considering increasing concerns about global water scarcity (Neira et al., 2023), it becomes imperative to discourage the cultivation of crops with high water demand. Instead, promoting the cultivation of more water-efficient crops, implementing advanced irrigation technologies, and encouraging sustainable agricultural practices contribute to a more resilient and resource-conscious agricultural landscape (Vadez et al., 2023).

8. Conclusion

The main aim of the study was to investigate the relation of banana production increase and performance indicator nexus in Mediterranean region of Türkiye and 3 WUAs where the fruit production has been dramatically increasing were chosen as material. As a result, the developing banana production in the Mediterranean region of Türkiye has revealed a multifaceted dynamic that has far-reaching effects on the performance of Water User Associations. The study illuminates the complex interaction between banana cultivation and Water User Associations in critical dimensions, including irrigation water use, management, operation, maintenance costs, production value, and water supply ratio. In the study years, it is observed that inconsistent water distribution may indicate management problems to achieve adaptation of water scarcity in the region. However, usage of modern irrigation technologies such as drip and sprinkler were increased by banana production area increase. The indicator values prove that irrigation water was used excessively and may indicate management and operation and farmers' irrigation application problems. Future projections of banana production show the tropical fruits such as banana, avocado, mango etc. gains its popularity in the region due to production value and climate adaptation. Thus, there is a need efficient agricultural water management to protect sustainable agriculture. For example, farmers, using modern technologies such as drip and sprinkler irrigation methods, need to adapt measuring systems to save water or new water pricing methods that increasing double when reach out of peak water requirement level. Demand for bananas continues to grow, and the study highlight the vital importance of adaptation of tropical fruits by WUAs can be achieved by farmer-oriented irrigation management programs in the region.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.agwat.2023.108650.

References

Abd-Elmabod, S.K., Muñoz-Rojas, M., Jordán, A., Anaya-Romero, M., Phillips, J.D., Jones, L., de la Rosa, D., 2020. Climate change impacts on agricultural suitability and yield reduction in a Mediterranean region. Geoderma 374, 114453.
Agritech. 2023. Expert Systems for Banana, Irrigation Management. URL: ⟨http://www.agritech.tnau.ac.in/expert_system/banana/irrigationmanagement.html⟩.
Alcon, F., García-Bastida, P.A., Soto-García, M., Martínez-Alvarez, V., Martin-Gorriz, B., Baille, A., 2017. Explaining the performance of irrigation communities in a water-scarce region. Irrig. Sci. 35, 193–203.
Alcon, F., Zabala, J.A., Martínez-García, V., Albaladejo, J.A., López-Becerra, E.I., De-Miguel, M.D., Martínez-Paz, J.M., 2022. The social wellbeing of irrigation water. A demand-side integrated valuation in a Mediterranean agroecosystem. Agric. Water Manag. 262, 107400.
Alpar, C. 2017. Uygulamalı çok değişkenli istatistiksel yöntemler. Detay Yayıncılık, Ankara, Türkiye.
Arslan, F. 2022. Muz (Musa Spp.) Özellikleri ve Sulama Yönetimi. Ziraat & Orman, Su Ürünlerinde Araştırma ve Değerlendirmeler - Aralık 2022, p. 222–230.
Arslan, F., Kartal, S., 2023. Water Management Effect On Tropical Fruits: Case Study Of Alanya, Turkey. Engineering For Rural Development, Jelgava, pp. 533–538.
Arslan, F., Córcoles Tendero, J.I., Rodríguez Díaz, J.A., Zema, D.A., 2023. Comparison of irrigation management in water user associations of Italy, Spain and Turkey using benchmarking techniques. Water Resour. Manag. 37 (1), 55–74.

Atilgan, A., Krakowiak-Bal, A., Ertop, H., Saltuk, B., Malinowski, M., 2023. The energy potential of waste from banana production: a case study of the mediterranean region. Energies 16 (14), 5244.
Ayenew, T., 2007. Water management problems in the Ethiopian rift: challenges for development. J. Afr. Earth Sci. 48 (2-3), 222–236.
Banerjee, R.R., 2015. Farmers' perception of climate change, impact and adaptation strategies: a case study of four villages in the semi-arid regions of India. Nat. Hazards 75, 2829–2845.
Bastiaanssen, W.G., Bos, M.G., 1999. Irrigation performance indicators based on remotely sensed data: a review of literature. Irrig. Drain. Syst. 13, 291–311.
Bridgit, T.K., Thomas, D., 2023. System intensification for enhanced productivity and water use efficiency in Banana [Musa (AAB) nendran]. Agric. Rev. 44 (1), 119–123.
Crovella, T., Paiano, A., Lagioia, G., 2022. A meso-level water use assessment in the Mediterranean agriculture. Mult. Appl. Water Footpr. some Tradit. Crops J. Clean. Prod. 330, 129886.
Dono, G., Cortignani, R., Dell'Unto, D., Deligios, P., Doro, L., Lacetera, N., Roggero, P.P., 2016. Winners and losers from climate change in agriculture: insights from a case study in the Mediterranean basin. Agric. Syst. 147, 65–75.
DSI. 2022. Sulama Birlikleri İzleme ve Değerlendirme Raporu 2022. Devlet Su İşleri Genel Müdürlüğü. Ankara, Türkiye.
Evans, E.A., Ballen, F.H., 2020. Banana production, global trade, consumption trends, postharvest handling, and processing. Handb. Banana Prod. Postharvest Sci. Process. Technol. Nutr. 1–18.
Eyduran, S.P., Akın, M., Eyduran, E., Çelik, Ş., Ertürk, Y.E., Ercişli, S., 2020. Forecasting banana harvest area and production in Turkey using time series analysis. Erwerbs-Obstbau 62 (3), 281–291.
FAOSTAT. 2017. Statistical database of the food and agriculture organization of the united nations (⟨http://faostat.fao.org/⟩).
Fox, R.L., 2019. Banana. Detecting Mineral Nutrient Deficiencies in Tropical and Temperate Crops. CRC Press, pp. 337–353.
González-Pavón, C., Arviza-Valverde, J., Balbastre-Peralta, I., Carot Sierra, J.M., Palau-Salvador, G., 2020. Are water user associations prepared for a second-generation modernization? The case of the valencian community (Spain). Water 12 (8), 2136.
Hancock, J., 2022. Origins of world agriculture. World Hist. Encycl. 2.
Jeyabaskaran, K.J., Uma, S., 2020. Water management for high productivity in banana. Int. J. Innov. Hortic. 9 (2), 95–103.
Kartal, S., Arslan, F., 2021. Comparison of methods used in predicting irrigation performance indicators. Turk. J. Agric. For. 45 (5), 634–641.
Kartal, S., Değirmenci, H., Arslan, F., Gizlenci, İ., 2023. Evaluation of some water, energy and financial indicators: a case study of esenli water user association in yozgat, Türkiye. J. Agric. Sci. 29 (2), 643–654.
Kourgialas, N.N., Dokou, Z., 2021. Water management and salinity adaptation approaches of Avocado trees: a review for hot-summer Mediterranean climate. Agric. Water Manag. 252, 106923.
Lionello, P., Malanotte-Rizzoli, P., Boscolo, R., Alpert, P., Artale, V., Li, L., Xoplaki, E., 2006. The Mediterranean climate: an overview of the main characteristics and issues. Dev. Earth Environ. Sci. 4, 1–26.
Neira, M., Erguler, K., Ahmady-Birgani, H., Al-Hmoud, N.D., Fears, R., Gogos, C., Christophides, G., 2023. Climate change and human health in the Eastern Mediterranean and Middle East: literature review research priorities and policy suggestions. Environ. Res. 216, 114537.
Noto, L.V., Cipolla, G., Francipane, A., Pumo, D., 2023. Climate change in the mediterranean basin (part I): Induced alterations on climate forcings and hydrological processes. Water Resour. Manag. 37 (6-7), 2287–2305.
Ntantos, P.N., Karpouzos, D.K., 2010. Application of data envelopment analysis and performance indicators to irrigation systems in Thessaloniki Plain (Greece). Int. J. Agric. Biosyst. Eng. 4 (10), 714–720.
Olumba, C.C., Onunka, C.N., 2020. Banana and plantain in West Africa: production and marketing. Afr. J. Food Agric. Nutr. Dev. 20 (2), 15474–15489.
Ouassanouan, Y., Fakir, Y., Simonneaux, V., Kharrou, M.H., Bouimouass, H., Najar, I., Chehbouni, A., 2022. Multi-decadal analysis of water resources and agricultural change in a Mediterranean semiarid irrigated piedmont under water scarcity and human interaction. Sci. Total Environ. 834, 155328.
Özdamar, K. 2010. Paket programlar ile istatistiksel veri analizi II (çok değişkenli analizler)[Statistical data analysis with package programs II (multivariate analysis)], Kaan Kitabevi, 7. Baskı, Eskişehir.
Panigrahi, N., Thompson, A.J., Zubelzu, S., Knox, J.W., 2021. Identifying opportunities to improve management of water stress in banana production. Sci. Hortic. 276, 109735.
Pathirana, R., Carimi, F., 2022. Management and utilization of plant genetic resources for a sustainable agriculture. Plants 11 (15), 2038.
Pérez-Blanco, C.D., Hrast-Essenfelder, A., Perry, C., 2020. Irrigation technology and water conservation: a review of the theory and evidence. Rev. Environ. Econ. Policy.
Pinar, H., Bircan, M., Unlu, M., Turkay, C., Uzun, A., Ercisli, S., Hanci, F., 2021. Selection and identification of superior banana phenotypes from Turkey. Genet. Resour. Crop Evol. 68, 667–677.
Rathod, S.R., Gavali, A.V., 2021. Economic analysis of banana production from Western Maharashtra. Pharma Innov. J. 10 (8), 379–384.
Rodríguez-Díaz, J.A., Camacho-Poyato, E., Lopez-Luque, R., Pérez-Urrestarazu, L., 2008. Benchmarking and multivariate data analysis techniques for improving the efficiency of irrigation districts: an application in Spain. Agric. Syst. 96 (1-3), 250–259.
Santana Junior, E.B., Coelho, E.F., Santos, M.R.D., da Silva, A.J., Reis, J.B.D.S., Pereira, B.L.D.S., 2021. Management of trickle irrigation for banana: hydrodynamic processes and sensor placement at the root zone. Rev. Bras. De. Eng. Agríc. e Ambient. 25, 312–318.
Sekaran, K., Meqdad, M.N., Kumar, P., Rajan, S., Kadry, S., 2020. Smart agriculture management system using internet of things. TELKOMNIKA (Telecommun. Comput. Electron. Control) 18 (3), 1275–1284.
Seyedzadeh, A., Khazaee, P., Siosemardeh, A., Maroufpoor, E., 2022. Irrigation management evaluation of multiple irrigation methods using performance indicators. ISH J. Hydraul. Eng. 28 (3), 303–312.
Sgroi, F., Modica, F., Sciortino, C., Fusté-Forné, F., 2023. Changing crops, changing diets: consumers' purchase intention of Sicilian tropical fruits. Int. J. Gastron. Food Sci. 33, 100777.
Vadez, V., Pilloni, R., Grondin, A., Hajjarpoor, A., Belhouchette, H., Brouziyne, Y., Bossuet, J., 2023. Water use efficiency across scales: from genes to landscapes. J. Exp. Bot. 74 (16), 4770–4788.
van Asten, P.J., Fermont, A.M., Taulya, G., 2011. Drought is a major yield loss factor for rainfed East African highland banana. Agric. Water Manag. 98 (4), 541–552.
Waseem, R., Mwalupaso, G.E., Waseem, F., Khan, H., Panhwar, G.M., Shi, Y., 2020. Adoption of sustainable agriculture practices in banana farm production: A study from the Sindh Region of Pakistan. Int. J. Environ. Res. Public Health 17 (10), 3714.
Yadav, A., Sharma, N., Upreti, H., Singhal, G.D., 2022. Techno-economic analysis of irrigation systems for efficient water use in the backdrop of climate change. Curr. Sci. 122, 664–673.
Zema, D.A., Nicotra, A., Tamburino, V., Zimbone, S.M., 2015. Performance assessment of collective irrigation in water users' Associations of Calabria (Southern Italy). Irrig. Drain. 64 (3), 314–325.
Zema, D.A., Filianoti, P., D'Agostino, D., Labate, A., Lucas-Borja, M.E., Nicotra, A., Zimbone, S.M., 2020. Analyzing the performances of water user associations to increase the irrigation sustainability: an application of multivariate statistics to a case study in Italy. Sustainability 12 (16), 6327.