Irrigation and Drainage

Performance assessment of collective irrigation in Water Users Associations of Calabria (Southern Italy)

Journal:	*Irrigation and Drainage*
Manuscript ID:	IRD-14-0112.R2
Wiley - Manuscript type:	Research Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Zema, Demetrio; Mediterranea University of Reggio Calabria, Department Agraria Nicotra, Angelo; Mediterranea University of Reggio Calabria, Department Agraria Tamburino, Vincenzo; Mediterranea University of Reggio Calabria, Department Agraria Zimbone, Santo; Mediterranea University of Reggio Calabria, Department Agraria
Keywords:	Water Users Association, collective irrigation, benchmarking, system operation indicators, financial indicators, irrigation performance

PERFORMANCE ASSESSMENT OF COLLECTIVE IRRIGATION IN WATER USERS ASSOCIATIONS OF CALABRIA (SOUTHERN ITALY)[†]

DEMETRIO ANTONIO ZEMA[*], ANGELO NICOTRA, VINCENZO TAMBURINO AND SANTO MARCELLO ZIMBONE

'Mediterranea' University of Reggio Calabria, Department 'AGRARIA', Italy.

ABSTRACT

In order to identify the weakness factors of the collective irrigation service, the system operation and financial performance of seven WUAs in Calabria has been quantitatively evaluated by a limited set of indicators and compared by common benchmarking techniques.

In relation to the surveyed system operation indicators, the investigation has highlighted a satisfactory fulfilment of crop water demand, but a very low efficiency in exploiting the available irrigation water in all the investigated WUAs. Concerning to the financial aspects of the irrigation service, the results have indicated a very low degree of financial self sufficiency of the WUAs, a high variability of the management, operation and maintenance costs and personnel requirements referred to the irrigated area unit and a very wide range of the average water price per hectare.

The application of the Principal Component Analysis has provided three derivative indicators, measuring the operative and economical performances of the WUAs. The clustering algorithms and the calculation of the Quality Index have shown respectively similarities among the irrigation service performances of the investigated WUAs and have allowed the ranking of these collective agencies.

KEY WORDS: Water Users Association; collective irrigation; benchmarking; system operation indicators; financial indicators; irrigation performance.

[†] Valutation des performances de Coopératives d'Irrigation et d'Amélioration Foncière en Calabre (Italie méridionale)

[*] Correspondence to: Demetrio Antonio Zema, University Mediterranea of Reggio Calabria - Department "Agraria". Località Feo di Vito Località Feo di Vito Reggio Calabria RC 89122, Italy. E-mail: dzema@unirc.it

RESUME

Pour découvrir les criticismes et les propositions améliorantes du service d'irrigation collective, on a évalué par des approches quantitatives les performances économiques et operatives de sept Coopératives d'Irrigation et d'Amélioration Foncière en Calabre (Italie méridionale); pour cette analyse on a fait recours à un nombre limité d'indicateurs synthétiques comparés entre eux par des techniques de benchmarking consolidées.

Pour ce qui concerne les indicateurs de fonctionnement du systhème irrigatoire la recherche a mis en évidence en général la satisfaction des besoins irrigatoires pour le cultures à côté d'un bas rendement dans l'exploitation de l'eau. Pour les aspects économiques du service irrigatoire, l'analyse a souligné un bas degré de suffisance financière en plus d'une grande variabilité des coûts de gestion et du personnel et de ceux de l'eau débitée aux exploitations agricoles.

L'application de l'Analyse des Composantes Principales a donné trois indicateurs dérivés qui décrivent synthétiquement les performances opératives et économiques des Coopératives examinées. Les algorithmes de clustering et le calcul de l'Index de Qualité ont permis respectivement de reconnaître les similitudes des Coopératives et d'effectuer un ranking parmi leurs prestations.

MOTS CLÉS: Association des Utilisateurs de l'Eau; irrigation collective; analyse comparative; indicateurs de fonctionnement du système; indicateurs financiers; performances de l'irrigation.

INTRODUCTION

Irrigation water in Southern Italy is usually supplied and delivered to farms by Water Users Associations (WUA). These organizations operate the technical and economic management of large water systems, built with the contribution of local administrations, by the financial revenues from the associated users of each irrigation district. As a consequence of water fees paid to the WUAs, users must obtain adequate irrigation performance standards, since water is a decisive input in their farming operations (Salvador *et al.*, 2011). Considering that in Mediterranean countries water represents an important limiting factor for agriculture, there is a need for structured analyses on performance of the irrigation service provided by these collective agencies.

The development of different performance evaluation tools for Water Users Associations (WUAs) is important for improving the management and service levels. The outcomes of these technical and economic performance analyses could help to identify the gap between current and achievable performance and make changes to realise higher standards of performance (Malano *et al.*, 2004).

The evaluation of collective irrigation systems is often neglected also because it is considered a time-consuming and costly activity (in fact, it requires identifying, collecting, processing and analysing a number of data needed for evaluating the level of service provision in the investigated WUAs), whose results are appreciable only on the long period.

One of the most utilised tools is the 'benchmarking' technique, which, by comparing the different WUAs, can provide a valuable insight on how well the organisation is performing in all areas of service delivery, resource utilisation and financial management; this technique also becomes an important element of the organisation's accountability to its shareholders (Malano and Burton, 2001).

The irrigation performance of collective agencies by benchmarking has been widely investigated. As regards to the Mediterranean basin (that is under similar climatic and structural conditions of the Italian agriculture), Rodríguez-Dìaz *et al.* (2004; 2008) have applied benchmarking and multivariate data analysis to evaluate the efficiency of some irrigation districts of Andalusia (Southern Spain). More recently, Còrcoles *et al.* (2010; 2012) have assessed the irrigation collective service of a representative sample of seven and six WUAs of Castilla-La Mancha (Spain) through the same techniques (in particular, by Principal Component Analysis and clustering algorithms).

The need for such assessment activities is particularly important in the WUAs operating in Calabria (Southern Italy); here the collective irrigation service suffers from poor performances both on an operative and economic point of views in a region where agriculture is by far the most important economic sector. This induces the inadequacy of water delivery to irrigated crops requirements and low satisfaction levels of farmers towards the collective irrigation service. Nowadays, the weak points of these WUAs are not completely known; furthermore, the infrastructural and management interventions needed to fill the performance gaps can be properly planned by a rational approach based on a quantitative and integrated analysis.

Therefore, the application of benchmarking techniques to the WUAs operating in Calabria Region for collective irrigation management (that, at the authors' knowledge, was never performed) could help to identify the crucial factors which negatively influence the collective irrigation performance in the studied WUAs: this could help to increase the levels of service provision for a more productive and efficient use of resources and a more sustainable irrigated agriculture, to identify what actions should be undertaken and to plan the investment choices and priorities. Calabria Region appears as a proper case study, in relation to the above mentioned importance of the agricultural sector among the local productive activities and to the typicality of the irrigation sector (in terms of infrastructural and management characteristics) among the regions of the Southern Italy (Istituto Nazionale di Economia Agraria, 2011). Moreover, given that there are few examples in the literature of improving efficiency by comparing several irrigation districts by means of performance indicators (Rodríguez-Dìaz *et al.*, 2008; Còrcoles *et al.*, 2010), this study contributes to validate and consolidate benchmarking techniques in the irrigation sector in an attempt to extrapolate this kind of quantitative and integrated analysis to other regions and countries and achieve a more efficient use of irrigation water resources.

This paper carries out an analysis of collective irrigation in Calabria by assessing the levels of service provided by a representative sample of WUAs; the irrigation performances of these collective agencies have been quantitatively evaluated and compared by common benchmarking techniques applied to a limited and universally applicable set of indicators surveyed in the investigated WUAs. In more detail: (i) the application of the Principal Component Analysis has provided a lower number of derivative indicators, measuring the operative and economical performances of the WUAs, and to show eventual correlations between couples of indicators; (ii) the clustering algorithm has highlighted similarities or differences among the investigated WUAs; (iii) the calculation of the quality index has allowed the ranking of the analysed irrigation agencies and indicated where and what actions are needed. Finally, on the basis of the results of the benchmarking some indications about possible improvements in infrastructural aspects, management methods and financial procedures have been suggested.

METHODS

Description of the Water Users Associations

The methodology has been applied to seven of the eleven WUAs supporting the collective irrigation service in Calabria (Figure 1).

Figure 1

The investigated WUAs globally cover over 55% of the irrigated territory of Calabria. In order to characterise the main infrastructural and management aspects, some of the most important key descriptors (background descriptive data such as the water source, type of crops grown, irrigated area, average farm size, irrigation systems, type of management, Malano *et al.*, 2004) have been reported in Table I.

Table I

Calabria Region is a peninsula, extending for about 250 km (North to South) on the Tyrrhenian (West) and Ionian (East) seas. The region is mainly hilly; in many areas mountains are very close to the sea. The region is characterized by a strong rainfall and temperature variability between Tyrrhenian and Ionian areas, separated by the Apennines mountain chain. The mean annual precipitation (P_a) is 1070 mm at the regional level, but 1190 mm in the Tyrrhenian and 1060 mm in the Ionian sub-regions. In typical lat semi-arid coastal areas P_a is equal to 683 mm, while mean annual temperature (T_{ma}) is 17.4 °C; in mountain areas P_a (equal to 1240 mm) and T_{ma} (9.1 °C) get the highest values in southern Italy.

The environment has large naturally wooded areas, with the exception of the coastal zones. The different vegetation belts follow the different altitude belts, ranging from those typical of hot, dry climates to those typical of cool, humid climates. Agriculture context of in the region is characterized by orchards and herbaceous crops (Capra *et al.*, 2013).

Description of the indicators

Several researchers (e.g. Molden and Gates, 1990; Malano and Burton, 2001) have developed performance indicators to study irrigation system efficiency and have attempted to standardize their use. Generally, in benchmarking of WUAs the guidelines provided by have been often adopted (e.g. Cakmak *et al.*, 2004; Ghazalli, 2004; Rodrìguez-Dìaz *et al.*, 2004; 2008; Còrcoles *et al.*, 2010; 2012). Several organizations have agreed on the set of performance indicators (*service delivery performance*, *productive efficiency* and *environmental indicators*) and the respective methodology developed by Malano and Burton (2001) for their application with the purpose of improving the efficiency of water use in irrigation.

In the investigated WUAs agronomic and economic yields of the irrigated crops depend on the peculiar cultivation and irrigation methods, which vary from a farm to another; moreover, the data of agricultural production and gross/net margins are not easily available for each farm o irrigation district, but are aggregated only at a provincial or regional scales. None of the investigated WUAs has carried out activities for measuring and surveying environmental indicators related to irrigation water quality and use of fertilizers. However, Còrcoles *et al.* (2010) stated that it is possible to reduce the set of indicators by omitting just the *production efficiency* and *environmental indicators* without loosing too much information. Therefore, in this work the analysis of these groups of indicators has been omitted and our attention has been mainly paid to *service delivery performance* indicators (grouped in *system operation* and *financial*); the data related to energy (limited to the electricity for water pumping in three WUAs only and to fuel of maintenance machines) have been evaluated in terms of the related costs and included in the set of financial indicators.

Most of the indicators usually utilised in benchmarking the irrigation performance have strong interrelations; for example, the main differences among some indicators lie in considering different types of unit areas (command or irrigated) and volume of irrigation water (supplied, delivered, consumed, required) (Còrcoles *et al.*, 2010). Moreover, these monitoring activities being time consuming and difficult to be implemented (Malano *et al.*, 2004). Thus, the indicators should be properly selected and their number reduced. Therefore, *system operation indicators*, characterizing water use, irrigation area, crop water requirements and thus addressing water resource management, have been selected and adapted to our study as follows:

- the *annual volume of irrigation water supply* (that is defined as the water diverted or pumped for irrigation), where measures of water supplied into the water systems were lacking, has been estimated through the volume of water available for irrigation in the supplying water source;
- the *annual volume of crop water demand* have been drawn by the '*Map of the water requirements in agriculture*' of Calabria (Agenzia Regionale per lo Sviluppo ed i Servizi in Agricoltura della Calabria, 2008);
- only the parameters referred to the irrigated area (thus neglecting those related to the command area) have been calculated; this has allowed a simplification of the analysis, also considering that the ratio between the irrigated and the command areas has been separately adopted as indicator.

Therefore, the resulting set of system operation indicators consists of the following parameters (Table II):

- *Irrigated area/Command area Ratio (ICR, %)*, which is an indicator of the coverage of the irrigation service over each WUA territory;

- *Annual irrigation water Delivery per unit of Irrigated Area (WDIA, m^3 ha^{-1})*, indicating the water consumption per unit of serviced area;
- *Annual Relative water Supply (RIS, %)*, index of the user fulfilment degree of water demand;
- *Water Delivery Efficiency (WDE, %)*, indicator of WUA efficiency in exploiting the water resource available for irrigation.

The *financial indicators*, related to input (revenues) and management (expenses) costs of each WUA (e.g. maintenance, personnel, energy, operation), have been selected as follows (Table II):

- *Cost Recovery Ratio (CRR, %)*, index of the degree of financial self sufficiency of the WUA;
- *Total Management, Operation and Maintenance (MOM) cost per unit Area (MOMA, € ha^{-1})*, which standardizes the management costs on the irrigated area; in general, the MOM expenses are adequate to assure a minimum maintenance and service level for the irrigation service as highlighted by the generally acceptable fulfilment degree of crop water demand from associated farmers in the investigated WUAs;
- *Revenue Collection Performance (RCP, %)*, indicating the capacity of due fee collecting;
- *Staffing number per Unit Irrigated Area (SUIA, persons 100-ha^{-1})*, measuring the personnel employed in the irrigation service, referred to the area unit.

In addition to the parameters mentioned above, the *Average Water Price per unit of irrigated area* (*AWP, € ha^{-1})* has been considered, in order to take into account the water resource cost for the users.

The other parameters reported by Malano and Burton (2001) and related to system operation indicators (e.g. *Water delivery capacity*, *Submergence of drainage outlet*, *Security of entitlement supply*) have not been considered due to the data unavailability or no recurrence in the investigated WUAs.

For calculating the selected indicators the input parameters reported in Table II have been surveyed in each WUA during the last three years (2011-2013) and the data collected have been averaged on the different survey years, achieving very low differences from one year to another (coefficient of variation, CV, lower than 5%).

Benchmarking process

Based on the previous experiences by Rodrìguez-Dìaz *et al.* (2008) and Còrcoles *et al.* (2010; 2012), benchmarking process of irrigation performance in the seven WUAs of Calabria has been carried out in three steps.

First, we utilised the Principal Component Analysis (PCA), a statistical multivariate technique which simplifies the analysis of a multidimensional phenomenon, loosing as little as possible information. By PCA, reducing the dimensionality of a data set of a large number of original and correlated variables (in our case represented by a number of performance indicators), new derivative and uncorrelated variables, called 'principal components' (PCs), are identified as linear combinations of the original variables.

In this study PCA has been performed through the following steps (Còrcoles *et al.*, 2010):

- standardization of indicators, by converting the original matrix data to zero mean and unit variance;
- computation of the correlation matrix, to identify correlation between indicators;
- calculation of the percentage of variance explained and selection of the PCs;
- computation of the rotated component matrix through Varimax rotation (Richman, 1986), the method most commonly used, because it reduces the variance of the data projection onto the rotated axis;
- selection of the PCs retaining as much as possible of the variance within the original data set; in our study the number of PCs explaining at least a percentage of 70% of the original variance has been chosen.

Secondly, the WUAs have been grouped using Agglomerative Hierarchical Cluster Analysis (CA), a distribution-free ordination technique to group sites with similar characteristics by considering an original group of variables. As similarity-dissimilarity measure the Euclidean distance has been used. WUA grouping through CA has been reported in a dendrogram.

Finally, the Quality Index (QI) of each WUA, proposed by Rodrìguez-Dìaz *et al.* (2008), was calculated. On the basis of the outcomes of the PCA the QI aggregates all the selected indicators into a single number that is easier and quick to interpret and compare.

The QI is made up of some compound ′levels′ that largely coincide with as many PCs. In order to determine each level, the indicators which are most useful in explaining the variance of the PC are used. Each level is determined by the sum of the standardised values of each performance indicator. Moreover, each level is assigned a weight that depends on the variance of its corresponding PC, in order to weigh the contribution of each level to the total value of the index.

The structure of QI of the WUA 'j' is shown in the following equation:

$$QI(j) = \sum_{i=1}^{n} \alpha_i \ L_i \quad (1)$$

where α_i is the weight - coming from the PCA - which depends on the percentual variance of the PC 'i', L_i is the value of the level 'i' and 'n' is the number of PCs taken into consideration.

RESULTS AND DISCUSSIONS

Analysis of the input parameters and performance indicators

In relation to the *system operation input parameters*, the irrigated area (IA) of the investigated WUAs is in the range 252 – 5044 ha and covers only from 0.2 to 3.6% of the administrative area (Tables I and II).

The annual volume of irrigation water supply (VIWS) per hectare varies from 6800 (WUA TVV) to 44200 (IKR) m^3 ha^{-1} (Table II); the annual volume of crop water demand (VCWD) per hectare, depending on the different irrigated crops, has a minimum value of 1900 m^3 ha^{-1} in the WUA BIRC (where the main crop is olive) and a maximum of 3900 m^3 ha^{-1} in BSCS (where crops with high water demand are cultivated, as citrus and vegetables) (Table II). Therefore, the total water available for irrigation is theoretically in general much higher than the volume required (Figure 2), but the resource is irregularly distributed along the year, due to the semi-arid climatic characteristics of these areas; water is in excess during the wet season (during the winter months), while the volume required by crops is not available during the dry season (from late April to early October). This means that, given that farmers sometimes complain water shortage in many analysed WUAs, the insufficient storage capacity of natural (lakes) and artificial (reservoirs) water bodies does not allow a proper water resource regulation for irrigation purposes and thus the high water demand of some crops during the irrigation season can not be always fulfilled.

Concerning the *financial input parameters*, the size of the irrigation staff (NPID) is strongly variable: from 21 (TVV) to 143 (IKR) persons (with different roles and jobs, ranging from field workers to directive charges) are employed in the irrigation service (Table II); in general, it has been noticed that the number of employees devoted to management and financial activities is quite constant, while the number of the field operators workers directly utilised for irrigation service maintenance is not proportional to the irrigated area.

The gross revenue amount invoiced to the users (GRI) per unit area is on the average equal to 0.42 € ha^{-1} with a high variability (CV = 104%) (Figure 2). Generally the higher is the irrigated area, the lower is the invoiced revenue per hectare (with the exception of the WUA AIRC) (Table II).

The MOM cost (MOMC) per hectare has a mean value of 0.46 € ha^{-1} and a CV of 92% (Figure 2). This parameter is weakly correlated ($r^2 = 0.31$) with the irrigated area of the analyzed WUAs.

Table II

Figure 2

The analysis of the surveyed *system operation indicators* highlights that:

- ICR shows a wide variability (from 13.7%, BIRC, to 78.3%, TVV) (Table II); this indicator, expressing the coverage of the irrigation service over the WUA territory, is not dependent ($r^2 = 0.07$) on the command area;
- the annual water consumption per unit of serviced area (indicated by WDIA) shows a mean value of 2700 m^3 ha^{-1} and a moderate variability (CV = 39%) (Figure 2);
- the fulfilment degree of crop water demand, expressed by RIS, is on the average higher than 100% (Figure 2); in two WUAs (ICZ and BIRC) the water consumption is higher than the crop demand and in the others is close to 90%, except for TVV, where the water demand is far to be fulfilled (RIS = 58.8%) (Table II);
- the efficiency in exploiting the water resource available for irrigation, indicated by WDE, is very low in all the investigated WUAs; on the average only the 14.5% of total annual water volume is delivered to farms (Figure 2) with a maximum value of WDE equal to 40.9% recorded in WUA ICZ (Table II); a weak correlation ($r^2 = 0.34$) has been found between this parameter and the irrigated area of the WUAs.

The analysis of the *financial performance indicators* shows a very low degree of financial self sufficiency of the WUAs, the average CRR being lower than 55% (Figure 2). Only in WUA TVV a complete cost recovery has been remarked; minimum values of 25-30% have been recorded for CRR in the WUAs AIRC and BIRC (Table II). In general, the financial self sufficiency is not correlated ($r^2 = 0.31$) to the command area of the WUAs.

The total MOM cost per unit area service by the irrigation system (MOMA) shows a high degree of variability (CV = 92%) with respect to the mean value (460 € ha^{-1}) (Figure 2); this variability is expected, considering that MOM costs vary according to the physical condition of scheme, whether routine maintenance-repair works are achieved or not, organization structure of the WUAs, collected irrigation fee revenue, size of irrigated area and rate of irrigated to command area, whether water is supplied by gravity or pumping, etc. (Koç, 2007). The highest MOMA (1280 € ha^{-1}, BIRC) is more than 10 times higher compared to the lowest value (105 € ha^{-1}, BSCS) (Table II). This indicator shows a weak tendency (r^2 = 0.31) to decrease with increasing irrigated areas, contrarily to what expected, considering that in districts of larger size the total MOM costs, are divided among several hectares (Rodrìguez-Dìaz *et al.*, 2008).

The WUA capacity of due fee collecting, expressed by RCP, is on the average equal to 63.3% (Figure 2); only one WUA (IKR) is able to completely collect the invoiced fees, while in the other WUAs (for example, BSCS, TVV and TRC) the payment evasion is very high (Table II). This could confirm that in these latter WUAs the satisfaction of farmers towards the collective irrigation service is low, RCP being a significant indicator for level of acceptance of irrigation water delivery as a service to the associated users (Marre *et al.*, 1998). Moreover, RCP indicates the effectiveness of the collection program, but it can also be affected by different factors, as the economic condition of the users, the degree to which they feel the system is worth supporting. Values greater than 100 are possible if overdue revenues related to previous years are collected (Koç, 2007). As a matter of fact, it must be highlighted that in the WUAs IKR, AIRC and BIRC (where the highest RCP values have been detected) the value of this indicator is affected by the recent enhancement of the revenue collection procedure; more specifically, the managers of these WUAs in the last two or three years prior to investigation have carried out a special collection not only of the service fees due for the current year, but also of the overdue amounts related to the previous periods, in order to rebalance costs and revenues.

It is interesting to remark that the revenue collection performance does not depend either on the users number (r^2 = 0.11) or the command or irrigated area (r^2 < 0.31); conversely, an increase of the capacity of due fee collecting with decreasing WUA size could be expected, considering that, presumably, the lower is the number of associated users or the area, the higher is the control of the due fees (Koç, 2007).

The personnel requirement for the irrigation service referred to the irrigated area unit (SUIA) shows a mean value of about 4 persons 100-ha^{-1} with a wide variability among the investigated WUAs (CV = 111%) (Figure 2), due to the normal variations of labour productivity, intensity of irrigation and distribution schemes and technology involved (Koç, 2007). This indicator is inversely correlated with the irrigated area (r^2 = 0.65), indicating that, as expected, the personnel employed in the irrigation service decreases when the WUA irrigated area increases.

Finally, the average water price per hectare (AWP) falls in a very wide range (from 125 € ha^{-1}, BSCS, to even 605 € ha^{-1}, BIRC). Generally, the WUAs located in the southern of the Calabria Region (TRC, AIRC and BIRC) show an average water price (about 420 € ha^{-1}) which is three times the mean value recorded in the other WUAs (about 140 € ha^{-1}). This could be due to the inadequacy of the water network and the low financial performance of these WUAs (see the low values of CRR and the high MOMC, Table II): as a matter of fact, the WUAs AIRC and BIRC must support a high incidence of energy costs for groundwater pumping about 50% of the total irrigation water (Table I) and of maintenance works; in addition to that, in the WUA TRC the percentage of free surface canals is high, which induce high water losses (Table I). The regression analysis shows an appreciable inverse correlation between AWP and the irrigated area (r^2 = 0.54), indicating that the size of the serviced area influences in a some way the irrigation service cheapness.

Statistical analysis of indicators using Principal Component Analysis

The PCA provides three Principal Components - explaining 92.8% of the total variance, - which appear highly significant to easily summarize the irrigation service performance in the investigated WUAs by a low number of new variables, derived from the original performance indicators.

As shown by the loadings (reported in Figure 3 for the PC_1 and PC_2), measuring how much each original variable (represented by one indicator) influences the PCs, the ICR and most of the financial indicators (CRR, MOMA, RCP and SUIA) are strongly influential (absolute values of the loadings higher than 0.79) on the PC_1, while PC_2 is mainly linked (absolute values of the loadings > 0.80) to the system delivery performance indicators (WDIA and RIS); the third PC is influenced only by the unit water price (AWP) (absolute value of the loading = 0.95). Therefore, high positive PC_1 characterize the WUAs with low ICR, WDE and CRR as well as high MOMA, RCP and SUIA, while a high positive PC_2 identifies the WUAs with high WDIA and RIS (Figure 3).

Figure 3

Given that PC_3 is correlated only to the average water price (AWP) and explains only 10.5% of the total variance, in the following discussion only PC_1 and PC_2 will be commented.

The indicators (original variables) and the scores of the WUAs are plotted on a PC_1-PC_2 chart (Figure 3). Only one evident cluster can be identified, grouping together the WUAs IKR, AIRC and BIRC, which have shown similar system operation and financial performance in the irrigation service.

The analysis of this plot allows some interesting considerations to be drawn:

- the WUAs AIRC, BIRC and IKR lies close to the positive x-axis (PC_1) (Figure 3), showing low coverage of the irrigation service (ICR) and water delivery efficiency (WDE) as well as poor financial performances (shown by low CRR as well as high MOMA and SUIA), but, in spite of that, good revenue collection capacity (RCP) (Table II); however, as mentioned before, this latter parameter is affected by the recent enhancement of the revenue collection procedure;
- the WUA TVV has got the lowest value of PC_1 (Figure 3), due to the highest ICR and CRR (which, as mentioned above, strongly influence PC_1, Figure 3) as well as the lowest value of MOMA (Table II); however, this appreciable performance is negatively affected by the low value of RCP (which contributes to increase PC_1);
- TVV is also characterized by a very low value of PC_2 (Figure 3), mostly influenced by the low WDIA and RIS (Table II), which get the lowest values among the investigated WUAs; this system operation performance is poor, despite the complete use of pressured pipelines in the water network, which however should improve water distribution and delivery to users (thus increasing WDIA) and fulfilments of crop water demand (therefore inducing a high value of RIS). Such a poor system operation performance is therefore presumably attributable to the inadequacy of water regulation and supplying works, even though more investigation is needed;
- ICZ lies close to the positive y-axis (PC_2) (Figure 3) and therefore it is characterized by the highest values of WDIA and RIS (Table II); moreover, this WUA shows a negative value of PC_1, which highlights its satisfactory financial performance, on the basis of the values of the related indicators (in particular SUIA and WDE, which get the highest values among the investigated WUAs) and ICR (Table II).

On the whole, the WUAs showing in general the best system operation and financial performances (except for the cost recovery capacity) are characterised by a low PC_1 and a high PC_2; conversely, a high PC_1 and a low PC_2 generally show that irrigation service needs improvements in the infrastructural, management and economic aspects. Therefore, from the analysis it emerges that PCA is a power tool to identify the system operation and financial weak points and good practices, because this statistical techniques simplifies the analysis of a large number of performance parameters.

Grouping of WUAs using Agglomerative Hierarchical Cluster Analysis

According to the position of the clustering line, the dendrogram reporting the results of the CA (Figure 4) shows a high dissimilarity among to the two identified clusters grouping the investigated WUAs; a cluster of five collective agencies includes the WUA BSCS, IKR, ICZ, TVV and TRC, while the second cluster groups the WUA AIRC and BIRC. Conversely, a high similarity has been found within the first cluster, as shown by the position of the related branches (falling below the clustering line).

Figure 4

The outcomes of the cluster analysis is basically in tune with the results of the PCA, both separating two WUAs (AIRC and BIRC) with the worst system operation and financial performances (except for the cost recovery ratio) from the other five collective agencies, whose irrigation service appears more satisfactory.

Calculation of the Quality Index (QI)

As mentioned in the method section, the structure of the QI is based on the PCA, which has provided the values of the coefficients of the 'levels' L_i of the QI in equation [1] (Rodrìguez-Dìaz *et al.*, 2008). Explaining the first three PCs more than 90% of the total variance of the original variables, only three levels (n = 3, corresponding to as many PCs) have been taken into consideration. Therefore, the QI of the investigated WUA 'j' is given by the following equation:

$$QI(j) = 64.2 \cdot L_1 + 18.2 \cdot L_2 + 10.5 \cdot L_3 \quad (2)$$

in which the significance of the symbols is given in section 2.3.

As it can be remarked from Table III, the best performing WUA is ICZ, followed by BSCS. It is confirmed, as previously shown by both PCA and CA, the poor efficiency and economic performances provided by the WUA BIRC, which even has got a negative value of the QI.

Table III

Quantifying the contribution of each indicators in calculating the QI (and thus the irrigation performance of each WUA), the scores of the levels 1, 2 and 3 (data not shown) allow the identification of the weak points and good practices in operative and financial performance of the irrigation service for each WUA. For example, the low score of the WUAs TRC, AIRC and BIRC for level 1 (linked to PC_1) suggests that major improvements should be introduced in the financial management (except for fee collection, which is adequate); the low score of the WUA TVV for level 2 should turn the managers' attention to system operation (given the low values of WDIA and RIS, correlated to PC_2), while the high value of level 2 for the WUA ICZ indicates that the system operation of the irrigation service is adequate and its improvement is not a priority. Finally, the values (negative or close to zero) of level 3 achieved by the WUAs TRC, AIRC and BIRC suggest to lower the water price for the users by proper infrastructural, management and financial solutions.

CONCLUSIONS

The application of benchmarking techniques applied to a limited set of indicators has allowed a quantitative evaluation of the system operation and financial performance of seven WUAs in Calabria Region.

In relation to the system operation indicators the investigation has highlighted in general a complete fulfilment degree of crop water demand, but a very low efficiency in exploiting the water resource available for irrigation in all the investigated WUAs. Concerning to the financial aspects, we have found for the analysed WUAs a very low degree of financial self sufficiency, a high variability of the MOM costs and personnel requirements and a very wide range of the average water price per hectare.

The clustering algorithms and the calculation of the QI have shown respectively similarities among the irrigation service performance and have allowed ranking the investigated WUAs.

On the whole, the combined application of the different benchmarking techniques has proven to be an useful and easy methodology for the diagnostic process (often resulting difficult and time consuming) of the collective irrigation system in Calabria Region, in order to identify its key and crucial factors and thus suggesting possible actions to policy makers and to managers and technicians of the WUAs. Finally, this study contributes to validate and consolidate benchmarking techniques in the irrigation sector in an attempt to extrapolate this kind of quantitative and integrated analysis to other regions and countries and achieve a more efficient use of irrigation water resources.

REFERENCES

Agenzia Regionale per lo Sviluppo ed i Servizi in Agricoltura della Calabria. 2008. *Map of the water requirements in agriculture* of Calabria (2008). ARSSA, Catanzaro (Italy) (In Italian).

Cakmak B, Beyribey M, Yildirim YE, Kodal S. 2004. Benchmarking performance of irrigation schemes: a case study from Turkey. *Irrigation and Drainage* **53**: 155–163.

Capra A, Consoli S, Scicolone B. 2013. Long-Term Climatic Variability in Calabria and Effects on Drought and Agrometeorological Parameters. *Water Resources Management* **27:** 601–617.

Córcoles JI, de Juan JA, Ortega JF, Tarjuelo JM, Moreno MA. 2010. Management evaluation of Water Users Associations using benchmarking Techniques. *Agricultural Water Management* **98**: 1–11.

Córcoles JI, de Juan JA, Ortega JF, Tarjuelo JM, Moreno MA. 2012. Evaluation of Irrigation Systems by Using Benchmarking Techniques. *Journal of Irrigation and Drainage Engineering* **138(3)**: 225–234.

Ghazalli MA. 2004. Benchmarking of irrigation projects in Malaysia: initial implementation stages and preliminary results. *Irrigation and Drainage* **53**: 195–212.

Istituto Nazionale di Economia Agraria. 2011. Atlante nazionale dell'irrigazione. INEA, Rome (Italy) (in Italian).

Koç C. 2007. Assessing the financial performance of water user associations: a case study at Great Menderes basin, Turkey. *Irrigation and Drainage Systems* **21(2)**: 61-77.

Malano H, Burton M. 2001. Guidelines for benchmarking performance in the irrigation and drainage sector. In *International Programme for Technology and Research in Irrigation and Drainage (IPTRID)*, Rome, Italy.

Malano H, Burton M, Makin I. 2004. Benchmarking performance in the irrigation and drainage sector: a tool for change. *Irrigation and Drainage* **53**: 119–133.

Marre M, Bustos R, Chambouleyron J, Bos MG. 1998. Irrigation water rates in Mendoza's decentralized irrigation administration. *Irrigation and Drainage Systems* **12**: 67-83.

Molden D, Gates JK. 1990. Performance measures for evaluation of irrigation water delivery systems. *Journal of Irrigation and Drainage Engineering* **116**: 804–823.

Richman M. 1986. Rotation of principal components. *Journal of Climatology* **6**: 293–335.

Rodríguez-Dìaz JA, Camacho E, López R, Pérez L. 2008. Benchmarking and multivariate data analysis techniques for improving the efficiency of irrigation districts: an application in Spain. *Agricultural Systems* **96**: 250–259.

Rodríguez-Dìaz JA, Camacho Poyato E, Lopez Luque R. 2004. Applying benchmarking and data envelopment analysis (DEA) techniques to irrigation districts in Spain. *Irrigation and Drainage* **53**: 135–143.

Salvador R, Martínez-Cob A, Cavero J, Playán E. 2011. Seasonal on-farm irrigation performance in the Ebro basin (Spain): Crops and irrigation systems. *Agricultural Water Management* **98**: 577–587.

LIST OF ACRONYMS

Input parameters/performance indicators

IA: Total annual irrigated area serviced by the system
VIWS: Annual volume of irrigation water supply
VIWD: Annual volume of irrigation water delivery
VCWD: Annual volume of water used by the crop to meet evapotranspiration demand
GRI: Gross revenue invoiced
GRC: Gross revenue collected
MOMC: Total management, operation and maintenance (MOM) cost
NPID: Total number of personnel engaged in I&D service.
ICR: Irrigated area/command area ratio
WDIA: Annual irrigation water delivery per unit irrigated area
RIS: Annual relative irrigation supply
WDE: System water delivery efficiency
MOMA: Total MOM cost per unit area
CRR: Cost recovery ratio
RCP: Revenue collection performance
SUIA: Staffing numbers per unit of irrigated area
AWP: Average water price.

Water Users Associations

BCSC:	Bacini Settentrionali del Cosentino
IKR:	Ionio Crotonese
ICZ:	Ionio Catanzarese
TVV:	Tirreno Vibonese
TRC:	Tirreno Reggino
AIRC:	Alto Ionio Reggino
BIRC:	Basso Ionio Reggino.

TABLES

Table I. Main characteristics of the WUAs (Calabria, Southern Italy) analyzed for benchmarking the collective irrigation performance.

Characteristics	WUA						
	BSCS	IKR	ICZ	TVV	TRC	AIRC	BIRC
Administrative area (ha)	120295	139369	115280	99997	96094	87905	108754
Associated users	48143	25800	48043	12000	36559	26652	29654
Number of irrigated farms	2024	1068	2840	125	1177	1793	651
Average farm size (ha)	4.45	19.46	3.52	9.06	6.86	1.84	2.82
Main crops	Maize, wheat, forage, fruits	Vegetables, cereals, maize, citrus	Vegetables, maize, citrus, fruits, forage	Citrus, fruits, vegetables, maize	Citrus, olives	Citrus, olives, vegetables, cereals	Citrus, olives, vegetables, cereals
Type of water distribution	Rotational schedule	n.a.	On demand	Rotational schedule	Rotational schedule	Rotational schedule	Rotational schedule
Irrigation system	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler	Sprinkler, surface	Sprinkler, flowing	Sprinkler, surface, microirrigation
Water source	Surface water (40%), groundwater (60%)	Surface water	Surface water	Surface water	Surface water	Surface water (50%), groundwater (50%)	Surface water (50%), groundwater (50%)
Irrigation water availability	Sufficient	Sufficient (occasionally not sufficient)	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
Method of water delivery	Gravity	Gravity	Gravity	Gravity	Gravity (60%), in pressure (40%)	Gravity	Gravity
Water delivery infrastructure	Pressured pipeline (90%), open canal (10%)	Pressured pipeline (60%), open canal (40%)	Pressured pipeline (90%), open canal (10%)	Pressured pipeline	Pressured pipeline (50%), open canal (50%)	Pressured pipeline (80%), open canal (20%)	Pressured pipeline (80%), open canal (20%)
Type of revenue collection	Charge on crop type and irrigated area	Charge on crop irrigated area	Charge on crop irrigated area	Charge on crop irrigated area	Charge on crop type and irrigated area	Charge on crop irrigated area	Charge on crop irrigated area
Type of water control equipment	None	None	None	None	None	None	None
Discharge measurement facilities	None	Weir in supply points	None	None	None	None	None

Note: n.a.: not available.

Table II. Values of the input parameters and selected indicators for benchmarking the collective irrigation performance in seven WUAs of Calabria (Southern Italy).

PARAMETER or PERFORMANCE INDICATOR	WUA						
	BSCS	*IKR*	*ICZ*	*TVV*	*TRC*	*AIRC*	*BIRC*
INPUT PARAMETERS							
System operation aspects							
IA (ha)	3000	5044	4000	886	2118	675	252
VIWS (Mm^3)(*)	78	223	44	6	39	24	18
VIWD (Mm^3) (*)	10.7	12.6	18.0	1.1	5.3	1.4	0.6
VCWD (Mm^3) (*)	11.7	13.6	10.0	1.9	5.5	1.4	0.5
Financial aspects							
GRI (k€)(*)	420	812	970	1200	480	177	132
GRC (k€)(*)	190	813	708	120	270	139	106
MOMC (k€)(*)	315	1750	1070	114	670	522	324
NPID	63	143	24	21	52	33	37
PERFORMANCE INDICATORS							
System operation aspects							
ICR (%)	33.3	24.3	40.0	78.3	26.2	20.4	13.7
WDIA (10^3 m^3 ha^{-1})	3.6	2.5	4.5	1.2	2.5	2.1	2.5
RIS (%)	91.1	92.8	179	58.8	97.2	97.9	130
WDE (%)	13.7	5.7	40.9	18.2	13.6	5.8	3.5
Financial aspects							
CRR (%)	60.2	46.4	66.2	105	40.3	26.5	32.8
MOMA (€ ha^{-1})	105	347	268	129	316	774	1280
RCP (%)	45.1	100	73.0	10.0	56.3	78.1	80.3
SUIA (persons 100-ha^{-1})	2.1	2.8	0.6	2.4	2.5	4.9	14.7
AWP (€ ha^{-1})	125	135	145	150	388	272	605

(*) Value per year

Table III. Values of Quality Index (QI) and rank of the collective irrigation performance in seven WUAs of Calabria (Southern Italy).

WUA	QI	Rank
ICZ	4470	1
BSCS	2240	2
TVV	2170	3
IKR	1710	4
TRC	946	5
AIRC	243	6
BIRC	-1410	7

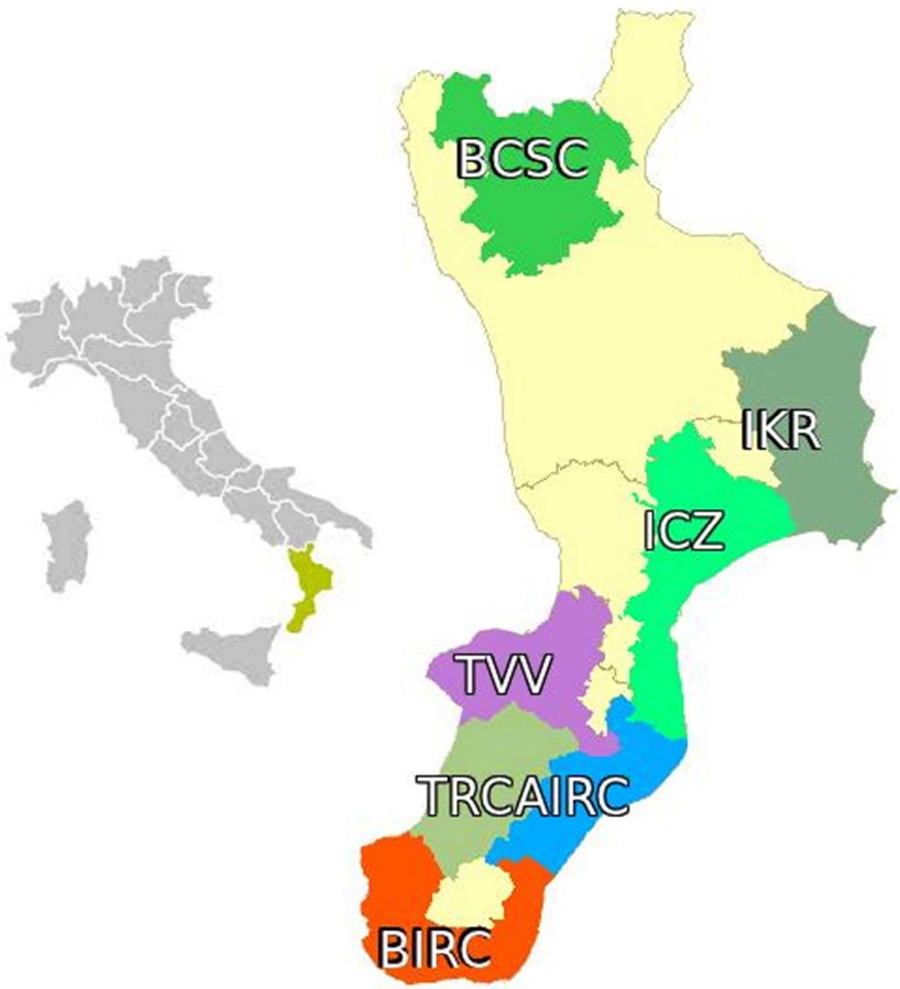

Figure 1 - Map of the analysed seven out of eleven WUAs covering the collective irrigation service and in Calabria (Southern Italy).
141x151mm (96 x 96 DPI)

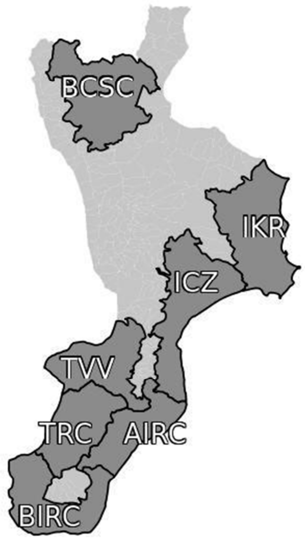

Figure 1 – Map of the analysed seven out of eleven WUAs covering the collective irrigation service and in Calabria (Southern Italy).
254x152mm (96 x 96 DPI)

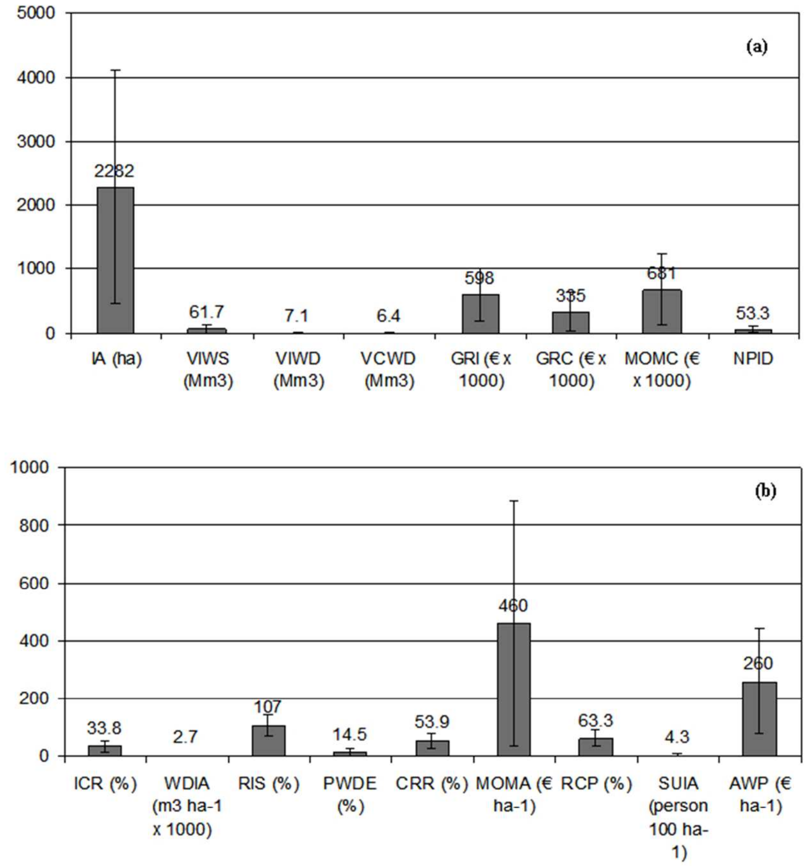

Figure 2a, b - Mean and standard deviation of input parameters (a) and performance indicators (b) for benchmarking the collective irrigation in seven WUAs of Calabria (Southern Italy).
190x254mm (96 x 96 DPI)

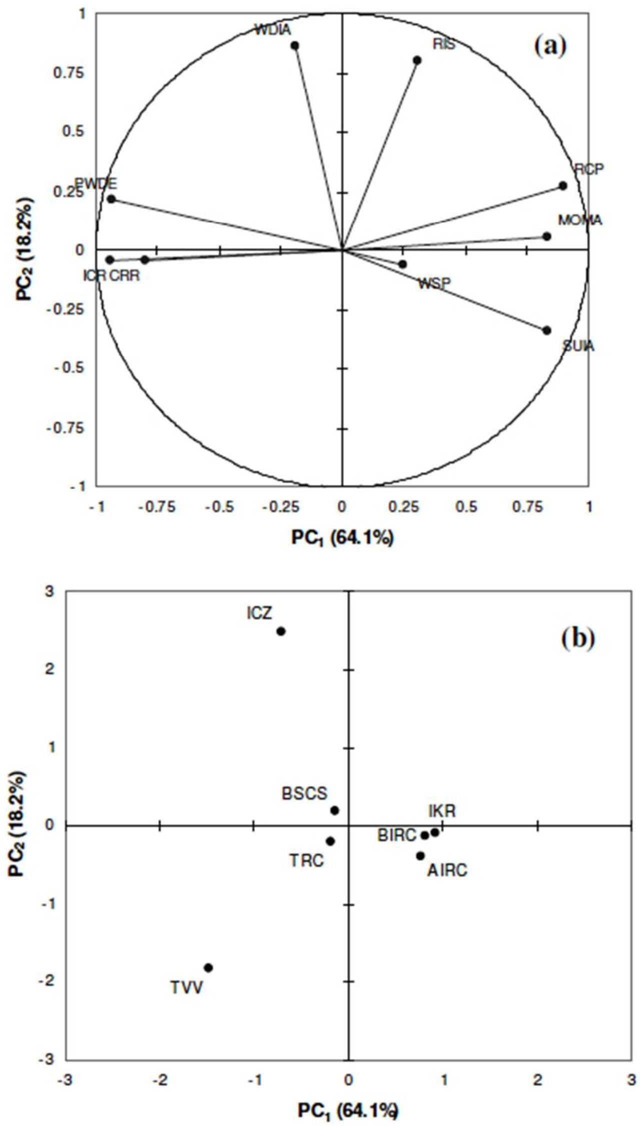

Figure 3a, b – Loadings of performance indicators (a) and WUA scores (b) on the first two principal components (PC1 and PC2) in benchmarking the collective irrigation in seven WUAs of Calabria (Southern Italy) (the percentage of variance explained by each PC is reported in brackets).
129x200mm (96 x 96 DPI)

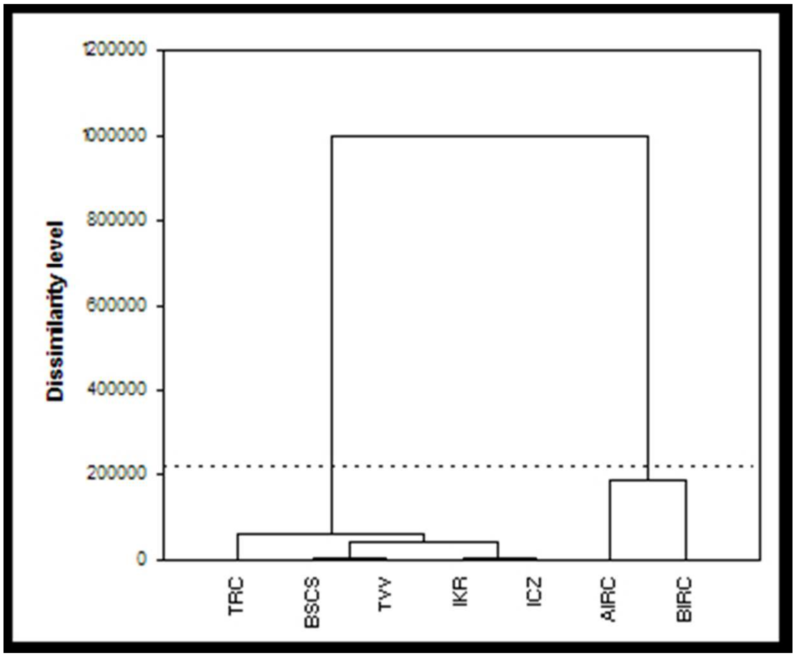

Figure 4 – Dendrogram of Agglomerative Hierarchical Cluster Analysis of seven WUAs of Calabria (Southern Italy) (y-axis reports the level of dissimilarity, while the dotted line the clustering level).
104x85mm (96 x 96 DPI)