sustainability

MDPI

Article

Analyzing the Performances of Water User Associations to Increase the Irrigation Sustainability: An Application of Multivariate Statistics to a Case Study in Italy

Demetrio Antonio Zema [1], Pasquale Filianoti [2,*], Daniela D'Agostino [1], Antonino Labate [1], Manuel Esteban Lucas-Borja [3], Angelo Nicotra [1] and Santo Marcello Zimbone [1]

1 Department Agraria, Mediterranea University of Reggio Calabria, Loc. Feo di Vito, I-89122 Reggio Calabria, Italy; dzema@unirc.it (D.A.Z.); daniela.dagostino@unirc.it (D.D.); labateantonino84@gmail.com (A.L.); angelo.nicotra@unirc.it (A.N.); smzimbone@unirc.it (S.M.Z.)

2 Department of Civil, Energy, Environmental and Material Engineering (DICEAM), University "Mediterranea" of Reggio Calabria Via Graziella, I-89122 Reggio Calabria, Italy

3 Higher Technical School of Agricultural and Forestry Engineering, Castilla-La Mancha University, Campus Universitario s/n, E-02071 Albacete, Spain; Manuelesteban.lucas@uclm.es

* Correspondence: filianoti@unirc.it; Tel.: +39-338-9706-172

Received: 20 July 2020; Accepted: 31 July 2020; Published: 6 August 2020

Abstract: Benchmarking techniques are useful and simple tools to analyze the performance of the collective irrigation in the Water User Associations (WUAs) towards an increase in service sustainability. Several benchmarking techniques have been proposed to process and predict performance indicators. Instead, some meaningful statistical techniques based on the distance of data samples, which overcome the limitations of the traditional benchmarking techniques, have never been applied to the collective irrigation sector. This study applies Permutational Multivariate Analysis of Variance (PERMANOVA), Multidimensional Scale Models (MDS), and Distance-Based Linear Models (DISTLM) as benchmarking techniques to evaluate the technical and financial performances of 10 WUAs in Calabria (Southern Italy). These benchmarking techniques revealed that the significant differences in the irrigated areas and financial self-sufficiency of the WUAs, shown by PERMANOVA, depend on the large variability of the remaining performance indicators. Both the MDS and DISTLM demonstrated that a higher number of associated users and larger irrigation service coverage allows an increase in the irrigated areas; this enlargement is facilitated if the water price and the size of the personnel staff decrease. The WUAs' self-sufficiency is mainly influenced by the number of workers and the maintenance, organization, and management costs, while the impacts of the due service fees and water price are more limited; it is also convenient to increase the number of the associated farmers since this increases the economy of scale and the gross revenues of the irrigation service. Overall, from the analysis carried out for the regional case study, these benchmarking techniques seem to be powerful and easy tools to identify the problems of the irrigation service and help in planning the most suitable policies to improve the sustainability of the collective irrigation at the regional scale.

Keywords: collective irrigation service; performance indicators; system operation; financial performance; associated farmers; benchmarking

1. Introduction

Water User Associations (WUAs) manage the irrigation service and hydraulic networks as well as supply and deliver irrigation water to the associated farmers in several regions devoted to agriculture (e.g., [1–4]). For the functioning of the large water networks and managing the irrigation service, these agencies may be funded by the financial revenues from the associated users with the possible participation of national or local administrations. The role of WUAs in managing the irrigation resources of agriculture through a "participatory irrigation management" approach [5] has been increasing since several decades because this approach appears to be suitable to face off the historical problems of irrigation management, for example, due to the water scarcity situation (e.g., in the Middle East [6]) and to the fact that agriculture is the largest consumer of water [7].

Often the performance of the collective irrigation service is poor (e.g., [8–10]), and thus shows low technical and financial sustainability. With regard to the technical management, the irrigation service shows low equity and continuity of water distribution, and the water amounts delivered to farms are often not sufficient for the crop irrigation requirements [11]. This is due both to the insufficiency of water (particularly aggravated in areas with political competition for water, such as in Jordan and, more in general, in the Middle East) and the mismanagement of water (because of unsuitable distribution, scarce user awareness, etc.) at both local and national levels [12–17].

Moreover, often the farm areas that are effectively irrigated are much smaller compared to the areas equipped with irrigation networks (e.g., [10]). From the financial point of view, the WUAs are not able to fully cover the management costs. Therefore, the agencies are forced to ask for loans or increase the water fees for the associated farmers. Both managers and farmers are not satisfied with the technical and financial management of the collective irrigation service. However, the reasons for these poor performances are not clear, since several factors influence these performances and the diagnostic activities are often neglected. According to [13], the main reasons for these problems consist of water insufficiency (linked to "population growth, immigration, and refugees"; "unfair sharing with neighboring countries"; "aridity and low precipitation"; and "climate change as an additional pressure") and water mismanagement ("non-revenue water due to leakages and physical losses and illegal wells and uses" and "unsustainable agricultural water use").

Given these problems, the research question is: Do any techniques exist that are able to identify the weak points of the WUA performances and suggest improvement policies?

To answer this question, several diagnostic tools ("benchmarking techniques") have been proposed and applied to WUAs worldwide. Benchmarking compares the technical, economic, and environmental performances of different WUAs using synthetic indexes [18]. To this goal, some input parameters must be collected and a set of performance indicators are calculated, giving a quantitative overview of the collective service performances. Thanks to benchmarking, important information can be acquired on how well the WUAs are performing in service delivery, resource utilization, and economic management [18].

Benchmarking is particularly important in Mediterranean agriculture, where an efficient, adequate, and timely irrigation service is compulsory to maximize crop production. Benchmarking of WUAs has been carried out in Italy [4], Spain [2,3,19,20], Tunisia [1], and Turkey [21–24]. However, these applications have been mainly carried out on individual WUAs or at a local scale (e.g., [8,20,21,25,26]). Conversely, the application of benchmarking techniques at a regional scale may be important for both WUA managers and authorities regulating the collective irrigation sector, in order to identify crucial problems and plan common strategic policies to enhance the service efficiency and increase the economic self-sufficiency of the WUAs. These goals require the identification of the input factors that mostly influence the technical and economic performance of these associations since the input variables are numerous, and the data collection and estimation of the performance indicators may be time-consuming and expensive [2,4,27].

Several benchmarking techniques have been proposed to process and analyze the performance indicators, depending on the specific aim of the planned analysis (e.g., quality index in Spain [20]; Principal Component Analysis in Italy [4], Spain [2], and in Kenya [26]; Cluster Analysis in Spain [3]; Data Envelopment Analysis in Tunisia [1], Spain [19] and, in Italy [9]). These diagnostic techniques are generally robust and meaningful, but sometimes they require some constraints in the input data.

For instance, the indicators to be processed using Principal Components Analysis must be normally distributed and this does not always happen; for instance, several indicators used by benchmarking techniques are strongly correlated and this generates biases in the analysis. Conversely, some statistical techniques, based on the distance of data samples, are able to overcome the limitations of the traditional benchmarking techniques. Permutational Multivariate Analysis of Variance (PERMANOVA), Multidimensional Scale Models (MDS), and Distance-Based Linear Models (DISTLM) [28] are examples of techniques that allow the avoidance of possible biases in results. However, these techniques have never been applied to diagnose the performance of Water User Associations and this is the novelty of this study. Better WUA performances lead to increases in economical and environmental sustainability of water management as well as improved user satisfaction and trust towards the collective service, along with higher cooperation and socio-cultural advantages [29].

The main objective of this study is the verification of PERMANOVA, MDS, and DISTLM as benchmarking techniques to evaluate the technical and financial performances of 10 out of the 11 WUAs operating in Calabria (Southern Italy) using input parameters and performance indicators. Through the benchmarking application, this study aims to identify the weak points of WUA performance and, on the basis of the analysis, suggest common policies to improve the sustainability of the irrigation service at the regional scale.

2. Materials and Methods

The research design of this study consisted of two steps. First, the performance indicators and their variability among the WUAs were calculated. Then, we evaluated whether the applied benchmarking techniques were able to interpret and predict the influence of the performance indicators on the irrigated area (when the managers plan an enlargement of the irrigated croplands and thus the increase of crop production at the regional scale) or the cost recovery ratio (whose increase is compulsory to ensure the financial self-sufficiency of WUAs).

2.1. Study Area

Calabria is located in the extreme southern part of the Italian peninsula. This region is mainly hilly and the mountains are very close to the sea. The regional hydrography shows a large number of torrents (intermittent watercourses) with small watersheds. These torrents rise to over 1500–2000 m above sea level in the central massif, flow through deep narrow valleys and wider floodplains downstream, and discharge water and sediments into the Ionian or Thyrrenian Seas [30].

The climate is mild temperate, with dry and hot summers (maximum temperature up to 40 °C) at the coast (Csa, according to the Koppen-Geiger classification [31]) and dry and warm summers in hilly and mountain areas (Csb), with some cold high-mountain zones (minimum temperatures of −5 °C). The mean annual values of precipitation and temperature are about 1100 mm (2000–2500 mm in the mountains) and 16 °C, respectively.

The irrigated croplands of the Calabria region, mainly served by collective irrigation, appear as a proper case study to test the suitability of the proposed benchmarking for several reasons. In this regard, we recall the importance of irrigated agriculture within the local economy and the peculiarity of the irrigation sector (in terms of infrastructural and management characteristics of the WUAs) among the regions of Southern Italy [32]. Compared to the other southern regions (Campania, Apulia, and Sicily) where the collective irrigation service is more efficient and loyalizes the associated farmers, the WUAs in Calabria suffer from heavy infrastructural, organization, and management problems since their establishment, which make the collective service unsustainable for profitable and environmentally sound irrigated agriculture [4,10]. Due to these problems, the agriculture of Calabria is more retarded compared to the other regions of Northern and Southern Italy since the cultivated areas are fragmented in many farms, most of which are even managed using familiar practices and business models. Also, the water resource management in Calabria does not show environmental sustainability, because several farmers use groundwater (often illegally) and larger water amounts compared the actual irrigation requirements of crops [33]; the hydro-electrical energy that is largely available in the water networks is practically wasted [34,35].

Agriculture is practiced both in plane areas and over hills. The main crops are olives, citrus, and grapes and vegetables, corn, and forage are also cultivated. Almost all croplands are irrigated. Farmers turn usually to the collective irrigation service, which is managed by 11 WUAs (called "Consorzi di Irrigazione e Bonifica" in Italian) (Figure 1). About 90% of the regional area is inside the administrative area of the WUAs, excluding only the mountain zones (10% of the Calabrian area). Each WUA covers an "administrated area" and manages the irrigation networks in this area ("command area"); water is delivered only to the irrigated croplands ("irrigated area").

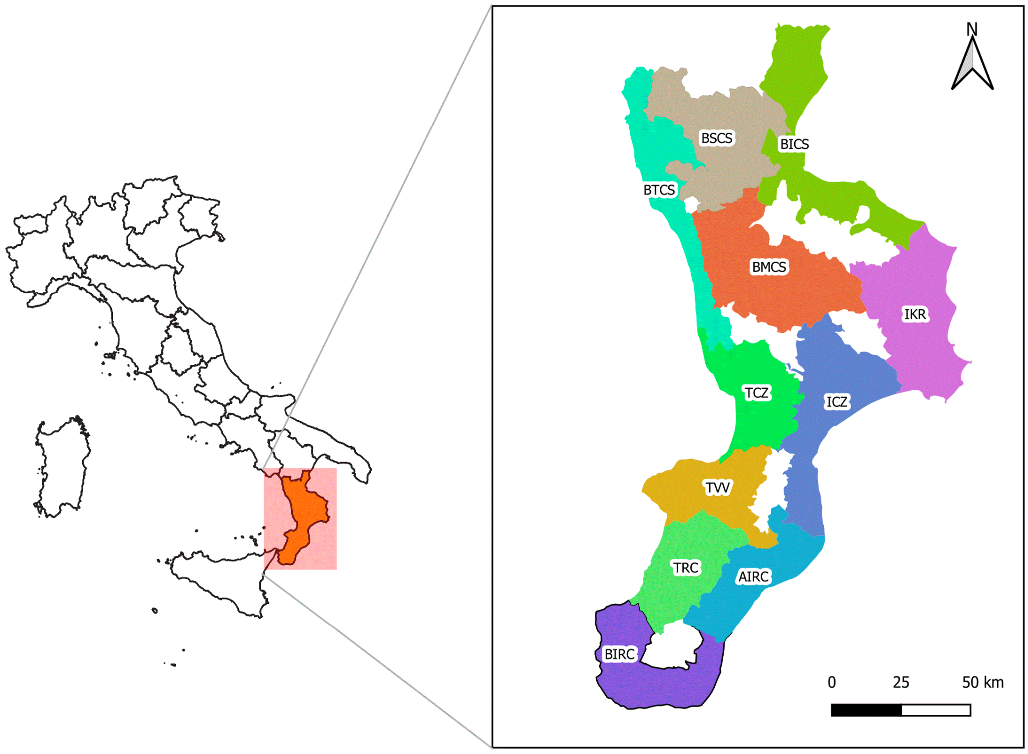


Figure 1. Distribution of the 10 studied Water User Associations in Calabria (Southern Italy).

Many of these WUAs are paid by local administrations for the ordinary maintenance of land reclamation works, purposed to soil conservation and watershed management; several works managed by the WUAs are important to avoid the flooding risk in valley areas, often highly urbanized [36–38]. Each WUA takes care of a portion of the Calabrian territory, where it manages most irrigation systems covering the command area.

One hundred and six irrigation systems are installed in the 10 WUAs, of which 104 are currently working. The majority of these systems cover a small area (<100 ha) and are more than 30 years old. Water is supplied from torrents, lakes, and artificial reservoirs but some WUAs also pump groundwater. Water is mainly distributed to farms by rotational systems and only occasionally by on-demand systems. The water networks mainly consist of pressured pipelines, but several kilometers of open canals still exist in some WUAs.

In general, irrigation water is often sufficient for the dry season. However, some periods of water shortage are recorded. The irrigation at the farm level is mainly based on surface and sprinkler irrigation systems, only a few farmers use micro-irrigation. Water fees are charged from the associated farms on the irrigated area and crop type. In a few WUAs, irrigation water fees are charged from farms using automated measuring devices (Table 1). The payment of the service fees is mandatory for associated users and represents the main revenue of the WUAs, which must pay the management, operation, and maintenance costs of the irrigation service.

Table 1. Main key descriptors and parameters of 10 Water User Associations (WUAs) in Calabria (Southern Italy) (source: [4,9,10]).

Key Descriptors/Input Parameters	WUAs									
	BSCS	BMCS	BICS	IKR	ICZ	TCZ	TVV	TRC	AIRC	BIRC
Size of the system										
Command area (CA, ha)	8419 (0.00)	4794 (0.29)	18685 (0.00)	18529 (0.15)	11303 (0.28)	5746 (0.00)	676 (0.00)	8138 (0.26)	3700 (0.07)	3152 (0.58)
Irrigated Area (IA, ha)	2712 (0.00)	816 (0.68)	10,007 (0.34)	5247 (0.82)	4000 (1.98)	1431 (0.00)	370 (0.00)	647 (13.55)	600 (3.45)	262 (0.87)
Number of associated users (UN, -)	2250 (1.01)	1224 (1.01)	5335 (0.56)	2501 (2.33)	2470 (2.55)	1200 (0.77)	150 (3.41)	1315 (1.25)	1600 (0.00)	900 (1.74)
Crops and irrigation infrastructure and management										
Main crops *	Citrus (41%), vegetables (29%), olive (18%)	Vegetables (79%), olive (18%)	Citrus (40%), vegetables (38%), olive (19%)	Olive (22%), cereals (23%), forage (21%), fruits (25%)	Citrus (11%), vegetables (48%), olive (40%)	Citrus (8%), vegetables (53%), olive (37%)	Vegetables (98%)	Citrus (49%), fruits (15%), vegetables (15%), olive (18%)	Citrus (10%), fruits (23%), vegetables (48%), olive (13%)	Citrus (24%), fruits (26%), vegetables (22%), olive (23%)
Method of water distribution	Rotational						On demand	Rotational		
Method of water fee collection	Charge on crop type and irrigated area	Charge on crop irrigated area	Charge on crop type and irrigated area	Charge on crop irrigated area				Charge on crop type and irrigated area	Charge on crop irrigated area	

Note: * Percentage of total irrigated area.

The WUA organization is usually split into three areas ("technical area", "agricultural and forestry area", and "administration area") and consists of personnel staff of variable size and different roles (managers, clerks, and fieldworkers).

2.2. Input Data Collection

An ensemble of multivariate statistical techniques, consisting of PERMANOVA, MDS, DISTLM, and dbRDA, were applied to 10 of the 11 WUAs since only one WUA did not provide feasible data. The managers and technicians of the WUAs were interviewed via questionnaire, in order to collect some basic information about WUA key descriptors (such as water sources, types of crops, average farm sizes, irrigation systems, types of management [39]) (Table 1). In addition to the following input parameters needed to calculate the performance indicators: command area, irrigated area, number of associated users, annual volume of irrigation water delivery, annual volume of irrigation water required, gross revenue invoiced and gross revenue collected, total management, operation and maintenance costs, total number of personnel employed in the provision of the irrigation service, and average water price per unit of irrigated area (Table 2).

All the data considered were collected throughout the last five available years and the annual variability was estimated by the coefficients of variation (CV) in time of each input parameter and performance indicator.

2.3. Calculation of the Performance Indicators

In order to proceed to the quantitative analysis of WUA performance, [18] proposed performance indicators. Data on agricultural production and environmental indicators related to irrigation water quality and use of fertilizers were not available for the studied WUAs, therefore the productive efficiency and environmental indicators were not calculated.

Based on these input parameters and following the indications given by [18], the following performance indicators related to system operation and financial management were calculated (Table 2): irrigated area/command area ratio; annual irrigation water delivery per unit of irrigated area; annual relative irrigation supplied; cost recovery ratio; total management, operation and maintenance (MOM) cost per unit area; revenue collection performance, staffing number per unit irrigated area.

Hereafter, the superscript "+" (e.g., CRR^+ and $MOMA^+$) beside the CRR and MOMA variables will indicate that the cost of personnel is included in the MOMC required for their calculation, while the superscript "−" (e.g., CRR^- and $MOMA^-$) will indicate that CRR and MOMA do not include the cost of personnel in MOMC.

For some performance indicators, literature (e.g., [40–44]) reports the evaluation criteria in Table 3.

2.4. Statistical Analyses

Benchmarking of the irrigation performance of the WUAs of Calabria was carried out by applying an ensemble of non-parametric multivariate statistical techniques to the performance indicators, IA, UN, ICR, WDIA, RIS, CRR^+, $MOMA^-$, RCP, SUIA, and AWP. Benchmarking consists of three steps.

First, the statistical differences in IA and CRR^+ were determined by the multivariate permutational analysis of variance (PERMANOVA, [28]), using the remaining indicators (UN, ICR, WDIA, RIS, $MOMA^-$, RCP, SUIA, and AWP) as factors. PERMANOVA tests the simultaneous response of one variable to one or more factors in an experimental design on the basis of any resemblance measure, using the permutation method. Before PERMANOVA, the indicators were $\log(x + 1)$ transformed, whereas IA and CRR^+ data were square-root transformed. The resemblance matrix was built using the Euclidean and Bray Curtis distance for IA or CRR^+ on one side, and the other indicators on the other side, respectively. The sums of squares type were type III (partial) and the 10 level factors were a fixed effect (the WUAs). The permutation method used was the unrestricted permutation of raw data and the number of permutations was 999.

Table 2. Input parameters and performance indicators collected and calculated in 10 Water User Associations (WUAs) of Calabria (Southern Italy).

	Parameter/Indicator	Definition	Symbol and Measuring Unit	Source/Calculation Method
		System Operation Performance		
Input parameters	Command Area	Nominal or design area provided with irrigation infrastructure	CA, ha	WUAs and cadastrial maps
	Irrigated Area	Total actual irrigated area during the year	IA, ha	WUAs maps
	Number of associated users	Number of farmers associated with each WUA and exploiting the collective irrigation service	UN, -	WUAs registers
Performance indicators	annual Volume of Irrigation Water Delivery	Total volume of water delivered to water users over the year	VIWD, $m^3\ yr^{-1}$	Estimation as the product of discharge (measured by weir) by distribution times in open canals or directly by counters in pipelines *
	annual Volume of Irrigation Water Required	Actual irrigation requirement of crops	VIWR, $m^3\ yr^{-1}$	Map of the water requirements in agriculture of Calabria (ARSSA, 2008)
	Irrigated area/Command area Ratio	Cover of the irrigation service over each WUA territory	ICR, %	Total annual irrigated area serviced by the system/Total command area of the system (IA/CA)
	Annual irrigation Water Delivery per unit Irrigated Area	Water delivered to crops per unit of irrigated area	WDIA, $m^3\ yr^{-1}\ ha^{-1}$	Total annual volume of irrigation water delivery/Total annual irrigated crop area (VIWD/IA)
	Annual Relative Irrigation Supply	Irrigation requirement satisfied by water delivered	RIS, %	Annual irrigation water delivery per unit irrigated area/Total annual volume of crop water demand per unit of irrigated area (WDIA/VIWR)
		Financial performance		
Input parameters	Gross Revenue Invoiced	Annual revenues due by the associated users for provision of irrigation service	GRI, € yr^{-1}	WUA annual budgets
	Gross Revenue Collected	Annual revenues paid from the associated users for provision of irrigation service	GRC, € yr^{-1}	
	Management, Operation, and Maintenance Costs	Total management, operation, and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/renewals (in these costs also the data related to energy—limited to the electricity for water pumping in three WUAs only and to fuel of maintenance machines—were included)	MOMC, € yr^{-1}	
	Number of Personnel of Irrigation service	Number of staff employed in the provision of the Irrigation service	NPI, -	WUA organization charts
Performance indicators	Total MOM cost per unit Area	MOM costs standardized on the irrigated area	MOMA, € $ha^{-1}\ yr^{-1}$	Total MOM cost per unit area/Total irrigated area serviced by the system (MOMC/IA)
	Cost Recovery Ratio	Degree of economic self-sufficiency of the WUA	CRR	Total MOM cost per unit area/Gross revenue collected (GRC/MOMA)
	Revenue Collection Performance	CIA's capacity of due fee collecting	RCP, %	Gross revenue collected/Gross revenue invoiced (GRC/GRI)
	Staffing numbers per Unit of Irrigated Area	Measure of the personnel employed in the irrigation service referred to the area unit	SUIA, persons ha^{-1}	Total number of personnel engaged in irrigation service/Total annual irrigated area serviced by the system (NPI/IA)
	Average Water Price	Annual fee of the water resource cost for the users	AWP, € $ha^{-1}\ yr^{-1}$	Average irrigation water price (per unit of delivered volume invoiced to the user or per unit of irrigated area)

Note: * Unfortunately none of the investigated WUAs have got any devices for measuring the water supply from sources.

Table 3. Evaluation criteria for Water User Associations (WUAs) performance indicators reported in literature (sources: [40–44]).

Performance Indicator	Level			
	Poor	Acceptable	Satisfactory	Good
RIS (%)	-	-	-	100
RCP (%)	<40	40–60	60–75	>75
CRR (%)	<40	40–60	60–75	>75
ICR (%)	<30	30–40	40–50	>50

Secondly, the non-metric Multi-Dimensional Scaling (MDS) and the Kruskal stress formula (minimum stress: 0.01) were applied to the performance indicators, to evaluate the influence of each performance indicator on the two response variables.

Thirdly and finally, the DISTLM function (distance-based linear modeling) was developed to determine the relative importance of each of the remaining indicators on IA or CRR^+ variables. For the DISTLM routine, we developed "marginal" tests of the relationship between the response variable (IA or CRR^+) and an individual variable (the remaining indicators), in order to identify the independent variables that explain the variations among WUAs. Following the marginal tests, "sequential" tests of individual variables were performed, in order to assess whether adding an individual variable contributes significantly to the explained variation of the response variable. This allowed the building of a regression model between IA or CRR^+ and a subset of the performance indicators. The AICc (Akaike Information Criterion, [45]) was adopted to select the best model and the step-wise procedure was followed to build the model.

For the statistical analyses, the software PRIMER V7® with the PERMANOVA add-on [28] and Statgraphics Centurion XVI® (StatPoint Technologies, Inc., Warrenton, VA, USA) were used. A significance level of 0.05 was used unless otherwise indicated.

3. Results and Discussions

3.1. Analysis of the Performance Indicators

With regard to the use of the collective irrigation systems, IA was on average 2609 ha. BIRC and BICS had the smaller and larger IA (262 ha and 10007 ha, respectively) (Figure 2).

The variability of irrigation service cover over the territory of the WUAs in Calabria was wide (ICR from 8.0%, TRC to 54.7%, TVV). The poor mean ICR (27.9%), according to the reference values of Table 2, showed a general underutilization of the collective irrigation networks (Figure 3a).

Concerning the self-sufficiency of the analyzed WUAs, CRR^+ was generally very low (and poor according to Table 2), varying from 7.9% (BIRC) to 34.5% (BICS) with an average value of 17.5% (Figure 3b).

In regard to the irrigation water usage, VIWD was on the average 24.32 Mm^3 $year^{-1}$, while the average VIWR of crops was 8.25 Mm^3 yr^{-1}. Based on these values, the mean WDIA was 9500 m^3 ha^{-1} yr^{-1} (minimum value 6500, TCZ; maximum value 14,900, TRC m^3 ha^{-1} yr^{-1}) (Figure 3b). In some WUAs, where crops with higher water needs (e.g., vegetables and fruits) were cultivated (e.g., TVV and TCZ), the water delivery was lower compared to other WUAs, where the main crops (wheat, maize and, olives) had a lower irrigation requirement (e.g., BSCS and BMCS). In general, the water delivered to crops was always excessive compared to the actual irrigation requirement, as shown by RIS (on average this indicator was 368%, but a peak even of 925% for TRC was recorded) (Figure 3b) that can be considered good (Table 2).

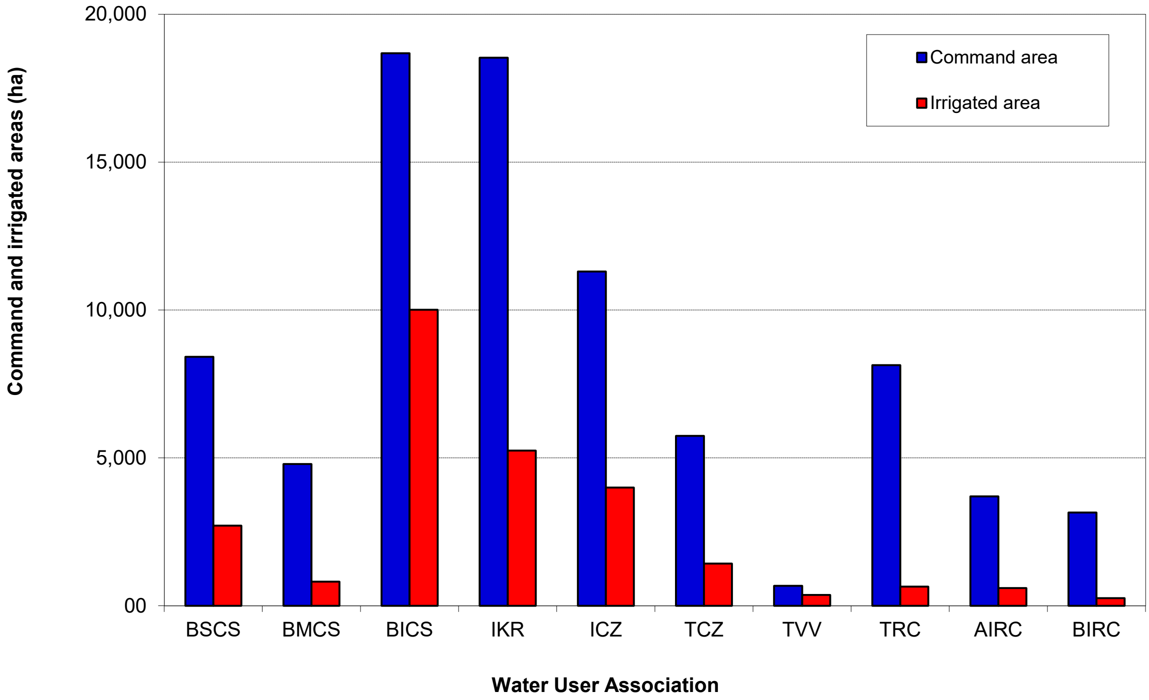


Figure 2. Command and irrigated area in 10 Water User Associations of Calabria (Southern Italy).

WDIA is much higher in WUAs of Calabria than the literature values for Mediterranean agriculture (between 1500 and 4300 m^3 ha^{-1} yr^{-1} [2,19,46–48] in Spain) and more similar but always higher than the unit water delivery measured in other agricultural contexts ([22,49,50] in Turkey, [51] in Malaysia). Consequently, the mean RIS of this study is much higher than the values reported in literature both for Mediterranean and external areas ([3,52–54] in Spain and [55] in Mauritania).

The high water surplus delivered to crops in the WUAs of Calabria is due to some critical factors, such as (i) the low storage capacity of natural and artificial reservoirs, and (ii) the very high water losses from the supplying point to the irrigated farms because of the oldness of many collective water networks and the presence of many free-surface canals, where water evaporation and unauthorized supply are significant. To face these problems, it is therefore imperative to (i) plan renovation on both the supplying reservoirs and water networks and (ii) install devices measuring water conveyed by the collective systems.

Concerning the financial performance of the analyzed WUAs, a severe unbalance between revenues and costs was generally noticed for all the investigated WUAs. First of all, the mean GRC (342 k€ yr^{-1}) was much lower than GRI (528 k€ yr^{-1}). From the differences between GRC and GRI, the RCP (on average close to 70%, Figure 3b) can be considered as satisfactory (Table 2). RCP is a significant indicator of the acceptance level of the service provided by the WUAs to the associated users [56]. Therefore, since many associated farmers that did not pay the due water fees are noticeable, we should conclude that, in general, in some WUAs of Calabria a significant share of the farmers are not satisfied with the collective irrigation. The MOM costs (including the personnel) are from 3-fold (BICS) to about 13-fold (BIRC) of the GRC, and thus the management expenses are much higher compared to the revenues collected from the irrigation service. Moreover, the MOMC was largely variable among WUAs and over time for several reasons, such as the water network condition, need of special maintenance-repair works, WUA's organization, level of fee collection, incidence of energy costs for groundwater pumping, etc. [4,57]. The MOM of WUAs in Calabria is much higher compared to other literature studies (e.g., [58] in Turkey, [48] in Spain).

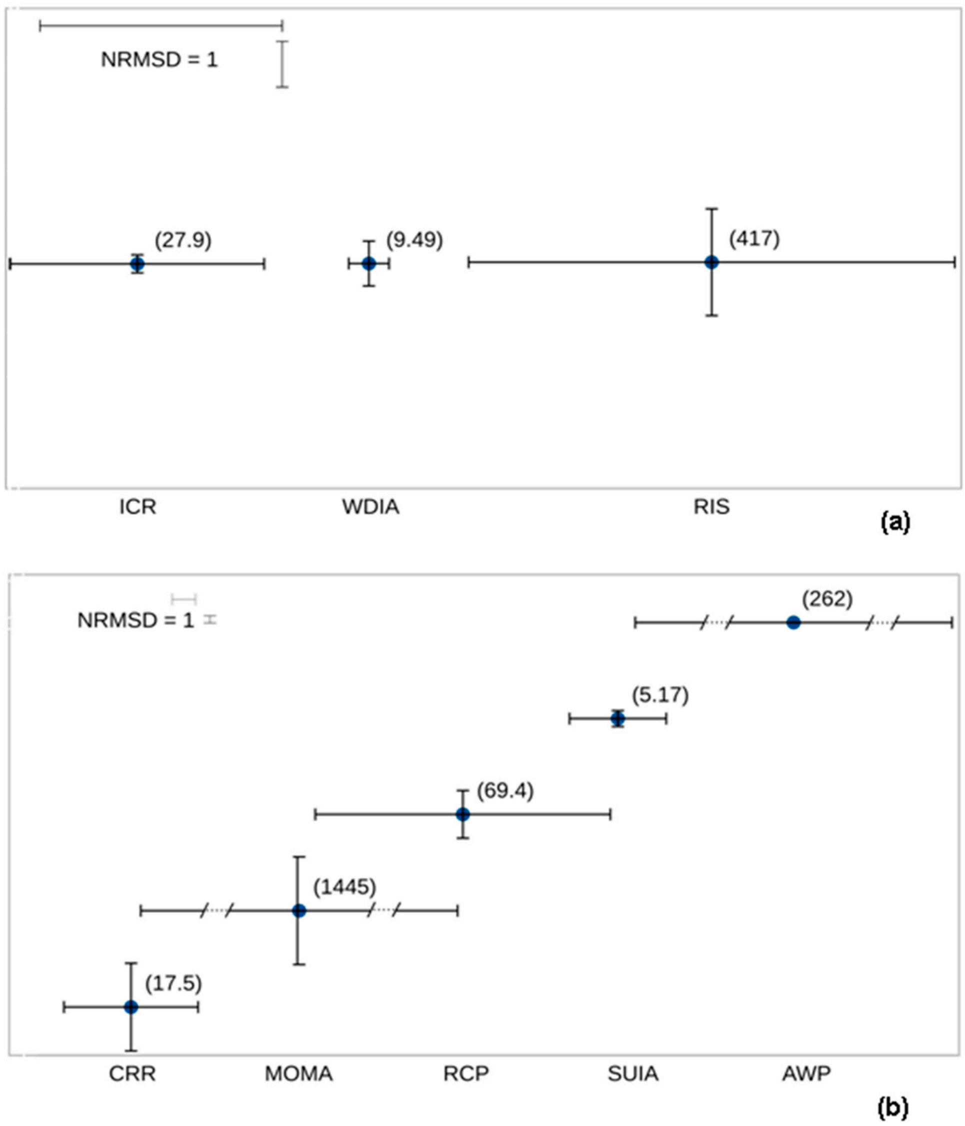


Figure 3. Plots of system operation (**a**) - excluding IA - and financial performance (**b**) indicators calculated in 10 Water User Associations of Calabria (Southern Italy). Note: The horizontal and vertical bars are the normalized root-mean-square deviation (NRMSD) among WUAs and years, respectively with respect to the mean value of each indicator. NRMSD is the ratio between the x or y standard deviations and the difference between the maximum and the minimum ($x_{max} - x_{min}$ or $y_{max} - y_{min}$) values of the indicator. Measuring units (reported in brackets): ICR (%), WDIA (10^3 m^3 ha^{-1} yr^{-1}), RIS (%), CRR (%), MOMA (€ ha^{-1} yr^{-1}), RCP (%), SUIA (persons 100-ha^{-1}), AWP (€ ha^{-1} yr^{-1}).

The NPI was largely variable, from 22 (TVV) to 120 (BICS) persons, and this variability was due to the usual variations in labor productivity and intensity, and technology of the service [57]. However, the staff size was practically constant over time (CV = 3.4%). If referred to IA, the average SUIA was 5.2 persons per 100 ha of IA with minimum and maximum values of 1.2 (BICS) and 21 (BIRC) persons per 100 hectares of IA (Figure 2). These values are much higher compared to the maximum and minimum values in literature ([59] in the USA; [60] in China) thus far.

The high incidence of personnel costs was another reason for the very low self-sufficiency of the WUAs in Calabria. If the staff cost is excluded from MOM, GRC was largely sufficient to cover $MOMA^-$ (on the average 156 € ha^{-1} yr^{-1}), because the mean CRR^- is over 200% (Figure 3b). Conversely, MOMA and CRR are calculated including the staff cost ($MOMA^+$ and CRR^+) in the calculations, mean $MOMA^+$ increased to 1445 € ha^{-1} per year and CRR^+ decreased to 17.5% (Figure 3b), as mentioned above. Therefore, none of the analyzed WUA MOM costs are fully recovered and thus their economic life depends on funds given by external sources. For CRR, literature shows values between 28% ([41] in Sri Lanka) and 170% ([50] in Turkey).

Finally, in Calabria AWP was on average 262 € ha^{-1} with high variability among WUAs (from 120 € ha^{-1} yr^{-1}, IKR and ICZ, to 611 € ha^{-1} yr^{-1}, BIRC) (Figure 3b). In the WUAs of Southern Calabria (TRC, AIRC, and BIRC) the irrigation water price (about 480 € ha^{-1} yr^{-1}) is much higher than in the other WUAs. This may be attributable to the poor conditions of the water network and the scarce financial performance (low CRR and high MOMA, Figure 3b). As a matter of fact, in the WUA AIRC and BIRC, the maintenance and energy costs are the highest in Calabria, in addition, the water networks of WUA TRC have a high incidence of free surface canals with consequent water theft and fee evasion.

3.2. Benchmarking Analysis

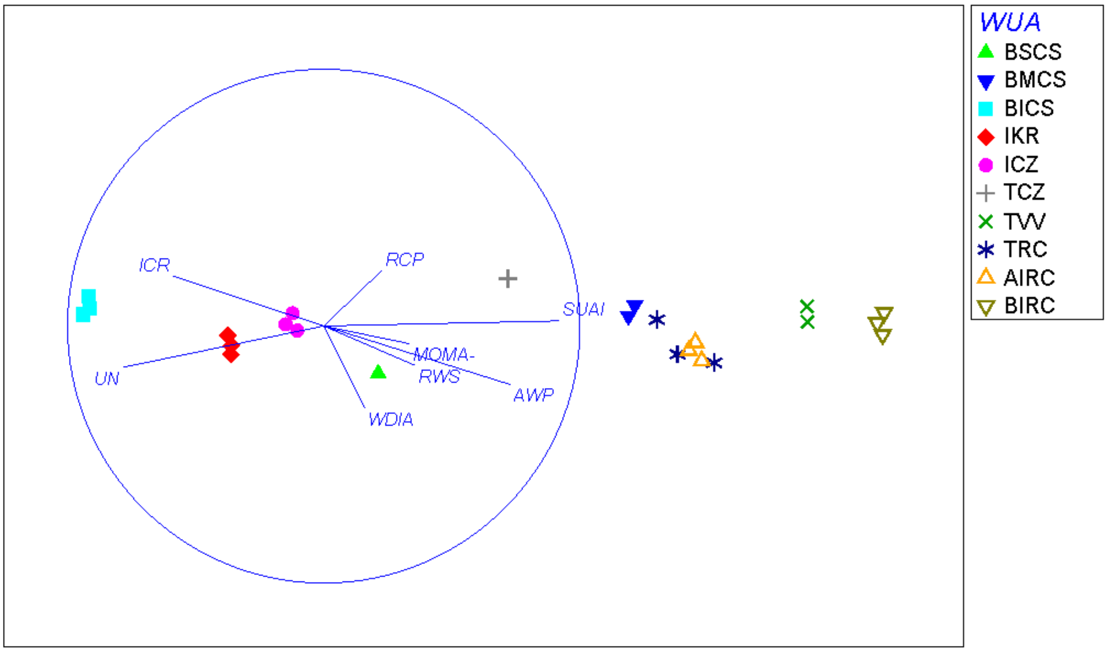
The application of PERMANOVA showed significant differences (at $p < 0.05$) in both in IA and CRR^+ of the 10 WUAs of Calabria (Pseudo-F = 1739; P(perm) < 0.001 and Pseudo-F = 3.05; P(perm) < 0.001, respectively). These significant differences in IA ad CRR^+ should be related due to the large variability of the remaining performance indicators detected among the evaluated WUAs and reported in the previous section, in spite of numerous similarities in terms of infrastructure, irrigation management, crop, and production inputs (Table 1).

When IA was considered the response variable, MDS clearly grouped the 10 WUAs in two clusters, depending on the values of the performance indicators (Figure 4a); conversely, no clustering was possible when MDS was applied to the WUAs considering CRR^+ as the response of the other performance indicators (Figure 4b).

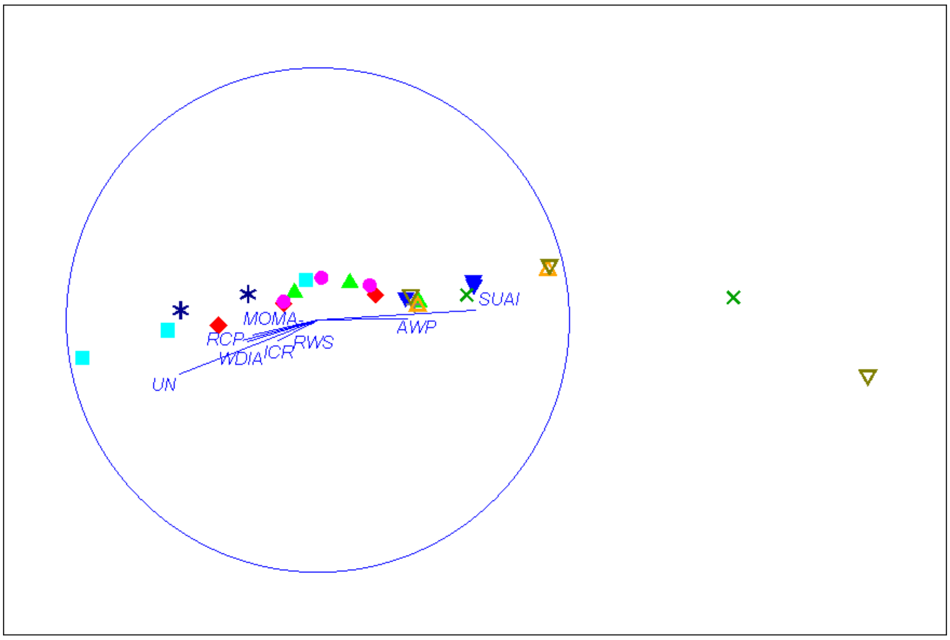
The importance of each indicator in clustering the WUAs is shown by the loadings of each variable on the two axes, MDS1 and MDS2 (Table 4). If IA is considered as the response variable, a clear gradient between the two groups of WUAs (AIRC, BIRC, TRC, and TVV, on one side, and the remaining WUAs, on the other side) is noticed along the first axis (MDS1). In more detail, RIS, SUAI, $MOMA^-$, and AWP positively weighted on MDS1, UN, and ICR had a negative influence on the same MDS, while only WDIA significantly impacted MDS2 (Figure 4a and Table 4).

Table 4. Loadings of performance indicators calculated in 10 Water User Associations (WUAs) of Calabria (Southern Italy) on the first two components using multidimensional scaling (MDS) routine.

Performance Indicator	Response Variable			
	IA		*CRR⁺*	
	MDS1	**MDS2**	**MDS1**	**MDS2**
UN	−0.783	−0.160	−0.552	−0.215
ICR	−0.589	0.195	−0.258	−0.059
WDIA	0.160	−0.319	−0.281	−0.086
RIS	0.356	−0.152	−0.161	−0.083
RCP	0.227	0.217	−0.298	−0.080
SUAI	0.920	0.020	0.627	0.039
$MOMA^-$	0.334	−0.068	−0.028	−0.019
AWP	0.726	−0.227	0.356	0.006



(**a**)



(**b**)

Figure 4. Plot of scores calculated for Water User Associations of Calabria (Southern Italy) using the MDS routine applied to IA (**a**) and CRR$^+$ (**b**) as response variables to performance indicators. See the related list for the abbreviations.

When instead, the response variable is CRR$^+$, a subset of performance indicators influenced MDS1 and MDS2 (i.e., SUAI and AWP positively, and UN and RCP negatively), but these influences were too low to determine clear differentiations among CRR$^+$ values of the WUAs (Figure 4b and Table 4).

By applying distance linear models (DISTLM), the marginal tests reveal that when considered as isolated, all the performance indicators significantly influenced IA except WDIA and RCP, while on the contrary, only UN, SUAI, and AWP influenced CRR^+ ($p < 0.05$) (Table 5).

Table 5. Marginal tests of the relationships between the response variables (IA or CRR^+) and individual performance indicators of 10 Water User Associations (WUAs) of Calabria (Southern Italy) using matched resemblance matrices (DISTLM).

Performance Indicator	IA			CRR^+		
	Pseudo-F	*P*	*Prop.*	*Pseudo-F*	*P*	*Prop.*
UN	53.77	0.001	0.658	13.20	0.002	0.320
ICR	7.99	0.006	0.222	1.42	0.217	0.048
WDIA	1.38	0.254	0.047	2.15	0.146	0.071
RIS	4.25	0.049	0.132	1.11	0.307	0.038
RCP	2.49	0.123	0.082	2.56	0.100	0.084
SUAI	24.74	0.001	0.469	12.26	0.004	0.305
$MOMA^-$	8.20	0.005	0.226	0.34	0.621	0.012
AWP	23.58	0.001	0.457	3.94	0.050	0.123

Note: Bold values show the indicators that significantly influence IA and CRR^+; *Pseudo-F*, pseudo-F statistic; *P* = *P*-value; *Prop.* = Proportion of the variability explained by the selected indicator. See the related list for the abbreviations.

The sequential tests indicated that the best distance linear model (R^2 = 0.88; AICs = 144) for predicting IA consisted of UN, AWP, ICR, and SUAI indicators, which explained more than 87% of the total variation of IA (Table 6). The same number of variables should be used in the best distance linear model (R^2 = 0.84, AICs = 117) for predicting CRR^+. This set consists of UN and SUAI, as for the model predicting IA but RCP and $MOMA^-$ should replace AWP and ICR, and this combination of indicators explains more than 84% of the total variation of CRR^+ (Table 6).

Table 6. Sequential tests of the relationships between the response variables (IA or CRR+) and individual performance indicators of 10 Water User Associations (WUAs) of Calabria (Southern Italy) using matched resemblance matrices (DISTLM).

Performance Indicator	*AICc*	*Pseudo-F*	*P*	*Prop.*	*Cumul.*
		IA			
+UN	167	53.77	0.001	0.658	0.658
+AWP	148	27.78	0.001	0.174	0.831
+ICR	144	6.59	0.008	0.034	0.865
+SUAI	144	2.61	0.102	0.013	0.878
		CRR^+			
+UN	151	13.20	0.001	0.320	0.320
+RCP	143	11.81	0.003	0.207	0.527
+SUAI	133	13.67	0.003	0.163	0.690
$+MOMA^-$	117	22.44	0.001	0.147	0.837

Notes: *AICc*, Akaike value for the model; *Pseudo-F*, pseudo-F statistic; *P*, *P*-value; *Prop.*, Proportion of the variability explained by the selected indicator; *Cumul.*, Cumulative proportion variability explained by the selected indicator; *Res. DF*, Degrees of freedom of the residual model; + indicates that the variable is added to the model, while - indicates a variable removed from the model. See the related list for the abbreviations; values in bold are significantly at *p* level < 0.05.

The findings provided by the application of DISTLM consistently confirm the outcomes of the separate analysis of the performance indicators. With regards to their influence on IA, while it is clear how the increase of UN and ICR (i.e., higher usage of the irrigation infrastructure) is linked to higher IA, less obvious is the influence of AWP and SUIA on IA. This influence is shown by the positive loadings of AWP and SUIA in the MDS built on IA (Figure 4a and Table 4), showing that, if the water price and the size of the personnel staff decrease (and, as a consequence, the costs of the irrigation service for the associated farmers are lower), the WUAs have the possibility to increase the areas effectively served by collective irrigation. This means that, in order to enlarge the IA, it is suggested to increase the number of associated users (UN) and the service coverage (ICR) and reduce the water price (AWP) and the personnel staff (SUIA).

Concerning the self-sufficiency of the WUAs, in this case, the increase of CRR^+ with UN is also expected. The strict influence of SUAI and $MOMA^-$ on CRR^+ revealed by DISTLM confirms that the high incidence of personnel costs (SUIA) is the main reason for the very low self-sufficiency of the WUAs in Calabria; conversely, the non-significant impact of RCP on CRR^+ according to DISTLM proves that the performance in collecting the due fees (measured by RCP) has limited weight on the overall financial performance of the WUAs because all the WUAs are quite efficient in collecting the due fees. It is also convenient to increase UN (i.e., the number of the associated farmers) since this increases the economy of scale and the gross revenues of the irrigation service. These outcomes are also consistent with the results of MDS, which identified in SUIA and UN as the most influential factors on CRR^+. $MOMA^-$ is another factor that must be taken into account to plan proper policies to increase the financial performance of the WUAs using DISTLM. Conversely, the increase of the water price (AWP) should be considered with caution to increase the WUA profitability, since a higher cost of the service could discourage the farmers from using the collective service; the low influence of AWP on the overall financial performance of the WUAs can be explained by the limited coverage of the irrigation service cost paid by the revenues of the associated farmers.

4. Conclusions

The research design of this study is evaluation of the feasibility of novel multivariate statistical techniques (PERMANOVA, MDS, and DISTLM), assumed as benchmarking tools, to evaluate and predict the technical and financial performances of Water User Associations by application in a case study in Calabria (Southern Italy).

A preliminary analysis of the performance indicators shows that in Calabria: (i) the irrigation service cover is much variable over the regional territory; (ii) the water delivered to crops exceeds the actual irrigation requirement of crops; (iii) the low self-sufficiency of the WUAs, due to which the collective irrigation service is not profitable, is because the fee revenues cover only MOM costs and the personnel staff is oversized.

The application of the benchmarking techniques has revealed that the significant differences in both in IA and CRR^+ of the 10 WUAs of Calabria depend on the large variability of the remaining performance indicators.

Both MDS and DISTLM have demonstrated that:

- Higher usage of the irrigation infrastructure (i.e., more associated users and a larger irrigation service) allows an increase in the irrigated areas and this enlargement is facilitated if the water price and the size of the personnel staff decrease.
- Self-sufficiency of the WUAs is mainly influenced by the size of the personnel staff, the maintenance, organization, and management costs, while the impacts of the due fees and water price are more limited. It is also convenient to increase the number of the associated farmers since this increases the economy of scale and the gross revenues of the irrigation service.

Overall, from the analysis carried out for this regional case study, the benchmarking techniques seem to be powerful and easy tools to identify the problems of the irrigation service and adopt the most impactful measures for efficient use of irrigation water resources and the sustainability of irrigated agriculture.

Author Contributions: Conceptualization, D.A.Z., M.E.L.-B., and S.M.Z.; methodology, D.A.Z., D.D., A.L., P.F., M.E.L.-B., A.N., and S.M.Z.; validation, D.A.Z., P.F., M.E.L.-B., and S.M.Z.; formal analysis, D.A.Z., P.F., M.E.L.-B., and S.M.Z.; investigation, D.D., A.L., and A.N.; resources, P.F.; data curation, D.D., A.L., and A.N.; writing—original draft preparation, D.A.Z., M.E.L.-B., and P.F.; writing—review and editing, D.A.Z., M.E.L.-B., P.F., and S.M.Z.; supervision, D.A.Z., M.E.L.-B., P.F., and S.M.Z.; project administration, P.F.; funding acquisition, P.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Input parameters/performance indicators	
AWP	Average Water Price
CA	Command area
CRR	Cost recovery ratio
CRR^+	Cost recovery ratio (with staff)
CRR^-	Cost recovery ratio (without staff)
GRC	Gross revenue collected
GRI	Gross revenue invoiced
IA	Irrigated area
ICR	Irrigated area/command area ratio
MOMA	Total management, operation, and maintenance cost per unit area
$MOMA^+$	Total management, operation, and maintenance cost per unit area (with staff)
$MOMA^-$	Total management, operation, and maintenance cost per unit area (without staff)
MOMC	Total management, operation, and maintenance cost
$MOMC^+$	Total management, operation, and maintenance cost (with staff)
$MOMC^-$	Total management, operation, and maintenance cost (without staff)
NPI	Total number of personnel employed in the Irrigation and Drainage services
RCP	Revenue collection performance
RIS	Annual relative water supply
SUIA	Staffing numbers per unit area
VIWR	Annual Volume of Irrigation Water Required
VIWD	Annual Volume of Irrigation Water Delivery
WDIA	Annual irrigation water delivery per unit irrigated area
Water User Associations	
AIRC	Alto Ionio Reggino
BCSC	Bacini Settentrionali del Cosentino
BICS	Bacini dello Ionio Cosentino
BIRC	Basso Ionio Reggino
BMCS	Bacini Meridionali del Cosentino
BTCS	Bacini del Tirreno Cosentino
ICZ	Ionio Catanzarese
IKR	Ionio Crotonese
TCZ	Tirreno Catanzarese
TRC	Tirreno Reggino
TVV	Tirreno Vibonese

References

1. Frija, A.; Speelman, S.; Chebil, A.; Buysse, J.; Van Huylenbroeck, G. Assessing the efficiency of irrigation Water Users' Associations and its determinants: Evidence from Tunisia. *Irrig. Drain.* **2009**, *58*, 538–550. [CrossRef]
2. Córcoles, J.I.; De Juan, J.; Ortega, J.; Tarjuelo, J.; Hidalgo, M. Ángel M. Management evaluation of water users associations using benchmarking techniques. *Agric. Water Manag.* **2010**, *98*, 1–11. [CrossRef]
3. Tendero, J.I.C.; De Juan, J.A.; Ortega, J.F.; Tarjuelo, J.M.; Moreno, M. Evaluation of irrigation systems by using benchmarking techniques. *J. Irrig. Drain. Eng.* **2012**, *138*, 225–234. [CrossRef]
4. Zema, D.A.; Nicotra, A.; Tamburino, V.; Zimbone, S.M. performance assessment of collective irrigation in Water Users' Associations of Calabria (Southern Italy). *Irrig. Drain.* **2015**, *64*, 314–325. [CrossRef]
5. Salman, A.; Al-Karablieh, E.; Regner, H.-J.; Wolff, H.-P.; Haddadin, M.J. Participatory irrigation water management in the Jordan Valley. *Hydrol. Res.* **2008**, *10*, 305–322. [CrossRef]
6. Mustafa, D.; Altz-Stamm, A.; Scott, L.M. Water User Associations and the politics of water in Jordan. *World Dev.* **2016**, *79*, 164–176. [CrossRef]

7. Mazahreh, N.; Shatanawi, M.; Ghezawi, S. Jordan experiences in water saving and participatory irrigation management. *Options Méditerranéennes Ser. B* **2000**, *48*, 171–184.
8. Phadnis, S.S.; Kulshrestha, M. Benchmarking for water users associations to enhance performance of the Samrat Ashok Sagar major irrigation scheme. *Irrig. Drain.* **2011**, *61*, 449–463. [CrossRef]
9. Zema, D.A.; Nicotra, A.; Mateos, L.; Zimbone, S.M. Improvement of the irrigation performance in Water Users Associations integrating data envelopment analysis and multi-regression models. *Agric. Water Manag.* **2018**, *205*, 38–49. [CrossRef]
10. Zema, D.A.; Nicotra, A.; Zimbone, S.M. Diagnosis and improvement of the collective irrigation and drainage services in Water Users' Associations of Calabria (Southern Italy). *Irrig. Drain.* **2018**, *67*, 629–644. [CrossRef]
11. Molden, D.J.; Gates, T.K. Performance measures for evaluation of irrigation? Water? Delivery systems. *J. Irrig. Drain. Eng.* **1990**, *116*, 804–823. [CrossRef]
12. Benedict, S.; Hussein, H. An analysis of water awareness campaign messaging in the case of Jordan: Water conservation for state security. *Water* **2019**, *11*, 1156. [CrossRef]
13. Hussein, H. Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environ. Sci. Policy* **2018**, *89*, 385–392. [CrossRef]
14. Yorke, V. *Politics matter: Jordan's Path to Water Security Lies through Political Reforms and Regional Cooperation*; CRR Trade Regulation, University of Bern: Bern, Switzerland, 2013.
15. Yorke, V. *Jordan's Shadow State and Water Management: Prospects for Water Security Will Depend on Politics and Regional Cooperation*; Springer: Cham, UK, 2016; pp. 227–251.
16. Hussein, H. Tomatoes, tribes, bananas, and businessmen: An analysis of the shadow state and of the politics of water in Jordan. *Environ. Sci. Policy* **2018**, *84*, 170–176. [CrossRef]
17. Militaru, A. *Private Activity in Water and Sewerage Continues to Contract in the First Semester of 2011*; World Bank: Washington, DC, USA, 2012.
18. Malano, H.; Burton, M. *Guidelines for Benchmarking Performance in the Irrigation and Drainage Sector*; Food & Agriculture Org.: Rome, Italy, 2001.
19. Díaz, J.A.R.; Poyato, E.C.; López-Luque, R. Applying benchmarking and data envelopment analysis(DEA) techniques to irrigation districts in Spain. *Irrig. Drain.* **2004**, *53*, 135–143. [CrossRef]
20. Rodriguez-Diaz, J.; Poyato, E.C.; López-Luque, R.; Pérez-Urrestarazu, L. Benchmarking and multivariate data analysis techniques for improving the efficiency of irrigation districts: An application in spain. *Agric. Syst.* **2008**, *96*, 250–259. [CrossRef]
21. Koç, C.; Bayazit, Y. A study on assessment financing of irrigation schemes. *Irrig. Drain.* **2015**, *64*, 535–545. [CrossRef]
22. Uysal Özlem, K.; Atış, E. Assessing the performance of participatory irrigation management over time: A case study from Turkey. *Agric. Water Manag.* **2010**, *97*, 1017–1025. [CrossRef]
23. Kartal, S.; Değirmenci, H.; Arslan, F. Ranking irrigation schemes based on principle component analysis in the arid regions of Turkey. *Agron. Res.* **2019**, *17*, 456–465.
24. Kartal, S.; Değirmenci, H.; Aslan, F. assessment of irrigation schemes with performance indicators in Southeastern Irrigation District of Turkey. *Tarım Bilim. Derg.* **2020**, *26*, 1–10. [CrossRef]
25. Chandran, K.M.; Joseph, E.J.; Sushanth, C.M. Performance evaluation of selected irrigation systems in Kerala State, India. *Irrig. Drain.* **2016**, *65*, 613–619. [CrossRef]
26. Muema, F.M.; Home, P.G.; Raude, J. Application of benchmarking and principal component analysis in measuring performance of public irrigation schemes in Kenya. *Agriculture* **2018**, *8*, 162. [CrossRef]
27. Sandri, S.; Alshyab, N.; Ghazo, A. Trade in goods and services and its effect on economic growth—The case of Jordan. *Appl. Econom. Int. Dev.* **2016**, *16*, 113–128.
28. Anderson, M.J. A new method for non-parametric multivariate analysis of variance. *Austral Ecol.* **2001**, *26*, 32–46.
29. Hussein, H. The Guarani Aquifer System, highly present but not high profile: A hydropolitical analysis of transboundary groundwater governance. *Environ. Sci. Policy* **2018**, *83*, 54–62. [CrossRef]
30. Bombino, G.; Zema, D.A.; Denisi, P.; Lucas-Borja, M.E.; Labate, A.; Zimbone, S.M. Assessment of riparian vegetation characteristics in Mediterranean headwaters regulated by check dams using multivariate statistical techniques. *Sci. Total. Environ.* **2019**, *657*, 597–607. [CrossRef]
31. Kottek, M.; Grieser, J.; Beck, C.; Rudolf, B.; Rubel, F. World map of the Köppen-Geiger climate classification updated. *Meteorol. Z.* **2006**, *15*, 259–263. [CrossRef]

32. Istituto Nazionale di Economia Agraria. *Atlante Nazionale Dell'Irrigazione*; INEA: Rome, Italy, 2011. (In Italian)
33. Zema, D.A.; Nicotra, A.; Zimbone, S.M. Improving management scenarios of water delivery service in collective irrigation systems: A case study in Southern Italy. *Irrig. Sci.* **2018**, *37*, 79–94. [CrossRef]
34. Algieri, A.; Zema, D.A.; Nicotra, A.; Zimbone, S.M. Potential energy exploitation in collective irrigation systems using pumps as turbines: A case study in Calabria (Southern Italy). *J. Clean. Prod.* **2020**, *257*, 120538. [CrossRef]
35. Zema, D.A.; Nicotra, A.; Tamburino, V.; Zimbone, S.M. A simple method to evaluate the technical and economic feasibility of micro hydro power plants in existing irrigation systems. *Renew. Energy* **2016**, *85*, 498–506. [CrossRef]
36. Aricò, C.; Filianoti, P.G.F.; Sinagra, M.; Tucciarelli, T. The FLO diffusive 1D-2D model for simulation of river flooding. *Water* **2016**, *8*, 200. [CrossRef]
37. Filianoti, P.; Nicotra, A.; Labate, A.; Zema, D.A. A method to improve the flood maps forecasted by on-line use of 1D model. *Water* **2020**, *12*, 1525. [CrossRef]
38. Filianoti, P.; Gurnari, L.; Zema, D.A.; Bombino, G.; Sinagra, M.; Tucciarelli, T. An evaluation matrix to compare computer hydrological models for flood predictions. *Hydrology* **2020**, *7*, 42. [CrossRef]
39. Malano, H.; Burton, M.; Makin, I. Benchmarking performance in the irrigation and drainage sector: A tool for change. *Irrig. Drain.* **2004**, *53*, 119–133. [CrossRef]
40. Bekisoglu, S. The current situation, operational and management problems of irrigation systems in Turkey. In Proceedings of the Congress on the Development of Soil and Water Resources, Ankara, Turkey, 1994; pp. 579–586.
41. Molden, D.; Sacthivadivel, R.; Christopher, J.; Perry, C.F.; Klozen, W.H. *Indicators for Comparing Performance of Irrigated Agricultural Systems*; Research Report 20; International Water Management Institute: Colombo, Sri Lanka, 1998.
42. Vermillion, D.L. Guide to Monitoring and Evaluation of Irrigation Management Transfer. 2000. Available online: http://www.impim.org/library.html (accessed on 5 March 2020).
43. Nelson, D. Performance indicators for irrigation canal system managers or water user associations. In Proceedings of the 18th Congress of International Commission on Irrigation and Drainage, Montreal, QC, Canada, 21–28 July 2002.
44. Yercan, M.; Atis, E.; Salali, H.E.; Atış, E. Assessing irrigation performance in the Gediz River Basin of Turkey: Water user associations versus cooperatives. *Irrig. Sci.* **2009**, *27*, 263–270. [CrossRef]
45. Akaike, H. A new look at the statistical model identification. *IEEE Trans. Autom. Control.* **1974**, *19*, 716–723. [CrossRef]
46. Garcia-Vila, M.; Lorite, I.; Soriano, M.A.; Fereres, E. Management trends and responses to water scarcity in an irrigation scheme of Southern Spain. *Agric. Water Manag.* **2008**, *95*, 458–468. [CrossRef]
47. Camacho, E. Uso de los indicadores de gestión y Benchmarking para la mejora del Regadío. In Proceedings of the XXIV Congreso Nacional de Riegos, AERYD, Lugo, Spain, 6–8 June 2006.
48. Alcon, F.; García-Bastida, P.A.; Soto-García, M.; Martínez-Alvarez, V.; Martin-Gorriz, B.; Baille, A. Explaining the performance of irrigation communities in a water-scarce region. *Irrig. Sci.* **2017**, *35*, 193–203. [CrossRef]
49. Cakmak, B.; Beyribey, M.; Yildirim, Y.E.; Kodal, S.; Beyribey, M. Benchmarking performance of irrigation schemes: A case study from Turkey. *Irrig. Drain.* **2004**, *53*, 155–163. [CrossRef]
50. Cakmak, B.; Polat Eylem, H.; Kendirli, B.; Gökalp, Z. Evaluation of irrigation performance of Asartepe Irrigation Association: A case study from Turkey. *J. Fac. Agric.* **2009**, *22*, 1–8.
51. Ghazalli, M.A. Benchmarking of irrigation projects in Malaysia: Initial implementation stages and preliminary results. *Irrig. Drain.* **2004**, *53*, 195–212. [CrossRef]
52. Lozano, D.; Mateos, L. Usefulness and limitations of decision support systems for improving irrigation scheme management. *Agric. Water Manag.* **2008**, *95*, 409–418. [CrossRef]
53. Díaz, J.A.R.; Poyato, E.C.; Pérez, M.B. Evaluation of water and energy use in pressurized irrigation networks in Southern Spain. *J. Irrig. Drain. Eng.* **2011**, *137*, 644–650. [CrossRef]
54. Soto-Garcia, M.; Álvarez, V.M.; García-Bastida, P.; Alcon, F.; Martin-Gorriz, B. Effect of water scarcity and modernisation on the performance of irrigation districts in south-eastern Spain. *Agric. Water Manag.* **2013**, *124*, 11–19. [CrossRef]
55. Mateos, L.; Lozano, D.; Baghil, A.B.O.; Diallo, O.A.; Gómez-Macpherson, H.; Comas, J.; Connor, D. Irrigation performance before and after rehabilitation of a representative, small irrigation scheme besides the Senegal River, Mauritania. *Agric. Water Manag.* **2010**, *97*, 901–909. [CrossRef]

56. Marre, M.; Bustos, R.; Chambouleyron, J.; Bos, M.G. Irrigation water rates in Mendoza's decentralized irrigation administration. *Irrig. Drain. Syst.* **1997**, *12*, 67–83. [CrossRef]
57. Koç, C. Assessing the financial performance of water user associations: A case study at Great Menderes basin, Turkey. *Irrig. Drain. Syst.* **2007**, *21*, 61–77. [CrossRef]
58. Yavuz, M.Y.; Kavdır, İ.; Delice, Y.N. Evaluation of current situations of irrigation associations in Lower Seyhan Basin. Harran University. *J. Agric. Fac.* **2004**, *8*, 43–49.
59. Ijir, T.A.; Burton, M.A. Performance assessment of the Wurno irrigation scheme, Nigeria. *ICID J.* **1998**, *47*, 31–46.
60. Cornish, G.A. Performance Benchmarking in the Irrigation and Drainage Sector. Experience to Date and Conclusions. 2005. Available online: http://eprints.hrwallingford.com (accessed on 5 March 2020).