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DIAGNOSIS AND IMPROVEMENT OF THE COLLECTIVE IRRIGATION AND DRAINAGE SERVICES IN WATER USERS ASSOCIATIONS OF CALABRIA (SOUTHERN ITALY)†

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ABSTRACT

There is a need of diagnostic processes of collective irrigation and drainage services in Southern Italy, helping to identify the weak points of management and to suggest the improving actions. To these aims, a comprehensive analysis of the collective services in the water users associations (WUA) operating in Calabria has been carried out, covering the infrastructural, organisation and management approaches.

The investigation has shown important shortcomings: i) the old and small irrigation systems need renovation; ii) the drainage service would benefit from a continuous and planned maintenance activity of the hydraulic network; iii) a rational re-organisation of the WUA's human resources together with education activities are suggested. Management of WUAs (affected by low service levels and economical imbalance) needs improvements in procedures of water distribution (from rotational schedule into on-demand delivery) and water charging (with taxation on the actual water consumption instead of irrigable area) together with the reduction of fee evasion and integration of profits (e.g. through sale of hydro-electrical energy by small turbines installed in the irrigation networks).

This survey proposes a methodological framework which could be a technical and scientific support enlarged to all the aspects influencing irrigation and drainage activities of

† Diagnostic et amélioration des services d'irrigation collective et de drainage dans les associations d'utilisateurs de l'eau de Calabre (Italie du Sud)

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collective agencies and transferable to other rural contexts.

KEY WORDS: irrigation system; drainage network; land reclamation; performance indicator; associated farmers.

RÉSUMÉ

Il y a un besoin de processus de diagnostic des services collectifs d'irrigation et de drainage dans le sud de l'Italie, aidant à identifier les points faibles de la gestion et à suggérer des actions d'amélioration. À ces fins, une analyse complète des services collectifs dans les associations d'usagers de l'eau (AUE) opérant en Calabre a été réalisée, couvrant les approches d'infrastructure, d'organisation et de gestion.

L'enquête a montré des lacunes importantes: i) les vieux et petits systèmes d'irrigation ont besoin d'être rénovés; ii) le service de drainage pourrait bénéficier d'une activité de maintenance continue et planifiée du réseau hydraulique; iii) une réorganisation rationnelle des ressources humaines de l'AUE ainsi que des activités éducatives sont suggérées. La gestion des AUE (affectée par un faible niveau de service et un déséquilibre économique) nécessite des améliorations des procédures de distribution d'eau (du calendrier de rotation à la demande) et taxation de l'eau (avec taxation de la consommation réelle d'eau au lieu de la zone irrigable) ainsi que la réduction des fraudes et l'intégration des profits (par ex. par la vente d'énergie hydroélectrique par de petites turbines installées dans les réseaux d'irrigation).

Cette enquête propose un cadre méthodologique qui pourrait être un support technique et scientifique élargi à tous les aspects influençant les activités d'irrigation et de drainage des agences collectives et transférable à d'autres contextes ruraux.

MOTS CLÉS: système d'irrigation; réseau de drainage; remise en état des terres; indicateur de performance; agriculteurs associés.

INTRODUCTION

In southern Italy management of water resources in rural lands (irrigation and drainage) has been carried out for several centuries by collective organisations, since the public interest has been always recognised. In Calabria region, where agricultural production has always been the main economic sector and the hydrogeological risk is pressing, a key role was played since long time by Water Users Associations (WUA). These institutions were born in the nineteenth century with the aims to reduce the hydrogeological risk and, subsequently, to satisfy the irrigation requirements in agriculture. Currently, the WUAs are associations of farmers with private-originated discipline, but are forced to follow public rules because of the public interest of water resource management.

In relation to collective irrigation, after several decades from WUAs' birth and in spite of the considerable public funds allocated throughout the last century, service quality is often not adequate to farmers' needs. This is due to infrastructural, organisation and management problems, resulting in low levels of water delivery services provided to the associated users and scarce financial self-sufficiency of the collective agencies.

With regard to drainage and land reclamation, Calabria territory is subject to a peculiar climate and hydrological response (typical of the Mediterranean semi-arid areas), inducing flash floods and high erosion rates in torrents, often causing hydrogeological instability and disruption (Zema *et al*., 2014). The countermeasures have been generally carried out by WUAs without a systematic planning activities and very often under emergency situations (that is, immediately before or after natural disasters). Due to both natural and human factors, high risks of flooding and degradation remain in many areas of Calabria.

Therefore, in this context the goals of improving the collective services of irrigation and drainage provided by Calabrian WUAs need deep and complete analyses, helping to identify the gap between current and achievable performance and make changes to realise higher standards of performance (Malano *et al*., 2004). Nowadays, since the weak points of these WUAs are not completely known, an updated and multi-sectorial knowledge of the performance and asset of Calabrian WUAs may support planning of future improvement actions by a rational approach (Còrcoles *et al*., 2015).

The irrigation performance of collective agencies has been evaluated in many areas worldwide. As regards the Mediterranean basin (that is under similar climatic and structural conditions of the Italian agriculture), a number of studies are available in literature. More specifically, Zema *et al*. (2015) found very low efficiency in exploiting the available irrigation water and financial self-sufficiency in seven Water Users' Associations (WUAs) in Calabria (Southern Italy). Rodríguez-Dìaz *et al*. (2004a; 2004b; 2008) applied Data Envelopment Analysis (DEA) and other benchmarking techniques to irrigation districts of Andalusia (Spain), which revealed great differences in terms of performance between districts with open channel water delivery systems and those with pressure water delivery systems. Benchmarking techniques were used also by Còrcoles *et al*. (2010; 2012) in WUAs of Castilla La Mancha

(Spain), resulting in useful tools to characterize WUAs and to analyze differences between them due to different crop systems, hydraulic design, irrigation systems, or management strategies, also by a limited set of performance indicators; the results showed a notable difference between WUAs with drip irrigation systems and WUAs with sprinkler irrigation systems. Frija *et al*. (2009) applied DEA and a Tobit model in WUas of Tunisia and found that technical characteristics and administrative and organizational variables of the irrigated district and network were the most important determinants of the WUAs' overall efficiency. Uysal and Atis (2010) as well as Koç and Bayazit (2015) found contrasting results (from poor to satisfactory) in analyses of financial performances and participatory irrigation management of some WUAs in Turkey.

This study evaluates the performances of irrigation and drainage collective services provided by the 11 WUAs operating in Calabria along four irrigation seasons, considering the aspects related to infrastructure, organisation as well as technical and administrative management. Based on this information, indications and recommendations for improving the service levels are given.

MATERIALS AND METHODS

Study area

Calabria region is a peninsula of Southern Italy (Figure 1), 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 environment has large naturally wooded areas, with the exception of the coastal zones, in which in general agriculture is practised.

The region, whose climate is semi-arid (typical of the Mediterranean basin), is characterized by a strong rainfall and temperature variability between Tyrrhenian and Ionian areas, separated by the Apennines mountain chain. Mean annual precipitation and temperature are 683 mm and 17.4 °C in semi-arid coastal areas and 1240 mm and 9.1 °C in mountain areas (Bombino *et al*., 2007; 2014). The low precipitation in the dry periods (late spring, summer, early autumn) induces high evapotranspiration rates with water deficit of crops. In the years monitored for this investigation (2011-2015) the mean annual precipitation was 1050 mm (minimum 734 - maximum 1530 mm), while the mean monthly temperature was 16.8 °C (minimum 11.2 - maximum 20.0 °C).

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).

The water users associations of Calabria

In Calabria 11 WUAs (locally called 'Consorzi di Irrigazione e Bonifica') operate (Figure 1). About 90% of Calabria territory falls within the administrative area of the WUAs; only high mountain zones (10% of the regional territory) are excluded.

As regards irrigation, the main crops are olive, citrus, other fruits and vegetables; at farm level these crops are irrigated by sprinkler and micro-irrigation systems (Table I).

Table I

In accordance with the local legislation, the Calabrian WUAs (except for the WUAs 'AIRC' and 'BIRC'), in addition to irrigation water management, carry out activities (design, construction and maintenance) targeted to land reclamation and soil conservation, which include:

- drainage networks (cleaning of natural and artificial canals, their coating in ordinary/reinforced concrete or gabions, removal of weeds, terracing of the longitudinal profile);
- torrent control works (earth works, check-dams, bank walls, etc.);
- reforestation and hillslope terraces;
- artificial reservoirs operation;
- roads and trails.

Construction of public works benefits of regional funds, while maintenance is fully charged to the associated users.

Historically, construction and maintenance of drainage networks and torrent control works show the highest incidence among land reclamation and soil conservation activities. Drainage is aimed at collecting and removing excess water (from natural runoff and irrigation) from cropland, in order to avoid prolonged water saturation conditions, harmful to crops, or waterlogging of farmlands. Drainage is performed also in the surroundings of urban areas, in order to avoid flooding of houses and other infrastructures.

Torrent control works (check dams and embankments) are installed in Calabrian torrents to control river dynamics and mitigate hydraulic risks, respectively. Check dams have been installed to reduce the magnitude of the erosive processes and the transport capacity of floods.

Artificial embankments are built to protect croplands and urban areas from the disruptive effects of floods.

Performance indicators and data survey methods

The *infrastructural, organisation* and *management* data related to the collective irrigation and drainage services were surveyed in the 11 WUAs of Calabria (Figure 1).

Concerning the *infrastructural* aspects, the hydraulic schemes and plans of irrigation and drainage networks (including water pumps in these latter) were surveyed from design or 'as built' plans and controlled in field surveys. In more detail, for the irrigation networks the number, length, age, type, material of supplying and distribution conduits were surveyed. For the drainage works, the equipped areas - assumed to be equal to the administrative area (see below), due to the fact that all WUA's territory benefits from drainage service - and length of drainage channels and ditches were surveyed.

In relation to the WUA *organisation*, the organisation charts and operating procedures (for instance, the water distribution and fee charging methods of the irrigation service) were identified at the investigated WUAs.

For the quantitative analysis of WUAs performance, Malano and Burton (2001) have proposed a set of performance indicators (*service delivery*, *productive efficiency* and *environmental performance*). Service delivery includes: (a) the adequacy with which the organization manages the operation of the irrigation delivery system to satisfy the water required by users (*system operation*); and (b) the efficiency with which the organization uses resources to provide this service (*financial performance*). More specifically, service delivery indicators include aspects such as water distribution and irrigation areas, while financial indicators are related to distribution of total MOM cost of the irrigation district (Ghazalli, 2004; Còrcoles *et al*., 2016).

Concerning the WUA *management*, the related analysis was carried out on a quantitative approach, adopting the indicators of *system operation* and *financial performance* (henceforth indicated as 'performance indicators') of both irrigation and drainage services, proposed by Malano and Burton (2001) and properly adapted to this investigation. The performance indicators of Malano and Burton (2001) refer only to irrigation systems; drainage operations were analysed adopting the density of the drainage works as parameter measuring the system management level.

To collect the input data needed for calculating the performance indicators, a questionnaire was proposed to the managers and technicians of the WUAs. These input data were surveyed in each WUA during the last five years (2011-2015) and then averaged. The input data related to the *system operation* performance concerned:

- *Administrative Area* (AA, ha), *Command Area* (CA, ha) and *Irrigated Area* (IA, ha), understood as the total area under the administration of the WUA, the area equipped with irrigation and drainage infrastructure and actual irrigated area during the concerning year, respectively;
- *Length of Surface Drains* (LSD, km), equal to the total length of the drainage networks (channels and ditches);
- annual *Volume of Irrigation Water Delivery* (VIWD, m^3 $year^{-1}$), calculated as the product of discharge (measured by weir) by distribution times in open canals or directly by counters in pipelines (when available);
- annual *Volume of Crop Water Demand* (VCWD, m^3 $year^{-1}$).

This latter parameter was calculated for each WUAs as weighted mean of covered areas by the net irrigation requirement of each crop (that is, the quantity of water exclusive of precipitation required for normal crop production). The net irrigation requirement was estimated using the CROPWAT 8.0 software (Clarke *et al*., 1998; Food and Agriculture Organization of the United nations (FAO), 2009) and performing the daily water balance for each crop over the five years. The daily meteorological data required by CROPWAT (maximum and minimum temperatures, precipitation, relative humidity, wind speed and daylight) were measured selecting for each WUA a barycentric meteorological station. In relation to the crop data, the root depth and crop coefficients for calculating evapotranspiration (estimated by Penman-Monteith model) were derived from FAO guidelines (Doorenbos and Kassam, 1986); the farm cultivation practices (i.e. dates and operations) were identified by interviewing the WUAs' managers. Soil hydrological parameters, in the absence of direct measurements, were estimated using the Pedo Transfer Function of Saxton *et al*. (1986) on the basis of the soil texture reported by the Soil Map of the Calabria Region (Agenzia Regionale per lo Sviluppo e per i Servizi in Agricoltura della Calabria (ARSSA), 2003). The total irrigation requirement of each crop (henceforth indicated as 'water required') was calculated from the net irrigation requirement, considering farm irrigation efficiency according to the methods commonly used in each cropped area: for sprinklers the value of 0.70 was assumed, while the values of 0.85 (sprayers) and 0.95 (drippers) were considered for micro-irrigation, accordingly to the CROPWAT guidelines (Clarke *et al*., 1998; FAO, 2009). Finally, daily data of total irrigation requirement were aggregated at annual scale.

As regards the *financial* performances *variables* the following input data were surveyed at the 11 WUAs:

- *Gross Revenue Invoiced* and *Gross Revenue Collected* (GRI and GRC, € year^{-1}), that is the annual revenues due by water users for provision of irrigation and drainage services and collected from the fee actually paid;
- *Number of Personnel employed in Irrigation & Drainage (I&D) services* (NPID);
- annual *Management, Operation and Maintenance Costs* (MOMC, € year^{-1}), providing the service (staff, maintenance, energy, management and other costs, excluding capital expenditure and depreciation/renewals).

This latter parameter was calculated both including or not the staff cost (in the first case MOMC was marked by the symbol '$^{+}$', while in the second case by '$^{-}$').

Based on the input data collected, the following performance indicators were calculated for the 11 investigated WUAs:

- *Irrigated area/Command area Ratio (ICR, %)*, which is an indicator of the coverage of the irrigation service over each WUA command area;
- *Annual irrigation Water Delivery per unit of Irrigated Area (WDIA, m^3 ha^{-1})*, the most important service delivery performance indicator (Malano *et al*., 2004; Frija *et al*., 2009);
- annual *Relative Irrigation Supplied (RIS, %)*, calculated as the ratio between WDIA and VCWD, this latter divided by the irrigated area (IA); thus *RIS* < 100% indicates that the water supply is insufficient to satisfy full irrigation demand, while *RIS* > 100% indicates that an excess of water is applied;
- *Density of the Drainage Networks* (DDN, m km^{-2}), calculated as the ratio between the *Length of Surface Drains* (LSD) and the administrative area (AA);
- *Cost Recovery Ratio (CRR, %)*, calculated as the ratio between GRC and MOMC, which represents an index of the degree of financial self-sufficiency of the WUA;
- annual *Management, Operation and Maintenance cost per unit Area (MOMA, € ha^{-1})*, ratio between MOMC and IA, which standardizes the management costs on the irrigated area;
- *Revenue Collection Performance (RCP, %)*, calculated as the ratio between GRC and GRI, indicating the WUA's capacity of due fee collecting (Koc, 2007);
- *Staffing number per Unit Area* (SUA, persons 100-ha^{-1}), the ratio between NPID and IA;
- *Average Water Price per unit of irrigated area* (*AWP,* € ha^{-1}), which is the unit fee paid by users to the WUAs for the irrigation and drainage services.

As regards the financial aspects, the relevant performance indicators CRR and MOMA were calculated including staff costs of both services (irrigation and drainage); however, also for these indicators the incidence of the staff cost was evidenced by the symbol '+' and '-' (as for MOMC).

Financial input parameters were collected for all the WUAs with the exception of WUA 'TCS', which denied data. The data related to energy (limited to the electricity for water pumping in three WUAs only and to fuel for machines) have been evaluated in terms of the related costs and included in the set of financial indicators.

Within the set of indicators suggested by these Authors, the *productive efficiency* and *environmental* parameters were not considered, because: i) data of agricultural production and gross/net margins were not available for each farm or irrigation district; ii) none of the investigated WUAs has carried out activities for measuring and surveying environmental indicators related to irrigation water quality, use of fertilizers and groundwater table depth. 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.

Figure 1a, b

Finally, linear correlations among performance indicators with the irrigated area were searched in order to explore possible scale effect of the service extension; the explanatory capacity of these correlations was measured by the related regression coefficients (r^2).

RESULTS AND DISCUSSIONS

Infrastructure

Irrigation water sources

The majority (64%) of the surveyed irrigation systems are fed by surface water bodies (about), mainly torrents; a small share (about 3-5%) supplies irrigation water from natural (lakes) and artificial (reservoirs) water bodies. Sub-surface water bodies provide irrigation water for 32% of the surveyed systems, while in four (4% of the total number) of these latter groundwater is pumped from wells for irrigation purposes (Table II). This percentage is strongly lower than the national value (34%), although these data may be affected by a substantial under-estimation, due to the lack of survey of the uncontrolled supplies. As a matter of fact, groundwater exploitation is often unauthorised and induces negative environmental impacts (over-exploitation and salination of groundwater due to upward movement of saline wedge from sea coast).

Table II

Unfortunately, given the lack of direct measurements or at least reliable hydrological estimations, the quantitative evaluation of water volumes supplied from sources and diverted into the single irrigation systems of the Calabrian WUAs was impossible. Conversely, the availability of these data would allow in the future an optimal planning of collective irrigation, beside a more suitable allocation of the different water uses (agricultural, urban, industrial).

The most recent analysis of the irrigation water availability in Calabria may be affected by errors: in fact, the data reported in the 'Water Conservation Plan' of the Calabria Region in 2009 were estimated through evaluations of the water discharges permitted by regional authorities or declared by the management institutions. The uncertainty of these estimates can be highlighted by the large difference (more than 30%) between the total irrigation water volume, reported in this plan (552 Mm^3 (million cubic metres) per year), and the same data estimated in 818 Mm^3 per year by Istituto Nazionale di Economia Agraria (INEA, 2007).

The majority of managers in the WUAs of Calabria consider unnecessary direct measurements of water volumes delivered in the irrigation systems. This is mainly due to the water charge systems of many WUAs, fixing the water fees on the irrigable area and/or crop type.

Crop irrigation requirements

The most recent survey of crop irrigation requirements was carried out in 2008 by ARSSA. This evaluation was carried out by estimating for the entire region the water losses (e.g. evapotranspiration, infiltration) and supplies from groundwater table and precipitation for each crop and soil type; the results were reported in the 'Map of the irrigation requirements of the Calabria region'. From this estimation, the total irrigation requirement of agriculture in Calabria is on average equal to 621 Mm^3 per year. This value is higher by only 11% compared to the minimum value of the total volume available for crop irrigation (552 Mm^3 per year, see above). However, this comparison should be done with care, not only for the uncertainty affecting the estimated values, but also because the climatic and hydrological trends (which, as well known, indicate a progressive decrease in the meteorological afflux at the global scale) have not been taken into account.

At smaller spatial scale, some critical situations can be locally recorded, such as, for example, some periods of water shortage in the agricultural lands of the Ionian coast (in general, drier than the Tyrrhenian coast). Such problems can be explained, rather than by the higher irrigation requirements, by other factors (often simultaneous), such as the seasonal fluctuations in supplying water courses, the climate variability from year to year, the insufficient capacity of the reservoirs, the oldness of irrigation systems supplying and distributing water, and the competition among the different water uses (with particular reference to the increasing requirement of water for drinking and hydro-electrical plants).

Irrigation systems and drainage

In the analysed WUAs 106 irrigation systems were identified, of which 104 currently are working (Table III). Almost all the analysed systems are supplied by a unique water source; usually the hydraulic network consists of a single conduit feeding distributor pipelines/canals, which convey water to the different irrigation sectors. The total length of conduits of the hydraulic networks is currently estimated in 5260 km, of which 88% consists of distributors (Table III).

Table III

The incidence of open canals in the hydraulic network is not negligible (on average 30% of the total number). Only two WUAs ('TCS' e 'TVV') has completely replaced open canals with pressured conduits (Table III). Water conveying by open canals, as well known, shows low efficiency due to the high water losses (quantified in Italy by 50% of the total water volume diverted into the hydraulic networks), scarce maintenance level and unauthorized withdrawals. Irrigation water conveyed in pressured pipelines is delivered to farms by hydrants, whose spatial density is much variable among the different irrigation systems.

In relation to the conduit materials, a noticeable diffusion of cement-asbestos pipelines/canals and earth channels (subject to sedimentation and bank/bed erosion) was detected (Table IV). Moreover, the materials of conduits are not homogenous within the same irrigation system.

Table IV

For 69 of the 106 irrigation systems the identification of the dates of operation start or renovation was possible. Figure 2 shows that about 60% of the surveyed systems is 30 years old or more.

Figure 2

From the distribution per class of irrigated area (Figure 3), it is possible to notice that the irrigation systems in WUAs of Calabria are generally small: only six systems cover irrigated areas of more than 1000 ha; the cumulated area irrigated by the largest systems is equal to one third (10100 ha) of the total irrigated area in Calabria (30400 ha). More than 45% of the surveyed systems (46 out of 99) covers individually an irrigated area of less than 100 ha (Figure 3).

Figure 3

Figure 1 reports the geographical distribution of the drainage networks managed by the WUAs in Calabria. These networks are in general located in the downstream reaches of many water courses and in coastal plains. The overall length of the drainage networks is about 1500 km. Removal of excess water is mainly carried out by gravity; in two WUAs ('BSCS' and 'ICS') water is pumped (with annual consumptions of electricity of 220 and 3000 MWh per year respectively).

However, the actions undertaken by the WUAs for land reclamation and soil conservation purposes are not always effective and incisive due to both organisation shortcomings and scarce financial funds. In spite of the efforts and the large amounts of funds, several situations with severe hydrogeological risk and absence of hydraulic safety in some sites remain in the Calabria region.

Organisation

A common scheme can be generally found in the organisation structures of the analysed WUA, with some differences surveyed (e.g. distribution of the areas within the units identified). The entire technical/administrative organisation of a WUA is headed by a 'general director'. He is assisted by some managers supervising and coordinating several 'activity areas'. These latter consist in general of a 'technical area', an 'agricultural and forestry area' and an 'administration area'. More specifically:

- in the 'technical area' the main activities are (planning, design and construction of infrastructures for irrigation and land reclamation, infrastructure management and maintenance, reservoir operation and maintenance, civil works, material and service procurement, land expropriation procedures, control of land reclamation works);

- the ‘agricultural and forestry area’ takes care of (planning and management of hydraulic, agricultural and forestry works, management and maintenance of irrigation systems and drainage network, monitoring and operation of irrigation systems, preparation of regulations related to facilities, management of WUA Cadastre[1], preparation of fee rolls and electoral lists[2]);
- the ‘administration area’ prepares all administrative and financial procedures related to the WUA activities.

The size of the personnel staff (NPID) is much variable: from 22 (‘TVV’) to 120 (‘BICS’) persons are employed in the services provided by the WUAs (Table VI), with different roles and jobs, ranging from field workers to directive charges. In general, the number of employees devoted to administrative activities is almost constant (about 10-20) with low differences from WUA to WUA. Conversely, the number of the field workers directly utilised for maintenance of irrigation and drainage infrastructure shows a large variability among the analysed WUAs; the number of field workers is not proportional to the served area, contrarily to what expected.

The analysis performed on the organization of technical-administrative structure highlighted in general some problems and shortcomings, such as:

- shortage or, even in some cases, lack of technically qualified workers in the irrigation sector (for example, engineers for technical management of the hydraulic network, agronomists for water delivery management according to crop cycles and water balance, surveyors for maintenance or technical and administrative management of the irrigation service), which leads, sometimes, the assignment of specialized tasks to underqualified personnel;
- task overlapping or even duplication among different workers with money waste and occasionally conflict of interest;
- personnel lack or shortage in some strategic sectors (such as technical assistance and consulting for the associated farmers, planning of infrastructure monitoring and

[1] The “cadastre” is a register reporting data of all real estate falling within the WUA’ perimeter; for that, the owners are called to pay fees for land drainage services.

[2] Elections are needed to choose the WUA president and other delegates of associated farms in government bodies.

maintenance).

Technical and administrative management

Technical management

As regards technical management of irrigation, infrastructure maintenance, essential for an efficient network, is incorporated in agricultural or technical area, or even in both, rather than being an autonomous area. As results from poor organization, the following shortcomings have been noticed in this surveys, as claimed also by users:

- lack of monitoring of the infrastructure efficiency together with poor or delayed maintenance, causing frequent technical and operational breakdowns in the hydraulic network with irrigation service block;
- slowness in strategic decisions in the case of drought or flood events;
- low spatial uniformity/time continuity in water delivery;
- inefficiency (waste or non-use) of the supplied irrigation water.

For irrigation, water distribution and fee charging methods among the users' farms change from an irrigation system to another, also within the same WUA. In other words, a WUA can deliver water by rotational turns or on demand or charge water fees on both irrigated area or water volume delivered in the different irrigation districts.

The majority of irrigation systems deliver water by rotational schedules (76% of the number of the systems) with fixed turns; this system is the unique for four of the eleven WUAs. Only one WUA ('TCZ') delivers water only on demand (Table V). The water discharge delivered to a farm noticeably varies among the different irrigation systems; usually water delivery is monitored by the WUA staff and manually recorded on paper. Duration of irrigation operations varies from case to case, in relation not only to the crop, but also to water availability. Many situations with differences, even substantial (due to operational problems or occasional water shortage), between the actual and planned durations of water distribution are found. Water delivery by turn is necessary in relation to several factors, such as farm size and layout (for instance, when farmland is fragmented into numerous small plots), practiced crop (often with low-income), water availability in dry periods, hydraulic network characteristics and obsolete and inefficient management methods. In addition, when drought events occur (with obvious variations of water availability), irrigation managers are forced to change in real time scheduling of water distribution operations during the irrigation season and, in extreme cases, to stop or limit water delivery in extreme situations.

Taxation of irrigation service is in almost all cases (93% of the irrigation systems) (Table V) calculated on the irrigable area or a combination of irrigable area and crop type, rarely on water volume delivered (only WUA 'TCZ'). This mainly depends on the WUA inability to make direct or indirect measurements (water discharge and delivery time) of water delivery. Generally, the due fee includes: (i) a fixed share, always paid (even in the absence of use) in proportion to irrigable area; (ii) a variable share, proportional to irrigated area and the crop type (reported by the user). In WUA 'TCZ' the fixed share is proportional to the irrigable area, while the variable share is proportional to the water volume delivered.

Table V

Administrative management

Administrative management of services (irrigation and drainage) provided by the WUAs to users requires the following financial costs, of which a share is fixed and another is variable: i) operating costs; ii) maintenance costs; iii) administration costs.

The surveys carried out in the analysed WUAs showed that the most weighing costs are, in order of importance on the annual budget survey, salaries of seasonal field-workers and permanent personnel (technical and administrative employees and managers) as well as expenses for energy, construction material purchase, equipment maintenance, fuel and lubricants.

The financial revenues for supporting the operating and maintenance costs are drawn primarily by the fees collected from the service users (43% and 34% from the drainage and irrigation service fees respectively) and secondarily by annual regional grants (currently more and more reduced down to only 23% of the total annual revenues. Some of the WUAs ('TVV') begins to profit from electrical energy produced in small hydro power plants installed in the irrigation systems, even though this revenue is still marginal, due to the limited power output installed.

Revenues from service fees, which have tax nature (and thus their payment is mandatory for the associated users), are collected by means of 'fee rolls' (relating to both irrigation and drainage services). The fee roll is classified in:

- 'drainage roll', a share that should be paid by all citizens living within the drainage area managed by the WUA;
- 'fixed irrigation roll', that is the share that must be paid by all users whose properties fall within the administrative area; this roll is a payment of the irrigation network structure maintenance;

- 'variable irrigation roll', a share due by all farms falling in the irrigated area; this share refers to the cost of irrigation water delivered.

It was found that, if the 'Land Classification Plan' (an important management and planning tool that makes easier quantification, charging and collection of users' fees, mandatory because of the regional law), is not adopted by a WUA, taxpayers often promote legal actions to contest the required fee. This induces high legal costs when WUAs are damned by courts to pay damages to claimant users.

In general, under the financial point of view, the revenues from fee rolls collected by the WUAs does not cover costs (see section 3.4) and, therefore, the external contribution from the regional administration is needed. Moreover, in relation to the differences in management methods (in terms of fee charging, water delivery and availability, see section 3.4), inequity remain between users of different WUAs, which contribute on the one hand to discourage exploitation of collective irrigation and on the other hand to a delayed or even missed fee payment with a consequent increased taxation for the other WUA members.

Further economic and administrative concerns, still related to organization problems, have been surveyed, such as:

- slow and complicated procedures, due to excessive bureaucracy, in particular for material purchase for infrastructure maintenance;
- lacking or incorrect issuing of fee rolls;
- inadequate technical support in legal controversies against some users.

These critical issues inevitably induce service inefficiency and diseconomy that are complained by users. A more detailed and careful analysis aimed at improving the operational effectiveness of WUA management procedures and ensuring a cheaper and more reliable organization is therefore needed.

System operation and financial aspects

Table VI reports the input data collected at the 11 WUAs analysed in this study. The annual variability of input data, quite limited throughout the surveyed years, was not reported in the chart.

Table VI

As regards the irrigation service, about 53% of the farms is irrigated with water delivered by WUAs, 29% supplies water autonomously (mainly groundwater), while 18% uses both private and public water (irrigation from WUAs + self-supply). The command area is on average 8% of the administrative area; only 32% of the command area is effectively irrigated (Table VI). The largest WUA is 'BICS' (CA of 18700 ha), while the smallest is 'TVV' (CA of 676 ha); IA is in the range 262 ('TVV') – 10000 ('BICS') ha with an average value of 2610 ha (Figure 4).

The analysis of the *system operation performance* highlighted a wide variability of service coverage over the WUA territory (ICR from 8%, 'TRC', to 55%, 'TVV') with a general underutilisation of the irrigation networks (Figure 4); ICR is not correlated with the irrigated area ($r^2 = 0.35$).

The annual water delivery per irrigated unit area (WDIA) is in the range 6500 ('TCZ') - 14900 ('TRC') $m^3\ ha^{-1}$, but this variability (CV = 28%) does not reflects the type of irrigated crop (Figure 4). As a matter of fact, the water delivered to farms cultivating crops with higher irrigation requirement (e.g. vegetables, fruits in 'TVV' and 'TCZ') is often lower compared to other WUAs in which wheat, maize and/or olives - requiring relatively low water - are produced (e.g. 'BSCS' and 'BMCS'). WDIA of Calabrian WUAs is much higher than the values reported by Còrcoles *et al*. (2010), Rodrìguez-Diaz *et al*. (2004a), Garcia-Vila *et al*. (2008) and Camacho (2006) in Andalusia (Spain) - between 1500 and 3800 $m^3\ ha^{-1}$ - and it is more similar to the values measured in other agricultural contexts (Cakmak, 2004, Turkey, 9800-15000 $m^3\ ha^{-1}$; Uysal and Atis, 2010, Turkey, about 8000 $m^3\ ha^{-1}$; Ghazalli, 2004, Malaysia, 9400-34000 $m^3\ ha^{-1}$).

Moreover, water delivered to crops is always in excess compared to the theoretical irrigation requirement, as shown by RIS indicator; this ratio is on average higher than 100% in all the investigated WUAs (Figure 4). Therefore, not only a high water surplus is delivered to crops compared to what needed (as shown by RIS), but the resource is irregularly distributed among WUAs (as some values of WDIA indicate), with some over-irrigated crops in some WUAs and some farms complain water shortage throughout the year in other WUAs. The mean RIS of our study is close to the maximum value (370%) reported by Còrcoles *et al*. (2012), but much higher than the estimation of Rodrìguez-Dìaz *et al*. (2011, 24%) in Andalusia (Spain).

With regard to the drainage service, the related indicator of system operation (DDN), measuring the spatial density of the canals over the administrative area, varies between 36 (WUA 'BSCS') and 420 ('BICS') $m\ km^{-2}$ with an average value of 151 $m\ km^{-2}$ (Figure 4). DDN generally shows the highest values in the WUAs ('TCZ', 'IKR', 'BICS' and 'TRC') draining the coastal planes of Calabria (Piana di Lamezia, Marchesato, Piana di Sibari and Piana di Gioia Tauro respectively), that is just where runoff excess, sourcing from surrounding mountains

(Serre, Sila and Aspromonte mountain chains), would induce flooding and swamping of large areas in the absence of collective drainage services. In WUA 'BICS' drainage of the archaeological area of Sibari (lying in the basin of Crati river under the average sea level) from surface runoff even requires the need of water pumping throughout the whole year with high energy costs.

Concerning the financial performance of the analysed WUAs, the personnel requirement for the services provided by the investigated WUAs per area unit (SUA) is on average 0.5 persons per 1000 ha of administrative area (AA) (Figure 5); the recorded variability (CV = 47%) is due to the normal variations of labour productivity, service intensity and technology involved (Koç, 2007). This indicator is correlated with IA (r^2 = 0.51). The RIS detected in Calabrian WUAs appear close to the minimum value reported in literature studies (0.4 persons per 1000 ha, Ijir and Burton, 1998, USA).

$MOMA^-$, if personnel costs are not considered in the analysis, is on average equal to 2.4 € ha^{-1} per year, but this value shows a high degree of variability (CV = 140%) (Figure 5). Other studies, however including staff costs, reports MOMA in the range 21.7 (Yavuz *et al.*, 2004, Turkey) - 260 (Malano *et al.*, 2004, Spain) € ha^{-1} $year^{-1}$.

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, organisation 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; Zema *et al*., 2015). If staff cost is included in this analysis, the average value of $MOMA^+$ increases up to 14.7 € ha^{-1} per year (but variability among WUAs decreases, CV = 61%). For both $MOMA^+$ and $MOMA^-$ correlations were found with IA (r^2 = 0.51).

CRR^- (thus without staff cost) is on average 200% (minimum 85% for 'AIRC' and maximum of 765% for 'TVV'), indicating that apparently MOM costs are covered by revenues from irrigation and drainage services. However, given that costs include also personnel beside MOM, CRR^+ decreases to an average value of 18% with a minimum value of 8% ('BIRC') and a maximum of only 35% ('BICS'), if staff costs are considered. Therefore, none of the analysed WUAs achieves a complete cost recovery and thus their financial survival depends on external funds (mainly from Calabria Region). For this indicator literature shows values between 28% (Molden *et al*., 1998, Sri Lanka) and 170% (Cakmak *et al*., 2009, Turkey). CRR^+ and CRR^- are fairly correlated to IA (r^2 = 0.69), which shows a higher financial self sufficiency for the larger WUAs.

As it can be easily deduced from the analysis, the reason of the very low self-sufficiency of the WUAs in Calabria is mainly due to the high incidence of staff costs. Another factor highly weighing on the poor financial performances is the low RCP, which measures the WUA capacity of collecting the due fees. This indicator is on average close to 70% (Figure 5). Only one WUA ('TRC') is able to fully collect the invoiced fees, while in some other WUAs (for example, AIRC) the payment evasion is very high (even up to 60%). This could confirm that, in general, in some WUAs of Calabria the satisfaction of farmers towards the 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). In a previous study of the same authors on a sample of seven WUAs of Calabria (Zema *et al*., 2015), this indicator was affected by bias (with values higher than 100%) due to the special collection of overdue revenues related to previous years. RCP is not correlated with IA ($r^2 = 0.06$); 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).

Finally, in Calabria the irrigation water price per hectare (AWP) is on average 260 € ha^{-1}. However, this price shows a high variability (from 120 € ha^{-1}, 'IKR' and 'ICZ', to even 610 € ha^{-1}, 'BIRC'). Generally, in the WUAs of Southern Calabria ('TRC', 'AIRC' and 'BIRC') the water price (about 480 € ha^{-1}) is much higher compared to all the other WUAs. 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, Figure 5): as a matter of fact, the WUAs 'AIRC' and 'BIRC' must support a high incidence of maintenance works and energy costs for groundwater pumping in some irrigation systems (Table IV); in addition to that, in the WUA 'TRC' the percentage of free surface canals is high, which induce high water losses (Table IV).

Figure 4

Figure 5

CONCLUSIONS AND RECOMMENDATIONS

The study has carried out a comprehensive analysis of the collective irrigation and drainage sectors in Calabria, where irrigated agriculture plays an important role in the economical sector and the hydrological risk is pressing. This survey has shown that the collective services of irrigation and drainage provided by Calabrian WUAs suffer from important structural, operation, organisation and management shortcomings. Therefore, in spite of the high amount of financial funds spent, the technical evolution of the analysed sectors has not been observed, contrarily to what happened in different regions of Northern Italy or other agricultural contexts of Southern Italy. Although deeper investigations are needed, focusing specifically each management aspect of collective services, starting from this survey some indications sources aiming at improving the service levels.

First, with regard to the infrastructural aspects, the irrigation systems of the Calabrian WUAs need a wide action of renovation through a conversion of open canals into pressure pipelines, replacement of cement-asbestos conduits beside an optimisation of water delivery operations. Concerning this latter, a monitoring activity of water volume delivery (compared to the actual irrigation requirements of crops, to be estimated by water balance of the complex soil-crop-plant) could increase adequacy, efficiency, dependability and equity of water distribution among the associated farmers (e.g. Molden and Gates, 1990; Hamid *et al*., 2011; Zaccaria and Neale, 2014). Concerning the drainage service, a continuous maintenance activity of the drainage network must assure the system efficiency, allowing a substantial contribution against flooding and hydrogeological risk in the region.

Secondly, from the organisation point of view, the flaws in the human resource asset of the surveyed WUAs (personnel excess and unsuitability of some tasks) could be faced off by a rational re-organisation of the personnel (for instance, among areas with surplus and shortage of workers) together with implementation of education activities aiming at improving the technical knowledge of labourers and employees. For operation and maintenance it is advisable to have an optimum number of man-days, so that higher investment of regular staff can be minimised (Phadnis and Kulshrestha, 2012).

Thirdly, in relation to management activities, it is advised:

- the establishment of remote control systems of hydraulic networks which may increase the irrigation performances of the irrigation systems and thus the satisfaction levels of the associated farmers;
- the adoption of irrigation advising systems by automated procedures of irrigation requirement estimation, suggesting to farmers volumes, durations and frequency for crop irrigation;
- the replacement of water charging systems on irrigable area with taxation on the actual water consumption (preferably with automated recording systems), which would also reduce water waste and fee payment evasion; this latter, beside the re-organisation of human resources (strongly weighing on the annual budgets of WUAs), could be in addition an optimal solution to increase the financial self-sufficiency of WUAs;
- an aggregation of the smallest WUAs in larger institutions, in order to benefit in a some

way from scale economy (as suggested for example from correlations of CRR, MOMA and SUA with IA) for costs and personnel;

- the exploitation of the hydro-electrical potential of the irrigation systems by small turbines would allow integrating the annual profits of the WUAs beside the positive environmental impacts from renewable energy production (Zema *et al*., 2016).

On the whole, this survey proposes a methodological framework, enlarged to all the aspects influencing irrigation and drainage activities of collective agencies, which could be a technical and scientific support transferable to other contexts. As a matter of facts, the combined application of diagnostic processes (often resulting difficult and time consuming) helps to identify key and crucial factors in the infrastructure, organisation and management of collective services and suggests consequently possible improving actions to policy makers and to managers and technicians of the WUAs.

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LIST OF ACRONYMS

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)
DDN	Density of the Drainage Networks
GRC	Gross revenue collected
GRI	Gross revenue invoiced
IA	Irrigated area
ICR	Irrigated area/command area ratio
LSD	Length of Surface Drains
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)
NPID	Total number of personnel employed in the Irrigation and Drainage services
RCP	Revenue collection performance
RIS	Annual relative water supply
SUA	Staffing numbers per unit area
VCWD	Annual Volume of Crop Water Demand
VIWD	Annual Volume of Irrigation Water Delivery
WDIA	Annual irrigation water delivery per unit irrigated area

Water Users 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

TABLES

Table I. Main crops and characteristics of farm irrigation systems in the WUAs (Calabria, Southern Italy)

Characteristics	WUA										
	BSCS	*BMCS*	*BICS*	*BTCS*	*IKR*	*ICZ*	*TCZ*	*TVV*	*TRC*	*AIRC*	*BIRC*
Main crops	Maize, wheat, forage, fruits	Maize, vegetables, olives	Citrus, fruits, vegetables	Vegetables, olives, citrus	Vegetables, cereals, maize, citrus	Vegetables, maize, citrus, fruits, forage	Citrus, fruits, vegetables, olives	Citrus, fruits, vegetables, maize	Citrus, olives	Citrus, olives, vegetables, cereals	Citrus, olives, vegetables, cereals
Irrigation system	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler, surface	Sprinkler	Sprinkler, surface	Sprinkler, flowing	Sprinkler, surface, microirrigation

Table II. Prevalent type of supply sources in the collective irrigation systems (n = 101) in Calabria

WUA	Surface water		Sub-surface water		Groundwater	
	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number
BSCS	9	41	13	59	0	0
BTCS	10	83	2	17	0	0
BMCS	3	100	0	0	0	0
BICS	6	75	1	13	1	13
IKR	3	100	0	0	0	0
ICZ	8	100	0	0	0	0
TCZ	6	100	0	0	0	0
TVV	5	100	0	0	0	0
TRC	7	100	0	0	0	0
AIRC	3	33	6	67	0	0
BIRC	7	33	11	52	3	14
Total	67	64 (*)	33	32 (*)	4	4 (*)

Note: (*) value averaged among all the irrigation systems surveyed.

Table III. Number, size and water conveying method of the irrigation systems in Calabria.

WUA	Number	Length (km)		Water conveying method (%)(*)	
		feeder	distributors	pressured pipelines	open canals
BSCS	22	52	943	91	9
BTCS	12	53	465	100	0
BMCS	3	0	277	50	50
BICS	10	68	778	58	42
IKR	5	96	656	50	50
ICZ	8	133	167	78	22
TCZ	6	32	246	75	25
TVV	5	45	62	100	0
TRC	7	73	421	29	71
AIRC	9	58	341	78	22
BIRC	19	34	258	64	36
Total	106	644	4610	70 (**)	30 (**)

Note: (*) percentage on the total number of homogenous (section and material) segments of the irrigation systems; (**) value averaged among all the irrigation systems surveyed.

Table IV. Length and materials of the irrigation systems of the WUAs in Calabria.

Type of conduit	Material	Length (km)	Length (%)
Open canals	Concrete	194	13.6
	Earth	3.1	0.2
	Steel	4.0	0.3
Pressured pipelines	Steel	268	18.7
	Iron	16.2	1.1
	Concrete and asbestos	515	36.0
	Concrete	145	10.1
	Plastics	286	20.0
Total		1430	100

Table V. Methods of water distribution and irrigation fee charging in irrigation systems of the WUAs in Calabria

WUA	Method of water distribution				Method of irrigation fee charging					
	rotational schedule		on demand		on irrigable area		on irrigable area and crop type		on delivered water volume	
	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number	Number of irrigation systems	% on total number
BSCS	22	100	0	0	0	0	22	100	0	0
BTCS	8	62	5	38	1	100	0	0	0	0
BMCS	5	100	0	0	0	0	5	100	0	0
BICS	3	60	2	40	0	0	9	100	0	0
IKR	1	50	1	50	3	100	0	0	0	0
ICZ	5	63	3	38	8	100	0	0	0	0
TCZ	1	17	5	83	2	33	0	0	4	67
TVV	4	80	1	20	9	90	0	0	1	10
TRC	7	100	0	0	0	0	7	100	0	0
AIRC	9	100	0	0	9	100	0	0	0	0
BIRC	13	100	0	0	5	100	0	0	0	0
Total	78	76 (*)	17	24 (*)	37	57 (*)	43	36 (*)	5	7 (*)

Note: (*) value averaged among all the irrigation systems surveyed.

Table VI. Input data for the analysis of WUAs performances in Calabria.

Input parameter	Measuring unit	WUA												
		BSCS	BMCS	BTCS	BICS	IKR	ICZ	TCZ	TVV	TRC	AIRC(*)	BIRC(*)	Mean	Total
AA	10^3 ha	120	135	117	113	139	115	85.6	100	96.1	80.8	109	110	1210
CA	10^3 ha	8.4	4.8	12.4	18.7	18.5	11.3	5.7	0.7	8.1	3.7	3.2	8.7	95.5
IA	10^3 ha	2.7	0.8	4.1	10	5.2	4.0	1.4	0.4	0.6	0.6	0.3	2.7	30.1
VIWD	Mm^3 $year^{-1}$	28.2	7.2	n.a.	105	42.7	30.0	9.2	2.7	9.6	4.9	3.3	24.3	243
VCWD	Mm^3 $year^{-1}$	11.3	4.2	n.a.	35.8	14.3	10.1	3.0	1.0	1.0	1.3	0.5	8.3	82.5
LSD	km	44	149	55	474	366	108	110	106	129	0.0	0.0	140	1540
GRC	10^3 € $year^{-1}$	287	104	n.a.	1500	438	330	192	61	248	144	117	342	3420
GRI	10^3 € $year^{-1}$	521	140	n.a.	2300	627	550	320	68	248	360	147	528	5280
$MOMC^+$	10^3 € $year^{-1}$	1680	976	n.a.	4340	2000	1750	1240	558	995	1100	1480	1610	16100
$MOMC^-$		258	101	n.a.	1340	170	200	135	8	145	170	131	266	2660
NPID	-	57	35	n.a.	120	73	62	44	22	34	37	54	53.8	538

Notes: n.a. = not available; (*) this WUA does not carry out land reclamation activities

FIGURE CAPTIONS

Figure 1a, b. Maps of the collective irrigation (a) and drainage (b) systems in Calabria (Southern Italy).

Figure 2. Temporal distribution of dates of operation start or renovation of irrigation systems (n = 69) in WUAs of Calabria (Southern Italy).

Figure 3. Distribution of irrigation systems (n = 106) and cumulated areas per size class of irrigated areas in Calabria.

Figure 4. Performance indicators of system operation activities in 10 WUAs of Calabria ('MEAN' refers to the value averaged among all the investigated WUAs).

Figure 5. Financial performance indicators in 10 WUAs of Calabria ('MEAN' refers to the value averaged among all the investigated WUAs).

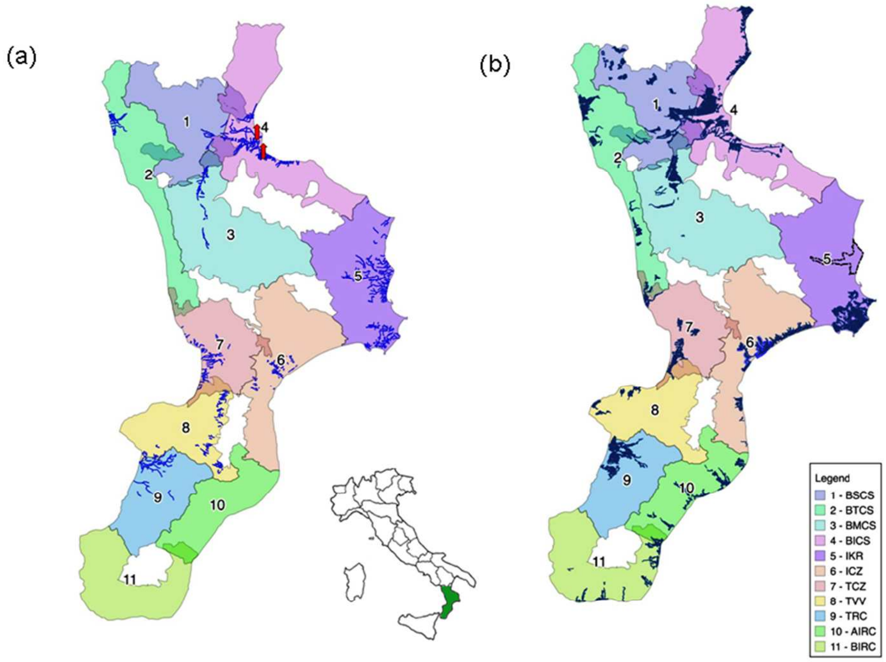

Figure 1a, b – Maps of the collective irrigation (a) and drainage (b) systems in Calabria (Southern Italy).

254x190mm (96 x 96 DPI)

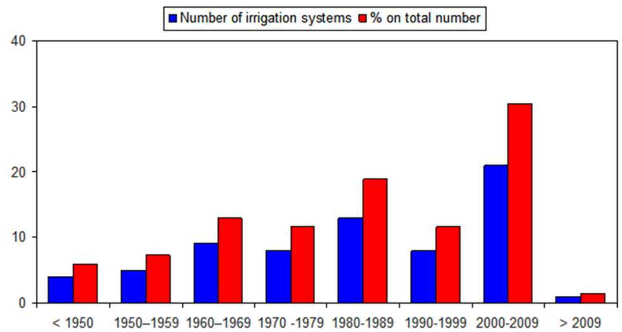

Figure 2 - Temporal distribution of dates of operation start or renovation of irrigation systems (n = 69) in WUAs of Calabria (Southern Italy).

254x190mm (96 x 96 DPI)

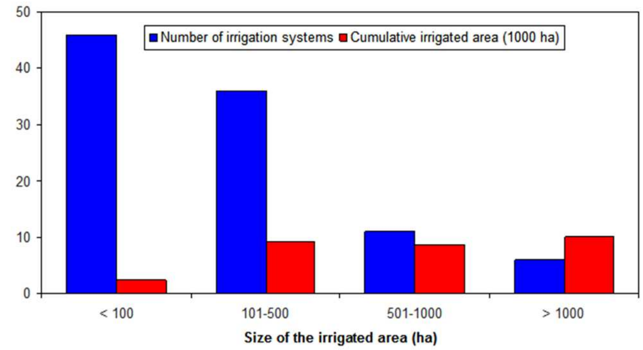

Figure 3 - Distribution of irrigation systems (n = 106) and cumulated areas per size class of irrigated areas in Calabria.

254x190mm (96 x 96 DPI)

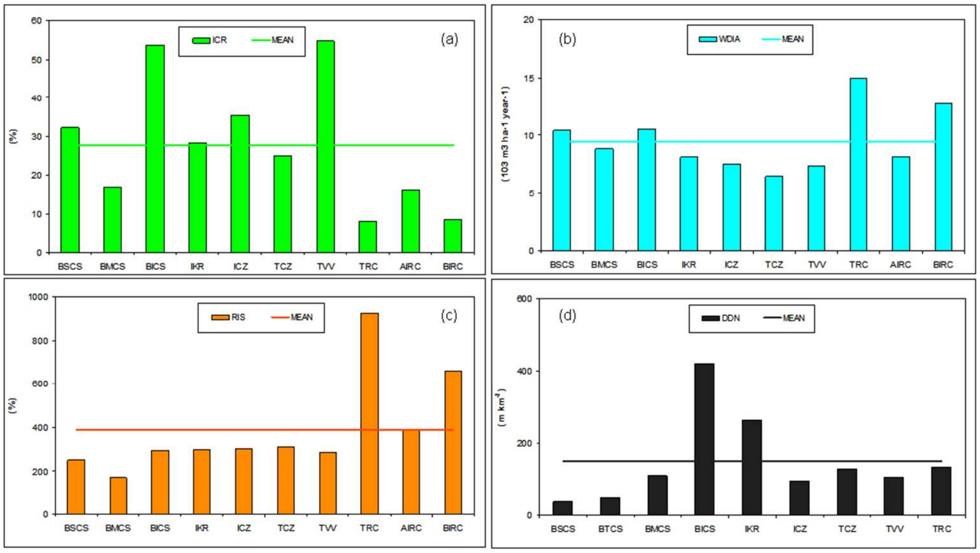

Figure 4 - Performance indicators of system operation activities in 10 WUAs of Calabria ("MEAN" refers to the value averaged among all the investigated WUAs).

289x165mm (96 x 96 DPI)

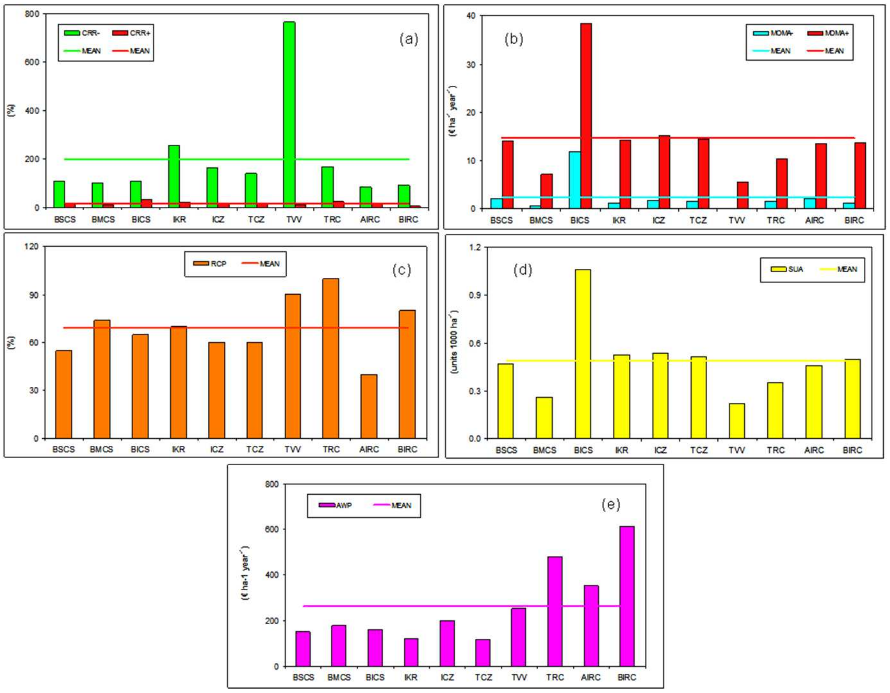

Figure 5 - Financial performance indicators in 10 WUAs of Calabria ("MEAN" refers to the value averaged among all the investigated WUAs).

296x209mm (96 x 96 DPI)