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Sustainability of collective irrigation under water competition between agriculture and civil uses: The case study of Alanya Water Users Association (Türkiye)

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ABSTRACT

This study explores the patterns of sustainable use and management of competing water sectors in the Alanya Water Users Association (WUA) in Southern Türkiye, over eight years (2013–2020) before the SARS-CoV-19 pandemic, focusing on the impacts of the recorded huge growth of tourism. Performance indicators of collective irrigation services are used to identify performance patterns and trends over time. The analysis has revealed a notable increase in water consumption for agricultural activities (+30 %), driven by the cultivation of tropical fruits, without a proportional rise in crop production. Concurrently, effective financial management is observed in the WUA, with a consistent reduction in unit Management, Operation and Maintenance costs (-40–70 %). Additionally, the total water demand has surged (+100 %) due to population growth and tourist flux. However, this increase has tensioned water delivery to crops, indicating higher pressures over water availability for all uses. The study has identified three distinct patterns in the technical, financial, and socio-economic performance of the WUA, particularly highlighting the last four years of increased water usage and the disruption caused by the SARS-CoV-19 pandemic in 2020. Despite the current adequacy of water resources, optimized strategies for water management are advocated to address anticipated demographic growth, the introduction of tropical crops and the environmental impacts of climate change.

1. Introduction

As the global population is rapidly growing and climate patterns are undergoing unprecedented changes, the sustainable allocation, use and conservation of freshwater resources have emerged as the most important imperatives (Maja and Ayano, 2021). Therefore, water management has become a mandatory aspect of contemporary social and environmental concerns (Playán and Mateos, 2006). Effective water management strategies serve as the basis for ensuring access to clean drinking water for billions of people and play an important role in protecting ecosystems, promoting food security and mitigating the effects of climate change (Shahzad et al., 2021). According to the FAO report 'Water for Sustainable Food and Agriculture' 2017, among the sectors competing for freshwater usage, agriculture approximately needs 70 % of total water, while 20 % and 10 % of water is used for industrial and domestic purposes, including households, municipalities, commercial establishments and public services (Gebre et al., 2021; Pisinaras et al., 2021). Issues about water supply and quality affect almost all sectors of the economy through impacts on health, agriculture, industry, transport, energy supply, non-market ecosystem services, fisheries, forestry, and recreation (Olmstead, 2014). These issues will increase in the next decades, when impacts of climate change consisting in long-term increases in frequency and magnitude of droughts and floods, and changes in precipitation, temperature, humidity, wind intensity, duration of accumulated

snowpack, nature and extent of vegetation, soil moisture, and runoff will result in severe changes in availability and distribution of fresh water on the global scale (Olmstead, 2014). The increase in water demand and freshwater degradation due to urbanisation, agricultural intensification and climate changes have become major concerns, and

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will be particularly severe in those regions that are already under water stress conditions (Ingrao et al., 2023). According to Levintal et al. (2023), more than 25 % of the World's population and more than 40 % of global agricultural production heavily rely upon unsustainable water management.

Agriculture is presumably the most important factor in the future growth of water consumption (Gössling et al., 2012). Hence, water scarcity in agriculture poses an urgent problem in regions with a Mediterranean climate (Iglesias and Garrote, 2015), where the delicate balance between water supply and demand is increasingly challenging (Blanco-Gutiérrez et al., 2013).

This need is even more pressing in those Mediterranean areas where the competition for water resources among the economic sectors has increased, especially when the value added to water can be very high. This is the case of the tourist sector, where the value added to water is 60 times higher than in the agricultural sector (Downward and Taylor, 2007; Gössling et al., 2012), which puts tourism in a position to outcompete agriculture for water. Moreover, the peak in the tourist season in Mediterranean areas occurs between July and August, when demand for agriculture is also higher (Papadimitriou et al., 2019). Tourism development, which grows more rapidly than agriculture, is threatening the sustainability of water control systems in many areas (Sriartha et al., 2015). As a result, in tourist areas, the sustainable cultivation of crops must face these challenges in addition to the progressive reduction in water availability, due to climate change (Sedana and Ali, 2019). Therefore, adaptive approaches to water management and governance are needed to face the effects of the climate forcing on one side, and the competition among water uses on the other side, although these efforts will be constrained by many challenges at the regional and country scales, which will likely increase in number and complexity at a global scale (Allan et al., 2013).

Thus, rational water management in irrigated agriculture at the collective level is required in water-scarce areas. In this regard, the role of Water Users Associations (hereafter 'WUAs') has emerged as prominent for sustainable water use in irrigated agriculture on a global scale (Kazbekov et al., 2009; Wang et al., 2013). In short, WUAs are non-profit organizations formed by groups of farmers, which operate irrigation facilities, perform repairs, support maintenance costs, and achieve equitable distribution of water (Aarnoudse et al., 2018; Abdullaev et al., 2010). In Mediterranean areas, affected by competition for water usage among the civil (including tourism) and agricultural sectors, and water scarcity due to climatic characteristics and trends, the collective action of WUAs plays a pivotal role in achieving sustainable use of water in agriculture to ensure agricultural products (Arslan et al., 2023; Rodríguez-Díaz et al., 2008).

Much literature has explored the impacts of tourism on the total water availability over a territory including those in irrigated areas (e.g., Alcon et al., 2017; Diaz et al., 2007; Gössling et al., 2012; Groenfeldt, 2006; Papadimitriou et al., 2019; Rogerson, 2012; Sriartha et al., 2015; Tanrivermis, 2003). In contrast, scarce studies exist on water usage in areas characterized by a huge growth of touristic entering flows in co-presence with agricultural activities, where water is managed by WUAs. This is the case of the Antalya province (Türkiye), hosting one of the most important agricultural contexts of the Mediterranean basin (Arslan and Kartal, 2023; Kartal et al., 2020), where Alanya city and surroundings are rapidly developing and growing, both in terms of tourism potential and agriculture. This importance has been increasing in the last years due to the increasing foreign population from the Russia-Ukraine war and conflict. Additionally, this district has become a sought-after settlement area due to the pandemic, driven by climate conditions and the abundance of rural settlements. As a result, the collective irrigation system that remains in former agricultural areas may prove to be insufficient for agricultural areas. In this context, farmers are seeking solutions to improve irrigation management. In the authors' opinion, the Alanya district is particularly representative in analysing the impacts of tourism on water usage in an important WUA with its agricultural district, and no similar case studies have been reported in the scientific literature. The increasing number of tourists and the cultivation of tropical crops with high evapotranspiration rates are yet seen as critical issues for sustainable water management and the development of rural areas in the region. Therefore, the main novelty of this manuscript relies on the joint analysis of two competing water sectors managed by the same institution using a common evaluation method. The specific case study may be a benchmark for other irrigated areas under scenarios of water competition.

To fill this gap, this study analyses water usage and management in Alanya WUA (Antalya province, Southern Türkiye) under the pressing factor of recent touristic developments in 8 years (2013–2020) before the SARS-CoV-19 pandemic. The specific objectives of the study are the following: (i) to analyse the WUA's technical and financial performances using a subset of the indicators proposed by Malano and Burton (2001); (ii) to evaluate the impacts of socio-economic variables associated with the growth of resident population and touristic flows on water usage; (iii) to identify reciprocal relationships and temporal patterns in the studied variables. The study should prove the sustainability of water management in the area under the aforementioned pressing factors.

2. Materials and methods

2.1. Study area

The study area is located in Antalya, South-Western Coast of Türkiye (Fig. 1). The climate of this area is of Csa type ("Hot summer Mediterranean climate"), according to the Koppen's classification (Kottek et al., 2006). Alanya Directorate of Meteorology reports that the average annual temperature and precipitation are 16.0 °C and 955 mm, respectively. In the study area, summers are hot and dry, while winters are warm and rainy (but sometimes with rainfall and temperature patterns not very different from summer). The effect of summer heat is reduced by the breeze wind blowing from the sea to the land in the afternoon.

The main crops are citrus (56 % of the command area) and banana (37 %). Production of tropical fruits (avocado, dragon fruit and mango) has increased in the region thanks to the favourable climate and high market value of those crops. This effect has led to an increase in water demand, which remains one of the biggest challenges to the sustainability of the agricultural sector.

The Alanya WUA, covering a command area of 1100 ha (the same being over the monitoring period), supplies water for the irrigation scheme primarily from Dim River, and, by a much minor share, also uses groundwater within the command area. Water distribution is mainly by gravity (90 % of the command area) and pumping (10 %) using open channels. Crops are irrigated by surface (76 % of the command area) and drip (24 %) methods, and this latter increases every year at the farm

Fig. 1. Geographical location of the study area (Alanya Water Users Association, Antalya, Southern Türkiye).

level.

2.2. Data collection

A subset of the system operation indicators of WUA's performance suggested by Malano and Burton (2001) was adopted as follows (Córcoles et al., 2010; Zema et al., 2018):

- Irrigation Cover Ratio, which is an indicator of the coverage of the irrigation service over the WUA's command area
- Relative Water Supply, which is a measure of the degree of irrigation requirement fulfilment
- Crop Irrigation Requirement, that is the quantity of water exclusive of precipitation required for normal crop production
- Water Delivery per unit IA, measuring the amount of water supplied to crops throughout the irrigation season
- O&M costs per unit IA or Water delivered, which standardize the management costs on the irrigated area or unit of water consumption
- MOM costs per unit IA or Water delivered, which refer to the maintenance and aforementioned O & M costs to the irrigated area or unit of water consumption
- Crop Production per unit IA or unit Water delivered, which quantifies the product of irrigated agricultural activities.

The selected indicators were calculated based on input data according to equations and measuring units in Table 1. The relevant WUA input data was obtained from the State Hydraulic Works (DSI-Devlet Su İşleri) between 2013 and 2021. The data includes irrigated area, total annual water used for irrigation, management, operation and maintenance costs, crop pattern, production, irrigation requirement, etc. DSI uses CROPWAT software to calculate the total crop irrigation requirement of crops (*WR*) based on weather, soil and crop parameters. Data of socio-economic features about population, number of tourists, city water distribution and electrical energy consumption were obtained from public and private organizations (Turkish Statistical Institute, Alanya Chamber of Commerce and Industry, Antalya Water and Wastewater Administration General Directorate, State Hydraulic Works, respectively). Raw data was provided by managers of the organizations in charge of recording and reporting this data.

Table 1
Selected input data, performance indicators and socio-economic variables in the study area (Alanya Water Users Association, Antalya, Türkiye, command area of 1100 ha).

Input data			
Irrigated area	IA	(ha)	
Crop cover	CC	(%)	
Water delivery	WD	(Mm^3/yr)	
Water required	*WR*	(Mm^3/yr)	
Crop production	CP	(Mt/yr)	
Production revenues	PR	(M€/yr)	
Organisation & Management (O&M) costs	OMC	(M€/yr)	
Maintenance, Organisation & Management (MOM) costs	MOMC	(M€/yr)	
Performance indicators			**Equation**
Irrigation Cover Ratio	ICR	(%)	IA/command area
Relative Water Supply	RWS	(%)	WD/*WR*
Crop Irrigation Requirement	CIR	(m^3/ha-yr)	*WR*/IA
Water Delivery per unit IA	WDIA	(m^3/ha-yr)	WD/IA
O&M costs per unit IA	OMA	(€/ha-yr)	OMC/IA
MOM costs per unit IA	MOMA	(€/ha-yr)	MOMC/IA
O&M costs per unit of Water delivered	OMW	(€/m^3-yr)	OM/WD
MOM costs per unit of Water delivered	MOMW	(€/m^3ha-yr)	MOMC/WD
Crop Production per unit IA	CPA	(tn/ha-yr)	CP/IA
Crop Production per unit Water delivered	CPW	(tn/m^3-yr)	CP/WD
Socio-economic data			
Total Resident Population	TRP	(Mpersons)	
Total Population (Residents + Tourists)	TRTP	(Mpersons)	
Total City Water Distributed	TCWD	(Mm^3/yr)	
Total Electricity Consumption	TEC	(GWh/yr)	

Based on data in Table 1, the performance indicators of the collective irrigation services as well as socio-economic indicators in Alanya Water Users Association were calculated for the period 2013–2020 (Table 2). Socio-economic indicators are estimated considering: (i) Total Resident Population (only residents throughout the whole calendar year); (ii) Total Population (Residents + tourists); (iii) Total City Water Distributed (that is, the annual amount of water delivered to civil and industrial users as well as to farms); and (iv) Total Electricity Consumption (the electric energy consumed by domestic and industrial users as well as by agriculture).

2.3. Data processing and analysis

First, the Mann-Kendall test (Kendall, 1948; Mann, 1945), a non-parametric test commonly used to analyze data collected over time for consistently increasing or decreasing monotonic trends in a dependent variable, was applied to the performance indicators and socio-economic variables to detect temporal trends throughout the observation period.

Second, the Principal Component Analysis (PCA) was used to reduce the dimensionality of the dataset of performance indicators and socio-economic variables estimated for the analysed WUA for each monitored year, most of which were highly correlated down to a smaller set of derivative and uncorrelated variables (the so-called 'principal components', PCs), which were calculated as linear combinations of the original variables. In more detail, after the standardization of the original variables, Pearson's correlation matrix (which also helped to identify correlations among the variables) was computed, and eigenvalues and eigenvectors were calculated. The PCs explaining at least a percentage of 75 % of the original variance were retained. The derivative variables calculated on performance indicators and socio-economic parameters with the 'factor loadings' (explaining the influence of the original variables on the PCs) were depicted in a 'biplot'.

Third, the original variables were then grouped in homogenous clusters using Agglomerative Hierarchical Cluster Analysis (AHCA). The latter is a distribution-free ordination technique that groups objects in clusters, starting from each object that is progressively merged to another object based on a similarity-dissimilarity measure until all clusters are grouped into a cluster containing all objects. The result of AHCA is a grouping of objects in clusters according to their level of similarity-dissimilarity. In this study, the Euclidean distance was used as a similarity-dissimilarity measure (Zema et al., 2015).

All statistical analyses were carried out using Origin(Pro) software, version 2024.b (OriginLab Corporation, Northampton, MA, USA).

3. Results

3.1. Analysis of WUA's technical and financial performance indicators

The temporal analysis of performance indicators in Alanya WUA reveals that the irrigation cover ratio (ICR, 66.6 ± 5 %) was constant throughout the monitoring period (in the range 56.3–77.4 %), except for a reduction to the minimum value detected in 2014 (Fig. 2).

Fluctuations around a mean value of 77.3 % were measured for the relative water supply (RWS), and minimum and maximum values of 56.2 % and 96.3 % were noticed in 2013 and 2017, respectively. These fluctuations mainly derived from the water usage (expressed by WDIA) rather than irrigation crop requirement (ICR), the latter being almost constant in the WUA over the years 2013–2020 (12600 ± 1000 m^3/ha-yr). More specifically, WDIA varied between 7200 and 11300 m^3/ha-yr, but this variability did not indicate an evident trend towards increasing water usage, as revealed by the lack of significance after Mann-Kendall's test (Fig. 2).

Table 2
Input data to calculate the performance indicators of the collective irrigation service as well as other socio-economic indicators (period of 2013–2020) in Alanya Water Users Association (Antalya, Southern Türkiye).

Year	Technical and financial performance indicators								Socio-economic indicators			
	IA	CC	WD	WR	CP	PR	OMC	MOMC	TRP	TRTP	TCWD	TEC
	(ha)	(%)	(Mm^3/yr)	(Mm^3/yr)	(Mt/yr)	(M€/yr)	(M€/yr)	(M€/yr)	(Mpersons)	(Mpersons)	(Mm^3/yr)	(GWh/yr)
2013	807	31	5.80	10.32	1.28	0.51	0.30	0.75	0.276	3.764	9.25	875
2014	619	33	6.65	8.08	1.04	0.36	0.23	0.66	0.285	4.884	9.93	964
2015	769	35	6.65	10.10	1.61	0.53	0.26	0.70	0.292	5.022	15.97	1212
2016	762	36	6.55	10.06	1.39	0.42	0.26	0.69	0.295	3.045	14.77	1062
2017	737	36	7.60	7.89	2.20	0.53	0.21	0.63	0.299	3.465	15.62	1172
2018	731	37	8.23	9.71	1.86	0.33	0.23	0.58	0.312	5.993	17.52	1309
2019	717	37	7.32	9.56	4.01	0.63	0.21	0.58	0.328	7.021	20.41	1354
2020	720	33	7.58	8.32	8.79	1.09	0.09	0.43	0.333	2.796	19.06	1029

Note: see Nomenclature for the meaning of acronyms.

In contrast, the financial management in the WUA shows a significant decreasing trend in O&M costs (from 369.000, in 2013, to 125.000, in 2020, €/ha-yr). This significant trend, although less evident, was also found for maintenance, operation and management (MOMC) costs, decreasing from 926.000 (2013) to 595.000 (2020) €/ha-yr. When referring to the unit water delivery, the mean value of O&M (operation and management) and MOM (maintenance, operation and management) costs were 0.033 ± 0.012 (OMW) and 0.091 ± 0.023 (MOMW) €/m^3, when referred to the unit water delivered (Fig. 2).

The value of the economic production per unit cropped area (CPA) or water delivered (CPW) was not monotone throughout the monitoring period, being on average 753 ± 336 tn/ha-yr (CPA) and 0.078 ± 0.031 (CPW) tn/m^3. The lowest and highest values were measured in 2018 (449 tn/ha-yr and 0.04 tn/m^3) and 2020 (1520 tn/ha-yr and 0.144 tn/m^3), respectively, for both indicators (Fig. 2).

3.2. Evaluation of impacts of socio-economic variables on water usage

The analysis of socio-economic data in the WUA's territory shows a progressive and significant increase in the resident population (from 276.000 to 333.000 inhabitants) and a fluctuating tourist flow, with a minimum and maximum of 2.8 (2020) and 7.02 (2019) million people, respectively. These trends are similar for water (in the range of 9.25–20.4 Mm^3/yr, with a significant increase over time) and energy (875, 2013, to 1354, 2019, MWh/yr, in this case non-significant) consumptions (Table 2).

Over the territory of Alanya Water Users Association, the water required for both agricultural and other uses has progressively increased from 15 (2013) up to 26.6 (2020) Mm^3/yr following a significant trend. This increasing trend is mainly due to the progressive increase in water demand from the civil sectors (from 61.5 % in 2013 to 71.6 % in 2020 of the total water availability) rather than from agricultural activities (Fig. 3).

3.3. Identification of reciprocal relationships and temporal patterns in water usage

The correlation analysis shows highly significant Pearson's coefficients between pairs of several variables. In more detail, concerning water usage, Water Delivery per unit IA (WDIA) was correlated with Relative Water Supply (RWS) ($r = 0.87$) and Irrigation Cover Ratio (ICR) (-0.74). With specific reference to the financial performances, MOM costs per unit IA (MOMA) were associated with O&M costs per unit IA (OMA) (0.92), while O&M costs per unit of Water delivered (OMW) and MOM costs per unit of Water delivered (MOMW) were both strictly linked to Relative Water Supply (RWS), Water Delivery per unit IA (WDIA), OMA, and MOMA ($|r| > 0.76$) and each to the other (0.97). Of the indicators related to the crop economic production, Crop Production per unit IA (CPA) was correlated with OMA, MOMA, OMW and MOMW ($|r| > 0.58$), while Crop Production per unit Water delivered (CPW) with OMA and MOMA ($|r| > 0.69$), and correlated each to other ($r = 0.95$). Finally, among the socio-economic parameters, Total City Water Distributed (TCWD) was significantly associated with all performance indicators (except ICR, CPW and TRTP, Total Population including Residents and Tourists) ($|r| > 0.44$) (Fig. 4).

The PCA calculated two PCs, explaining together more than 75 % of the total variance in the original variables. More specifically, PC1 explains 53 % of this variance, and PC2 another 23 %. RWS, all indicators of financial performance (OMA, MOMA, OMW and MOMW), TRP and TCWD have significant loadings on the first PC (absolute value > 0.282), while the other performance indicators (ICR, CIR, WDIA, crop production, TRTP, and TEC) are highly influential on the second PC (Fig. 5). Therefore, the first PC1 is mainly related to irrigation water costs as well as resident population dynamics, while PC2 can be associated with water usage, crop production and total population trends.

The AHCA grouped the annual data of WUA's performance in three clusters according to their level of similarity-dissimilarity. Cluster one contains data from 2013, 2014 and 2016, the second cluster groups years from 2017 to 2019, and 2015, and the third cluster only consists of 2020 (Fig. 5). AHCA considers the disruption caused by the SARS-CoV-19 pandemic in 2020, dissimilar to the others from 2013 to 2019.

4. Discussion

The almost constant value of ICR shows that the irrigated croplands in the studied WUA was stable throughout the monitoring period. This stability supports the analysis of water usage under stable conditions in the agricultural system.

Water delivered to crops was always insufficient to match the crop irrigation requirement (on average 25–30 % less than the annual need). Moreover, water usage has been progressively increasing in absolute value, and this was because, in recent years, the production of tropical fruits has increased (Arslan and Kartal, 2023), presumably more than irrigation technology to match the demand for a sustainable use of irrigation water and suitable methods for crop pattern. Banana (*Musa* spp.) shows a water consumption between 1200 and 2200 l/m^2, and therefore its cultivation needs a high volume of water to be delivered to the cultivated areas, thus emphasizing the importance of effective water management (Ndlovu et al., 2021). It is also interesting to note the inverse and direct correlations of WDIA with ICR and RWS, showing that water delivery increases with a lower irrigation coverage (due to higher availability of water for the associated farmers), and, as expected, the fulfilment of crop water demand increases with water delivery.

The increase in the demand of irrigation water for agriculture makes the competition for water challenging with the other civil and industrial sectors. Considering the future projections of crop pattern patterns, water management in the area has become very important. For example, the cultivation areas for bananas increase every year in the Alanya

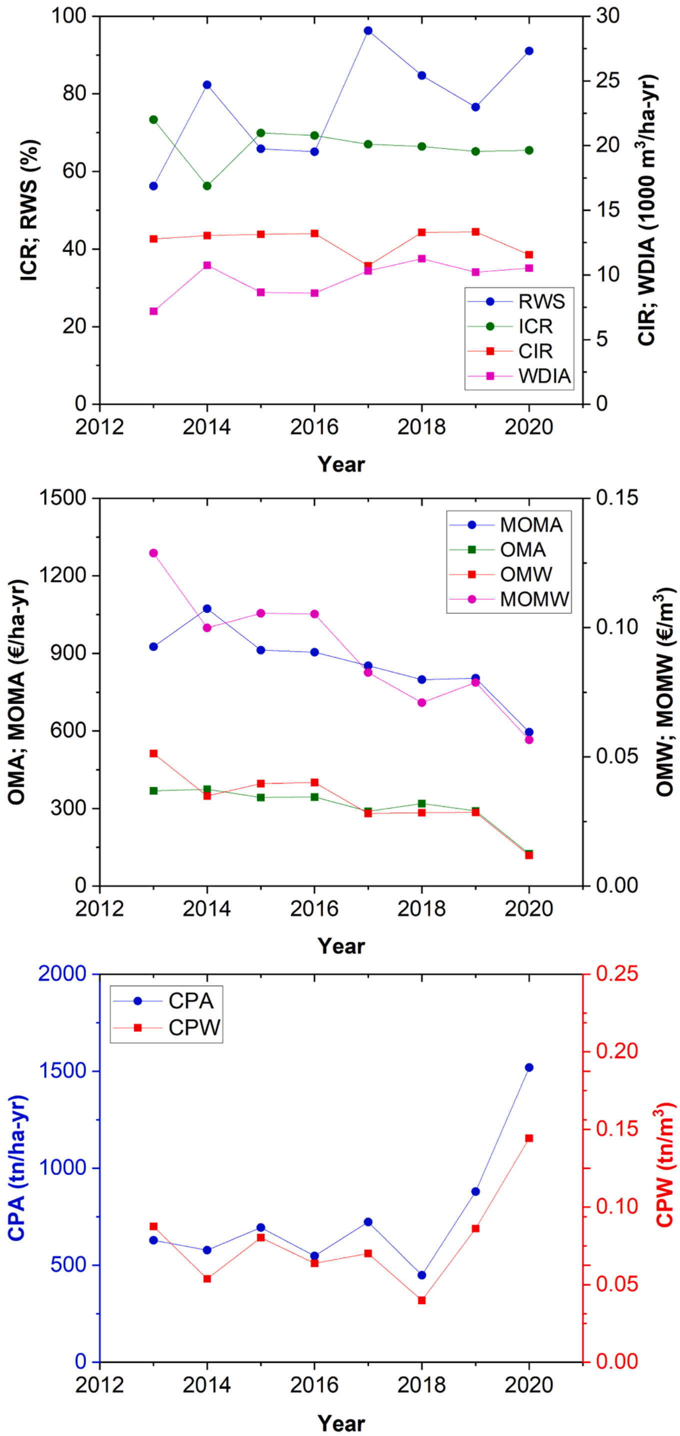

Fig. 2. Performance indicators of the collective irrigation service (period of 2013–2020) in Alanya Water Users Association (Antalya, Southern Türkiye). Note: see Nomenclature for the meaning of acronyms.

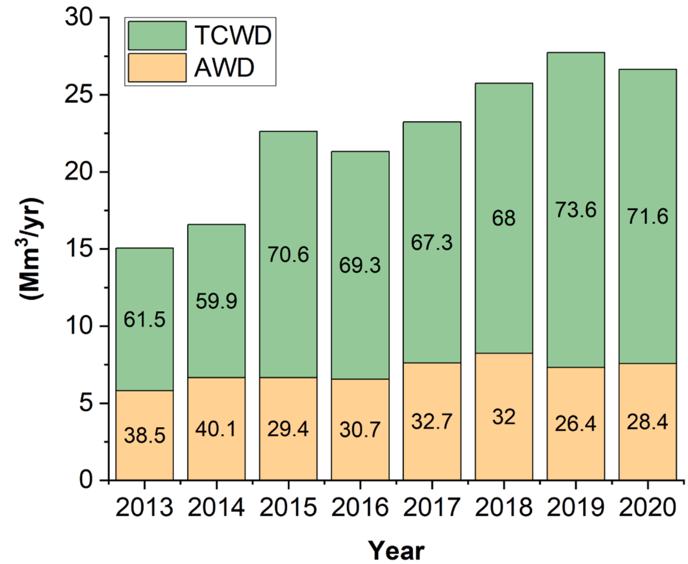

Fig. 3. Water volumes for agriculture (Agricultural Water Delivery, AWD) and other civil and industrial uses (Total Civil Water Distributed, TCWD) in the period of 2013–2020 in the territory of Alanya Water Users Association (Antalya, Southern Türkiye).

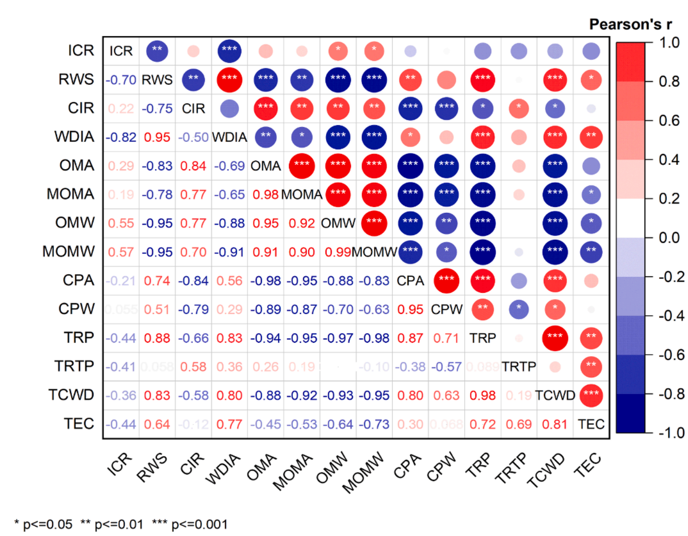

Fig. 4. Pearson's correlation matrix (with r coefficients) of pairs of performance indicators of the collective irrigation service as well as socio-economic indicators (period of 2013–2020) in Alanya Water Users Association (Antalya, Southern Türkiye). Note: see Nomenclature for the meaning of acronyms.

district. In addition to banana production, the cultivation of other tropical fruits, such as avocados, is also becoming increasingly popular, since farmers are attracted by its high benefits. This situation is altering the crop pattern in Alanya and leading to irrigation problems. It is worth noting that the progressive increase in water usage in the studied WUA has not led to a corresponding increase in crop production, as shown by the fluctuations in CPA and CPW indicators, which have never been in phase with the monotonic increases in WDIA.

The financial management was particularly effective in progressively reducing the operation and management costs as well as the expenses for water network maintenance. The unit MOM costs are strictly correlated to O&M costs (as shown by the high coefficients of correlation, > 0.92), but MOMA shows a lower coefficient of variability compared to O&M (16 % against 26 %), showing that, in the analysed WUA, the operation and management costs are easier to be effectively managed given the economic optimisation of the collective irrigation service. The costs of the irrigation service per unit water delivery decrease more with increasing water usage than with larger irrigated areas (as shown by the coefficients of correlation among those WUA's aspects). The decrease in the collective irrigation service is beneficial for the farmers' profits, which is demonstrated by the negative correlations between the financial and production indicators (mainly when referring to the irrigated areas).

The progressive increase in the resident population (about 20 % in

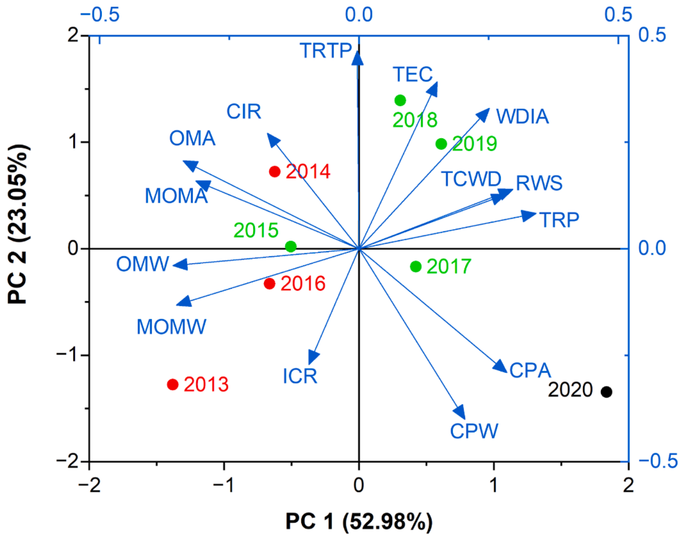

Fig. 5. Biplot from Principal Component Analysis applied to performance indicators of the collective irrigation service as well as socio-economic indicators in Alanya Water Users Association (Antalya, Southern Türkiye). Note: different colours of points indicate different clusters according to AHCA's results; see Nomenclature for the meaning of acronyms.

less than 10 years) together with an incredible but fluctuating flow of tourists has clearly led to huge increases in requirements in water (practically 2-fold the baseline value measured in 2013) and energy (compared to 2013 more than 50 % in 2019, the most recent year before 2020, probably affected by the planetary impact of SARS-CoV-19 pandemic). These changes impacted the water usage for crop production, as shown by the significant coefficients of correlation between the resident population, showing an increasing food demand, and water delivered to crops, progressively increasing to match that demand.

As expected, the higher the resident population, the higher the consumption of water and electrical energy (shown by very high coefficients of correlation, $>$ 0.79). What is, instead, surprising is that the increasing water delivery to crops did not negatively affect the water distributed to the population in the city (see the positive coefficient of correlation), contrary to what was expected. This means that water is sufficient for each use, but this statement needs cautious considerations. Alanya is a town, where tourism, besides leading to an enormous demographic and economic growth, led to various harmful effects on the agricultural sector, which should be attributed to the increasing value of the land close to the seaside where suitable agricultural production core areas. Moreover, the rapid expansion of cultivation areas of tropical fruits will increase the crop water requirements. This is not of current concern, since the majority of banana producers in the Alanya district use drip irrigation systems. However, the installation of drip irrigation technology alone may not be sufficient for the sustainable use of agricultural water. In addition, farmers pay the delivered water on a product and area basis (as usually done in Türkiye and other WUAs of the Mediterranean Basin, Hazneci et al., 2014), but this water pricing method does not result in an environmentally sound usage of water, since this does not stimulate water saving in the irrigated agriculture. Planning irrigation strategies and scheduling according to the crop water demand is essential for effective irrigation management. Therefore, despite the non-harmful competition in water usage among the agricultural and civil sectors, the enhancement in the efficiency of agricultural water use is essential to mitigate the effects of diminishing water resources and climate variability (Córcoles et al., 2010; Loureiro et al., 2023; Zema et al., 2015).

According to the results of PCA and AHCA, three different temporal patterns for WUA's technical, financial and socio-economic performances can be noticed: (i) the first three-four years (2013–2016), except 2015, when water usage was lower and service costs were higher under limited increases in population, and use of civil water and energy; (ii) the following period (2017–2019), associated to progressive increases in the socio-economic variables as well as in water usage; and (iii) the year 2000, when increases in crop production were recorded, but data is however biased by the socio-economic impacts of SARS-CoV-19 pandemic. The first two groups of data are associated with negative and positive values of PC1, respectively, while the observations made in 2020 are characterised by higher absolute values of PC1 and PC2 (the latter except data recorded in 2013). Therefore, the calculated PCs may be considered synthetic indicators of different values of the overall WUA's performances and socio-economic conditions in the studied territory.

Overall, these results may resolve the current speculations in Türkiye on Alanya, as an example of a frequent problem in water-scarce areas worldwide, about water management under competitive uses. Some productive sectors are against cropping tropical fruits in Alanya, while the agricultural sector is not allowed to get enough water due to the growing demand of the tourism sector in summer. This situation tensioned relationships between water stakeholders and now urges a consensual agreement on future water policy. Despite sufficient available water in the WUA's territory, in the authors' honest opinion, there is a need for optimization of water management in the area, which should balance the expected reduction in water resources for tourist and agricultural uses due to demographic increases and environmental impacts of forecasted climate changes. This optimisation should be based on policies targeted to the rational use of water in agriculture (e.g., precision irrigation, rational water delivery among farms, irrigation with non-conventional water) and civil sector (water saving and recycling water loss management). More specifically, irrigated agriculture should rely on increases in the efficiency of water supply to crops thanks to water-saving technologies (such as drip irrigation), techniques (such as regulated deficit irrigation) and automation of irrigation scheduling according to the actual soil-plant water requirements. Therefore, tropical fruit production led farmers to use modern irrigation practices, search for effective ways to meet high irrigation water requirements and prevent water loss by surface irrigation methods (Arslan, 2024; Arslan and Kartal, 2023). About civil uses, policies targeted to reduce freshwater consumption are essential, for instance, by increasing public awareness about the issues of water usage and quality, encouraging the re-use of reclaimed water both in the private and public sectors as well as reducing the water waste in the entire usage cycle (Li et al., 2022; Seelen et al., 2019).

5. Conclusions

In the Alanya WUA (Türkiye), in 8 years (2013–2020) under the pressing factor of recent touristic developments before the SARS-CoV-19 pandemic, a progressive increase in water usage (by more than 30 %) in agricultural activities, due to the production of tropical fruits without a corresponding increase in crop production, has been measured. Moreover, effective financial management of WUA with a progressive decrease in unit O&M (-70 %) and MOM (-40 %) costs has emerged from the analysis. Effective financial management may indicate total management, operation and maintenance costs of providing the irrigation service were reduced by qualified staff (managers, engineers, technicians or workers, etc.), good agricultural practices, increased beneficiaries (farmers), and better control of diversion and control structures, reduced cost of repair works etc. in serviced area of WUA. It has also been found an increase in total water requirements in the WUA territory (practically doubled between the start and end of the monitoring period) due to the growth of the resident population and huge flow of tourists. A surprisingly low impact of this increase on water delivered to crops, associated with the current availability of water for all uses, has been also detected. Three different patterns for WUA's technical, financial and socio-economic performances have been evidenced by the statistical analysis, showing an increase in water usage (approx. +20 %) in the last four years of the monitored period and a bias in 2000, due to the socio-economic impacts of SARS-CoV-19 pandemic.

Overall, considering the forecasted increases in tourism and population, it can be inferred that effective measures need to be implemented to ensure that rising water consumption does not negatively impact agriculture. In this regard, proactive strategies, such as enhancing water conservation techniques, optimizing irrigation systems, and investing in sustainable infrastructures for water management, are essential to maintain the balance between the needs of the growing population, the influx of tourists, and the agricultural sector. These measures will be crucial in safeguarding the water resources necessary for crop production, while accommodating the future demands of urban and tourism development.

Nomenclature

IA=Irrigated Area
CC=Crop Cover
WD=Water Delivery
W*R*=Water Required
CP=Crop Production
PR =Production Revenues
OMC=Operation & Management (O&M) costs
MOMC= Maintenance, Operation & Management (MOM) costs
ICR=Irrigation Cover Ratio
RWS=Relative Water Supply
CIR=Crop Irrigation Requirement
WDIA=Water Delivery per unit IA
OMA=O&M costs per unit IA
MOMA=MOM costs per unit IA
OMW=O&M costs per unit of Water delivered
MOMW=MOM costs per unit of Water delivered
CPA=Crop Production per unit IA
CPW=Crop Production per unit of Water delivered
TRP= Total Resident Population
TRTP = Total Population (Residents + Tourists)
TCWD= Total City Water Distributed
TCE = Total Consumption of Electricity

CRediT authorship contribution statement

Francisco Alcon: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft. **Demetrio Antonio Zema:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft. **Firat Arslan:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – original draft, Software. **Kubilay Erdoğan:** Conceptualization, Investigation, Visualization, Writing – original draft, Data curation. **Sinan Kartal:** Data curation, Investigation, Resources, Software, Writing – original draft.

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.

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Data Availability

Data will be made available on request.

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