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AN INCENTIVE-BASED PRICING FOR IRRIGATION WATER CONSUMPTION: THE ITALIAN CASE STUDY.

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ABSTRACT.

The Water Framework Directive 2000/60/EC (WFD) establishes the key principles for all uses of water resources: 1) full cost recovery for water service provision, 2) an incentive-based pricing structure to convey price signals to users, and 3) the "polluter pays" principle. This position paper monitors the application of the key principle of incentive-based pricing in the Italian agricultural sector. The evidence brings new insights on the most effective methods for defining the structure of irrigation fees and suggests that European Institutions launch an extensive monitoring of pricing systems applied to agricultural water use for a comparative assessment. Given the strategic importance for irrigation for food security, climate adaptation, and water resilience, a structured research initiative at European scale could meaningfully contribute to the Commission's ongoing work on strengthening the economic, environmental and governance pillars of EU water policy.

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THE EU-WIDE PRINCIPLES ON THE USE OF WATER RESOURCES

Water resources are becoming increasingly strategic for global economies. In addition to traditionally water-intensive sectors such as agriculture and industry, high-tech, and energy sectors have also become major users of water: their demand is not driven only by production needs, but also by infrastructure requirements, such as the cooling of data centres.

Agriculture as a strategic sector in Europe

Agriculture is a strategic sector for Europe, particularly for Mediterranean countries. According to Eurostat, between 2013 and 2023 EU trade in agricultural products grew at an average annual rate of 4.6%, with exports increasing slightly faster (+4.7%) than imports (+4.4%). In Italy, exports of "Made in Italy" agri-food products grew by 8% in 2023[1]. The country shows a strong agricultural vocation, supported by an extended agri-food supply chain worth €586.9 billion in turnover (29% higher than in 2015) and generating almost €335 billion in value added, equal to about 19% of GDP[2].

Economic impact of irrigation

Water use for irrigation is essential for the competitiveness of the agri-industrial sector and for ensuring food security. From an economic perspective, the value added generated by irrigation for arable crops, orchards, vegetable crops, and meadows is estimated to reach up to €52,000 per hectare in northern Italy, with a national average of about €40,000 per hectare. The average difference in income between irrigated and non-irrigated land is approximately €13,500 per hectare. In percentage, this difference is higher in central and southern Italy (60–80%) than in the north (39%), although the gap has recently been narrowing[3].

It should nevertheless be emphasized that **non-irrigated crops often generate profitability only slightly above production costs, with insufficient margin to ensure the long-term sustainability of farms** and the realization of required investments for crop modernisation and water management.

In Italy as well as in other Mediterranean countries with a strong agricultural vocation, production volumes are largely ensured by irrigation, supported by water intake systems, capillary irrigation networks, and irrigation systems. At EU level, agriculture accounts for about 40% of total water consumption, according to the European Environment Agency (EEA).

In Italy, approximately 2.5 million hectares are irrigated out of a total of 13 million cultivated hectares. In some areas, irrigated surfaces are increasing due to climate change, which has extended irrigation seasons and raised water needs even for traditionally rain-fed crops such as vines and olive trees[4].

From an economic and sectoral policy perspective, strengthening irrigation infrastructure and promoting water efficiency have become indispensable to ensuring a future-proof agricultural sector. Within this framework, the Common Agricultural Policy (CAP 2023–2027) includes wa-

[1] CREA Politiche e Bioeconomia. (2023). *32° Rapporto CREA sul commercio estero dei prodotti agroalimentari.*

[2] The European House-Ambrosetti. (2024). *8ª edition of the forum "La roadmap del futuro per il Food & Beverage"* (Bormio, Italy, June 7–8, 2024).

[3] Zuccaro, R. (2014). *Condizionalità ex-ante per le risorse idriche: Opportunità e vincoli per il mondo agricolo.* Istituto Nazionale di Economia Agraria (INEA). Report developed as part of the MiPAAF project "Attività di ricerca e supporto tecnico per la definizione di una politica dei costi per l'uso irriguo dell'acqua". https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/14922

[4] Manganiello, V., Ferrigno, M., & Pergamo, R. (2024, September). *Imprese agricole che non fanno acqua/1: Lo scenario*. CREA Futuro. https://creafuturo.crea.gov.it/12435/

ter resource management among its objectives, calibrating specific interventions to promote its efficient use.

Key principles of the Water Framework Directive

Within the European regulatory framework, Article 9 of the Water Framework Directive 2000/60/EC (WFD) remains the main reference for efficient water use and related economic aspects. It introduces three key principles:

- **Full cost recovery (FCR)** for water services (referred to the provision of water for all type of usage), assuring the recovery of opportunity costs for alternative uses of consumed water, environmental costs related to restoration of aquatic ecosystems affected by negative externalities associated with withdrawals, and financial costs linked to infrastructure construction and management;
- **Incentive-based pricing**, for sending appropriate price signals to users to promote efficient water consumption;
- **Polluter-pays principle**, whereby environmental costs are borne by those who generate pollution.

The European Commission's monitoring document on the implementation of River Basin Management Plans (RBMPs) provides useful insights into Member States' compliance with these principles[5].

Exclusion of irrigation services from full cost recovery

Regarding the principle of Full Cost Recovery (FCR), monitoring shows that at least one third of EU countries apply a narrow definition of water services subject to cost recovery, typically limited to drinking water supply. Although this represents an improvement compared to the first monitoring cycle, in which about half of Member States did not comply with FCR for a large part of uses, it still remains a critical issue. **Irrigation services are among the uses most frequently excluded from FCR, especially in cases of self-abstraction**, which are difficult to monitor and regulate. While some countries, such as Latvia, apply a broad definition of water service and report information on cost recovery for each type of use, others apply narrower definitions, omitting in most cases information on irrigation services and self abstractions in their RBMPs[6].

Role of reclamation and irrigation consortia

In Mediterranean countries, irrigation is largely managed by special entities for collective water supply. In Italy, irrigation services are provided by reclamation and irrigation consortia, which, unlike individual self-abstraction, have the organisational and managerial capacity to adapt to evolving regulatory frameworks. Within this framework, the structure of irrigation contributions progressively changed. Tariffs increased from approximately €0.07/m^3 prior to the introduction of the WFD to peaks of up to €0.80/m^3 in subsequent periods (from approximately €150 per hectare up to €1,705 per hectare), with cost-recovery rates between 50% and 80% [7].

[5] European Commission. (2019, February 26). *European overview – river basin management plans* (Commission Staff Working Document No. SWD(2019) 30 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019SC0030

[6] European Commission. (2019, February 26). *Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC)* (COM(2019) 95 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2019:095:FIN

[7] Giannakis, E., Bruggeman, A., Djuma, H., Kozyra, J., & Hammer, J. (2016). Water pricing and irrigation across Europe: Opportunities and constraints for adopting irrigation scheduling decision support systems. *Water Supply*, 16(1), 245–252. https://doi.org/10.2166/ws.2015.136

However, according to some authors[8], the adoption of full cost recovery to irrigation use — by charging the agricultural sector for access to infrastructure that is partly state-owned and also provides ecosystem services—may generate distortive effects, shifting onto a single group of users costs that should, at least in part, be borne by the wider community through general taxation. This may also undermine the economic viability of the sector, given price dynamics that are beyond the control of individual farms.

Transparency in cost recovery by use to support decision-making

Although Article 9.4 of the WFD allows for derogation from full cost recovery, **it is essential that RBMPs clearly disclose how different types of usage contribute to cost recovery and the corresponding recovery rates. This would enable public decision-makers to take more informed and effective policy decisions**, for example by directing infrastructure funding to areas with lower recovery levels, particularly where positive externalities such as ecosystem services are generated, or by requiring the application of appropriate tariff rules in sectors where the economic benefits derived from water use are significantly higher than the costs actually borne by users.

Measuring consumption as a prerequisite for incentive pricing

Regarding the use of incentive based pricing structures, many RBMPs at the European level do not report detailed information. Since accurate consumption measurement is a prerequisite for effective price signals, the situation in Europe remains critical, with partial diffusion of meters for irrigation. Consequently, volumetric tariffs are applied to about 59% of monitored irrigation services, while in the remaining 41% measurement is partial or absent. More generally, among the recommendations included in the Commission's Overview document (2019) is the request that Member States provide within the RBMPs an adequate level of information regarding pricing policies applied for each type of use.

The Italian context

The situation does not differ significantly in Italy. Despite ministerial guidelines issued in 2015 for the regional regulation of water consumption measurement[9], metering based tariff systems remain limited outside the drinking water service, where increasing block tariffs are applied to discourage overconsumption[10]. This is partly due to the high costs associated with the technical complexity of monitoring withdrawals from certain types of networks, such as open channel water systems. Then, where water-saving technologies are already in use the support given by metering could be low, since the marginal cost for achieving additional water savings is disproportionate to the expected benefits, reducing the effectiveness of incentive-based pricing, particularly in light of the widespread adoption of water-efficient irrigation techniques by farmers[11].

In the light of the evidence emerging from the cited monitoring reports of the European Commission, **this paper examines the methods used in Italy to calculate irrigation contributions charged to farmers as compensation for the benefits derived from the provision of water resources**. The study seeks to address the existing knowledge gap regarding tariff systems

[8] EAlfonso, E., & Berbel, J. (2017). Why is water pricing ineffective for deficit irrigation schemes? A case study in southern Spain. *Water Resources Management*, 31, 349–362. https://doi.org/10.1007/s11269-016-1563-8

[9] Ministero delle politiche agricole, alimentari e forestali. (2015, July 31). *Linee guida per la definizione di criteri omogenei in base ai quali le regioni regolamentano le modalità di quantificazione dei volumi idrici impiegati dagli utilizzatori finali per l'uso irriguo* (Decreto ministeriale). https://www.gazzettaufficiale.it/eli/id/2015/09/14/15A06988/sg

[10] See in this regard the Integrated Text on Water Service Charges (TICSI) – ARERA Resolution 665/2017/R/idr. For an overview of the methods used to define tariffs in the water service sector in European countries, reference is made to the WAREG report, Tariff Regulatory Frameworks in WAREG Member Countries, 2019. https://www.wareg.org/articles/water-tariffs-in-europe/

[11] Alfonso, E., & Berbel, J. (2017). Why is water pricing ineffective for deficit irrigation schemes? A case study in southern Spain. *Water Resources Management*, 31, 349–362. https://doi.org/10.1007/s11269-016-1563-8

for uses other than drinking water by providing policymakers with a clear decision-making framework, identifying best practices at regional level and within individual irrigation consortia, and supporting **the development of a pathway towards common national rules capable of delivering consistent price signals across the agricultural sector, while avoiding distortions arising from the current application of widely differentiated methods**.

REGULATION OF IRRIGATION SERVICES IN ITALY: THREE REGIONAL CASES

Tariff structures and drivers used to allocate costs to users

As said, at national level, the Ministerial Decree of 31 July 2015 issued by the Ministry of Agriculture (MASAF) established Guidelines for the regions on measuring procedures of water withdrawn for irrigation purposes. These Guidelines provide general indications on how reclamation and irrigation consortia should calculate irrigation contributions. The Guidelines are rather broad and permissive, allowing for both single-component and two-component tariff structures, consisting of a fixed item to cover infrastructure maintenance costs and a variable item linked to operating costs. The drivers for allocating costs to users are listed in order of increasing incentive strength for efficient water use: irrigated surface area; crop type, in terms of water requirements and economic value; irrigation system; and volumes of water delivered, where appropriate measuring instruments are in place.

Regional disparities in irrigation contribution calculation methods

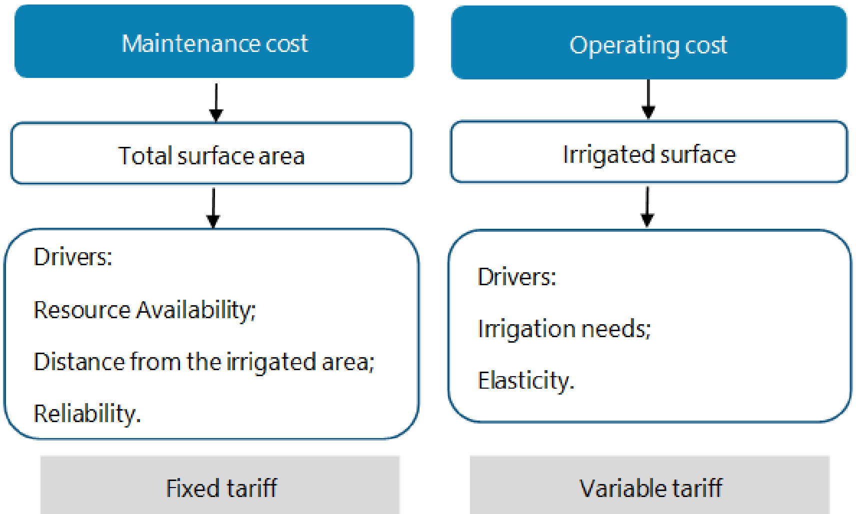
At regional level, however, only some administrations have introduced detailed criteria for drafting the Classification Plan (PdC), which is the document that defines the rules for allocating costs among the beneficiaries of reclamation and irrigation works and specifies the cost drivers to apply. The remaining Italian regions, do not regulate in detail the methods for calculating irrigation contributions, delegating this task entirely to each irrigation consortia.

The measures adopted in three Italian regions that have been particularly active in regulating the criteria for calculating irrigation contributions are briefly described below. Their most recent provisions were issued almost simultaneously with the publication of the MASAF Guidelines.

Criteria for drafting the PdC in Lombardy

The Lombardy Regional Government Resolution No. 3420/2015 establishes the criteria for drafting the PdC. Its annex defines the area subjected to the payment of the contribution, the cost items to charge and, with specific reference to irrigation services, the methods for calculating the fee, which must follow a two-component structure. Irrigation contributions are calculated using a set of drivers: irrigated surface area; resource availability; network length and capillarity; irrigation elasticity; and irrigation reliability. The latter is a a driver determined on the basis of historical performance of the service. An additional index that may be applied is a resilience indicator, which measures for an area the degree of correspondence between resource availability and the related irrigation needs, calculated on the basis of pedo-cultural characteristics.

FIGURE 1. COST ALLOCATION CRITERIA FOR CALCULATING THE IRRIGATION CONTRIBUTION – DGR 3420/2015



Source: authors' elaboration based on DGR 3420/2015 information

Guidelines for drafting the PdC in Tuscany

The Tuscany Regional Council Resolution No. 25/2015 introduces guidelines for drafting the PdC and defines the Irrigation Plan as an integral part of that document. Within the area subjected to contribution payment, costs are charged through a two-component tariff that takes into account both potential benefit and actual irrigation benefit. Potential benefit is associated with the surface that can be irrigated thanks to the availability of infrastructure, while actual benefit is quantified through indices reflecting actual water use. These indices refer to irrigation rotations, delivery methods, and pedological characteristics.

Irrigation contribution calculation system in Emilia-Romagna

Finally, the Emilia-Romagna Regional Government Resolution No. 385/2014 also established a system for calculating irrigation contributions based on fixed and variable components. The resolution promotes the adoption of systems for measuring water withdrawals in order to improve transparency and fairness in cost allocation among users. It also provides incentives for the adoption of more water-efficient irrigation techniques.

Divergent approaches among consortia in the absence of regional regulation

Despite some differences in regional approaches, partly reflecting the absence of detailed national legislation on this matter, regional interventions have contributed to a certain degree of uniformity within individual territories, as emerges from the analysis of the PdCs discussed in the following section. Where regional authorities have not intervened, however, widely differing approaches can be observed among consortia within the same region, or even the absence of clearly defined criteria.

THE WATER PRICING IN ITALY: A SURVEY ON IRRIGATION CONSORTIA

Sample used for the analysis

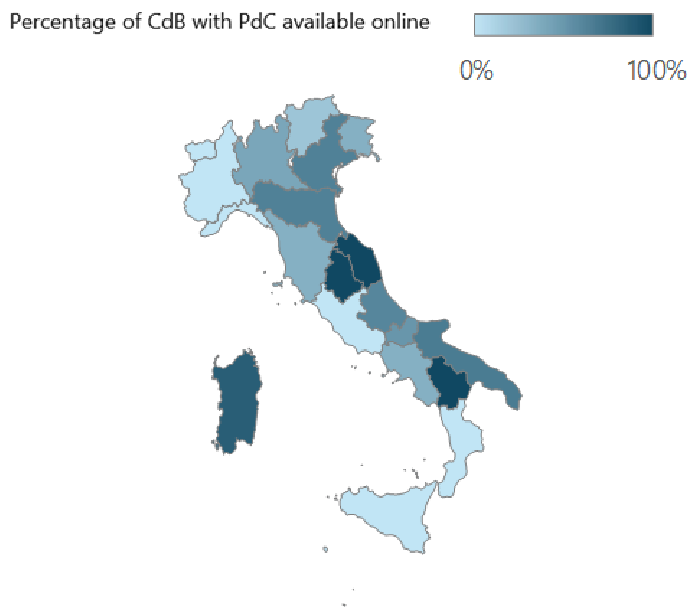
This section presents the results of the empirical analysis of the PdCs adopted by Italian consortia responsible for the provision of irrigation services. The population of entities considered was identified by listing all consortia associated with the National Association of Reclamation, Irrigation and Land Improvement (ANBI), as reported on the Association's website, for a total of 130 entities. For each consortium, its website was enquired in order to collect the documentation required for the analysis.

As noted above, the PdC is the core document underpinning the current assessment, as it defines the criteria for allocating costs among the beneficiaries of reclamation and irrigation services. It considers, among other aspects, land surface areas, their agricultural type of use designations, and the potential benefits derived from irrigation. The PdC generally has multi-year validity and is distinct from the Annual Allocation Plan (AAP), which determines the amounts of the contributions which must be annually paid.

In most cases, PdCs were collected from the "Transparent Administration" section of consortia websites, under the heading "General Acts". A total of 47 plans were retrieved out of 130 entities, a minority of which had been published several years ago.

Figure 2 shows, using different colour gradations, the share of consortia in each region that have published their PdC online. While some regions show high levels of transparency—such as Marche, Umbria, Basilicata, and Sardinia, where PdCs are available for all consortia—others include entities whose PdCs could not be collected through online sources (Campania, Lazio, Liguria, Piedmont, and Sicily).

FIGURE 2 - PUBLICATION OF PDCS ACROSS THE NATIONAL TERRITORY



Source: authors' elaboration based on PdC information available online

Elements analysed in the PdCs

The elements observed in the PdC and considered during the analysis include:

- the accounting structure;
- the structure of tariffs;
- the criteria for estimating benefits for the purpose of cost allocation among users;
- the indices used to estimate technical benefit.

Use of cost-centre accounting

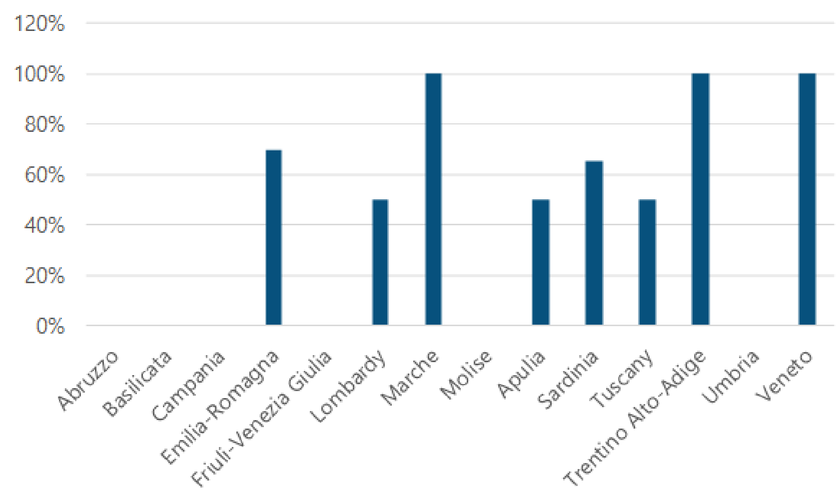
Some PdCs provide a detailed description of the procedures used by consortia to identify relevant costs and allocate them to users. In these cases, the accounting system typically distinguishes homogeneous acrivities carried out for providing a specific type of service — primarily hydrogeological risk prevention, hydraulic drainage, and irrigation services—and subsequently it allocates costs to these clusters.

Under these first clustering, some subgroups could be created which represent areas of cost aggregation that are homogeneous in terms of climatic and geographical characteristics or, more often, that are served by the same irrigation infrastructure: these subgroups are labelled as ”cost centres”.

In some cases, cost centres are defined where specific groups of users rely on infrastructures with different technical characteristics and service quality, such as pressurised versus gravity-fed networks. In such situations, cost aggregation by cost centre represents an intermediate step that enables more accurate and representative cost allocation to users. Where distinct cost centres are defined, different allocation drivers are often also applied, resulting in more articulated accounting systems and greater reliability in cost attribution.

Figure 3 shows, for each region, the proportion of consortia adopting cost-centre accounting. At national level, this corresponds to 51% of consortia that have published a PdC (24 out of 47).

FIGURE 3 - USE OF COST CENTRES



Source: authors' elaboration based on PdC information available online

Tariff structures

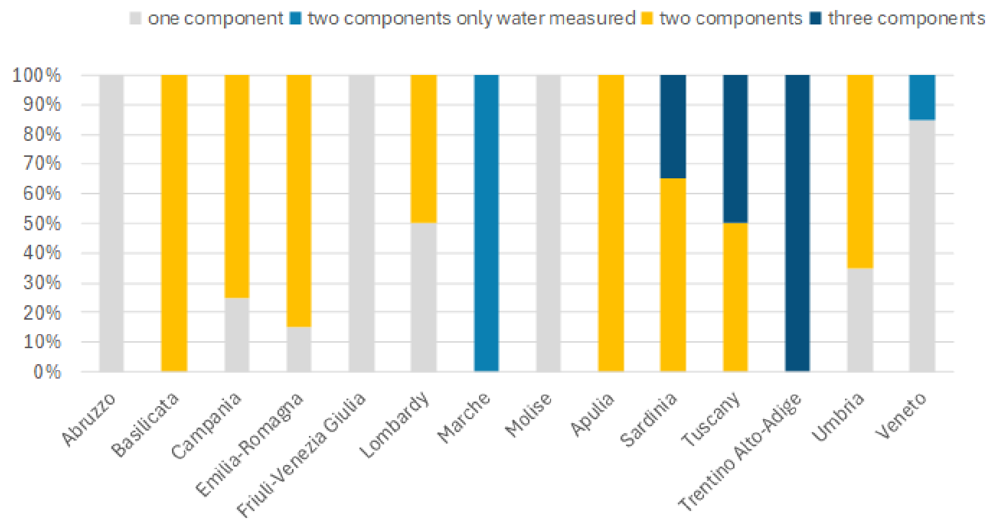
As indicated in the MASAF Guidelines, fees may be defined using either a single-component or **a two-component tariff structure**. In general, the latter **provides greater cost reflectivity, as it aligns user charges more closely with the cost structure of service provision**, which includes both fixed costs—related to infrastructure construction and maintenance as well as administrative and organisational activities—and variable costs linked to infrastructure operation.

Even in the case of reclamation consortia, where investment costs are largely covered by public funds and the weight of fixed costs is therefore reduced, overall cost dynamics remain characterised by both fixed and variable components.

Among the consortia that have published a PdC, 53% apply a two-component tariff structure, including maintenance and administrative costs in the fixed component and defining the variable component on the basis of certain operating costs items, such as electricity and part of technical staff costs. A further 9% adopt a three-component structure, distinguishing: a per-capita fixed quota related to overhead costs; a fixed quota usually calculated on the basis of potential benefit derived from the availability of irrigation infrastructure; and a variable quota based on actual benefit, measured through consumption or other indicators. Sardinia, Tuscany, and Trentino–Alto Adige apply this three-component structure.

Abruzzo, Friuli-Venezia Giulia, and Molise apply simplified single-component tariff systems. Veneto also partly follows this approach, except where consumption measurement is available; in this case a two-component structure is applied and the variable component is based exclusively on volumes withdrawn by individual users.

FIGURE 4 - TARIFFS STRUCTURES



Source: authors' elaboration based on PdC information available online

Estimating benefits for cost allocation

Cost allocation , which may be distinguished into two components: technical benefit, measured through indices expressing the quality and effectiveness of irrigation services, including potential access; and **economic benefit**, which seeks to quantify, in monetary terms, the value generated for farmers by the availability of irrigation services.

Economic benefit is measured by the increases in land value and income deriving from the presence of consortium infrastructure. It is estimated by comparing income from crops traditionally grown under rain-fed conditions with income from crops cultivated with the support of irrigation infrastructure. For example, in the area served by the Southern Sardinia Reclamation Consortium, typical rain-fed crops include wheat, durum wheat, and legumes. Economic benefit is estimated using ISMEA[12] data on gross saleable production net of costs for both rain-fed and irrigated crops. The difference between these values represents land benefit deriving from irrigation, to which the consortium assigns an economic benefit score ranging from 0 to 1, proportional to the value generated.

In some cases, such as the Piana di Venafro Consortium in Molise or the Piave Consortium in Veneto, the economic index, although measured, is set equal to 1 for all users, due to the complexity and uncertainty of the estimates, which could otherwise introduce distortions in the AAP. In other cases, particularly in Veneto, economic benefit is used as a correction factor for technical benefit, to mitigate the effect generated on the contribution paid by crop plans used for estimating irrigation needs. For example, the Delta Po Consortium estimates economic benefit based, as in formula (1), on land income and adjusts it by considering, for each user, the deviation of land income per hectare (R.D./sup) from the average value across the served area (media) found in the entire served area. This differential is applied as a correction to technical benefit using a homogenisation factor "K" set at 2%, thus making the effect of economic benefit relatively marginal.

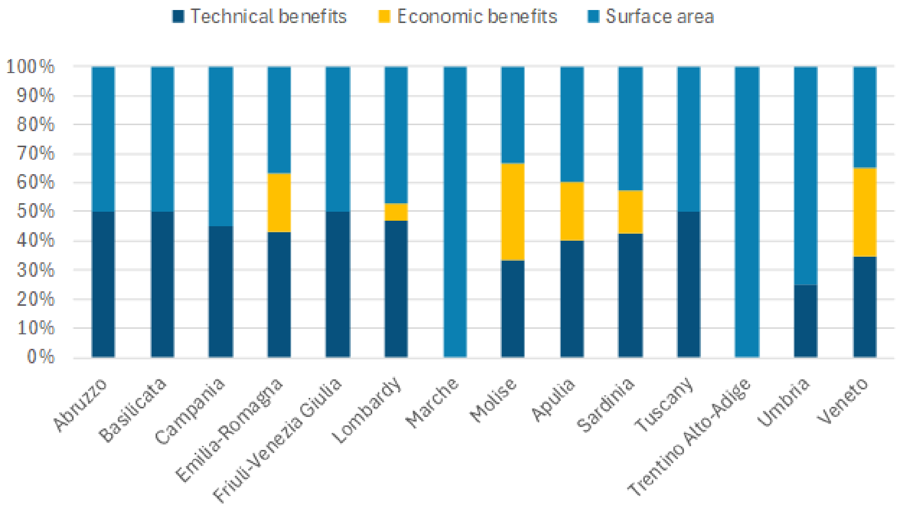
Formula (1): $IC_E = K\,x\,\frac{\frac{R.D.}{SUP}}{media\frac{R.D.}{SUP}}$

Benefit determination methods across regions

Figure 5 shows, for each region where PdCs are available, the methods used to estimate benefits. Economic benefit is applied in only 6 of the 14 regions, while technical benefit is widely adopted, with specific indices used by consortia in 12 regions. **Surface area is used by all consortia as a size-related driver, generally weighted by benefit indices to calculate a "virtual surface" for determining unit costs per hectare**. In a minority of cases, actual surface area is used directly for allocating fixed costs, combined with measured volumes for allocating the variable component (two cases in Campania, two in Umbria, one in Marche, and one in Trentino–Alto Adige). In Umbria, a transitional two-component tariff method is applied using surface area only: total surface for fixed costs and irrigated surface for variable costs. A similar approach, but in single-component form, is applied by the Marche Reclamation Consortium, where gravity irrigation systems prevail.

[12] ISMEA is Italy's national public economic body dedicated to supporting the agricultural and agri-food sector through market information, financial tools, land services, and risk-management instruments. It operates under the supervision of the Ministry of Agriculture and plays a central role in improving competitiveness, transparency, and access to credit for farms and agri-food enterprises.

FIGURE 5 - CRITERIA FOR ESTIMATING BENEFITS



Source: authors' elaboration based on PdC information available online

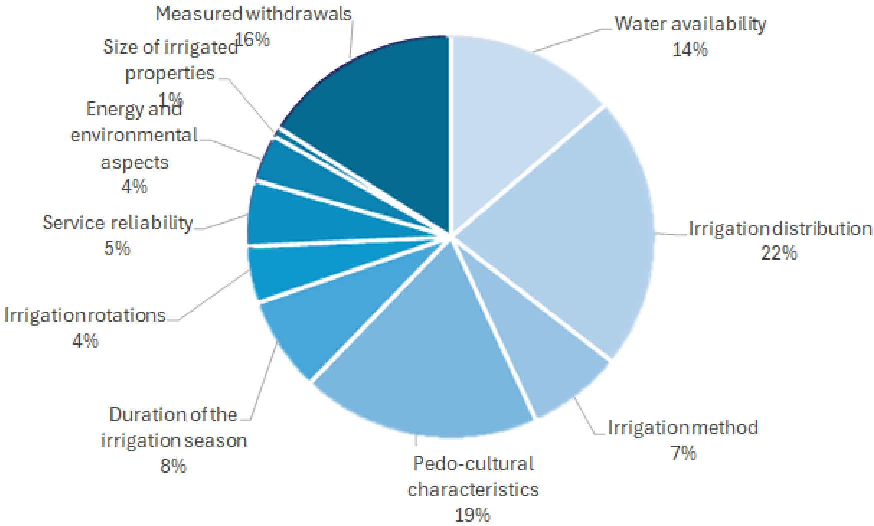
Technical benefit indicators

The fourth dimension analysed concerns the set of indicators used to estimate technical benefit. The main indicators include:

- "Water availability", defined as the nominal volume that a user may request from the consortium during the irrigation season;
- "Irrigation distribution", reflecting network characteristics such as gravity or pressurised systems, network density, distance from infrastructure, and pressure levels;
- "Irrigation method", distinguishing between flooding, furrow, sprinkler, and drip irrigation, with benefit scores increasing as efficiency decreases;
- "Pedo-cultural characteristics", referring to soil types and moisture retention capacity, including application of the crop-hectare method based on declared crop plans;
- "Duration of the irrigation season", measured in days or hours;
- "Irrigation rotations", with lower benefit scores associated with longer intervals between irrigation turns;
- "Service reliability", based on historical continuity of service;
- "Energy and environmental aspects", reflecting electricity consumption in pressurised systems and pumping stations, sometimes measured in kWh per hectare;
- "Size of irrigated properties", used in only one consortium to reflect scale-related service constraints;
- "Measured withdrawals", expressed as cubic metres withdrawn per user during the irrigation season.

Figure 6 shows that the most frequently used indicators relate to distribution network characteristics, pedo-cultural factors, and measurement, the latter often applied only in pressurised networks.

FIGURE 6 - INDICATORS USED TO ESTIMATE TECHNICAL BENEFIT



Source: authors' elaboration based on PdC information available online

Combining consumption and infrastructure indicators

A longitudinal analysis of indicator combinations shows that in 62% of cases measurement of consumption is combined with distribution characteristics, and pedo-cultural indicators are also frequently used alongside irrigation distribution index. This suggests that many pricing systems combine measures of consumption measures, whether actual or estimated, with irrigation equipment characteristics, linking volumes requested to the potential availability of water ensured by dense infrastructural networks. As a matter of fact, users served by high density infrastructural systems cultivating low water-demand crops may receive benefit scores similar to those of users served by less accessible infrastructural systems, due to distance from irrigated surfaces, but cultivating water-intensive crops.

Joint consideration of service accessibility and water demand

For estimating technical benefit, it therefore appears appropriate to consider both accessibility to water resource and irrigation needs at user level, reflecting both infrastructure quality and intensity of use. Furthermore, irrigation requirements may be estimated either objectively, through the measurement of withdrawn volumes, or through proxy indicators such as pedo-cultural characteristics. In 52% of cases, both approaches are used by the same consortium: either complementarily, with pedo-cultural indicators applied to fixed costs and volumes to variable costs (as in the Centro Sud Puglia Consortium), or alternatively, depending on whether measurement is feasible in specific water districts within the same consortium (as in the Dugali Naviglio Adda Serio Consortium).

Measurement and proxy indicators in cost allocation: trade-offs and limitations

While the alternative use of the two indicators represents a reasonable solution for having a proxy of consumption where persistent technical difficulties make the installation and management of meters unfeasible or excessively costly for individual farmers, the complementary use of both indicators appears to present certain limitations. Where it is possible to measure volumes for calculating the variable component of the irrigation fee, the simultaneous use of pedo-cultural characteristics to allocate the fixed component may weaken incentives to reduce consumption at user level, for example through the adoption of more efficient irrigation systems. In such cases, the use of indicators based solely on estimated consumption—even for allocating maintenance and structural costs—may discourage users from achieving per-hectare consumption levels below the standard values applied by the consortium under the crop-hectare method, particularly where these standards are not supported by updated plot-level and daily irrigation requirement calculations reflecting optimal resource use. This potential distortion could be mitigated through the use of additional indicators alongside crop irrigation needs.

Use of irrigation season duration as a service and consumption indicator

When used together with direct measurement or pedo-cultural characteristics (in about 80% of cases), the duration of the irrigation season is generally applied to allocate the fixed component of the contribution, following the same logic as the irrigation distribution index: longer duration is associated with higher estimated benefit. In the remaining 20% of cases, duration is instead used to determine the variable component, allowing for an approximate estimation of required water volumes while taking other factors into account (as in the Est Ticino Villoresi Consortium). Overall, the most appropriate use of the duration indicator is as a characteristic of the irrigation service; however, it may also serve as a proxy for consumption, but only in territorial contexts where a close relationship between service duration and crop water consumption can be clearly identified, and where the installation of measurement systems is not considered cost-effective.

Linking network characteristics and on-farm efficiency

It is also worth noting that the irrigation method indicator—adopted to provide incentives for improving efficiency at farm level—is combined in 70% of cases with the irrigation distribution indicator. Combining characteristics of the consortium network with those of the user's irrigation system appears to be a sound practice, as it reflects both the investment effort made by the consortium in public infrastructure, which is directly proportional to user benefit, and the effort made by farmers in their private systems, which is inversely proportional to benefit where it results in lower water use.

MAIN IMPLICATIONS OF THE STUDY

Initial insights for reflecting on the most effective ways to structure irrigation contributions

This analysis is intended as a first step of a broader monitoring action that must be carried out at the institutional level, aimed at ensuring that River Basin Management Plans (RBMPs) include adequate information on compliance with the economic principles introduced by the Water Framework Directive (WFD), with reference to all uses of water resources, including irrigation. The evidence provides initial insights for reflecting on the most effective ways to structure irrigation contributions, based on the analysis of the PdCs available online by consortia associated with ANBI. While it is essential that RBMPs provide **complete information on 1) cost recovery, 2) the use of incentive-based pricing for efficient water use, and 3) the application of the polluter-pays principle; each EU member state, with a significant water consumption for irrigation, should introduces national guidelines. This could provide clear and consistent indications to regions and consortia regarding the most effective methods for defining irrigation contributions, while respecting the wide territorial and infrastructural differences that affect their practical implementation**.

The current empirical analysis made it possible to identify some **best practices, as well as useful operational rules for designing effective pricing systems**.

Role of cost centres in ensuring representative cost allocation

First, the predominantly indirect nature of cost items incurred by consortia makes it **necessary to identify cost centres** in order to apply allocation drivers that are truly representative of the services provided to different categories of users. Where distribution systems differ significantly in technological characteristics—for example, between pressurised and gravity-fed networks—allocating costs uniformly among all users would be distortive, as electricity and operational costs associated with pressurised systems would also be charged to users served by gravity networks. While the use of a single cost centre was historically justified to support equalisation mechanisms and promote the diffusion of more efficient pressurised systems, greater equity and less distortion of competition can be achieved by defining cost centres that group homogeneous activities. These may reflect, for example, different distribution technologies or withdrawal sources with varying quality and availability. Although appropriate cost drivers can partially address heterogeneous cost absorption even without cost centres, the use of intermediate allocation to cost centre allows for greater objectivity in tariff calculations.

Aligning tariff structures with cost dynamics

Fee structures should also be aligned with the cost dynamics of consortia, taking into account that some cost components are fixed, while others vary with delivered volumes. A two-component tariff structure is therefore clearly preferable to a single-component structure, except in cases where contributions are calculated exclusively on residual costs that are predominantly variable. In line with a principle of reasonableness, it seems appropriate to allocate part of fixed costs to all users who have, even potentially, access to the irrigation network, as this availability represents an opportunity closely linked to land value and thus to economic benefit. At the same time, variable costs should be allocated to users who have actually withdrawn water during the irrigation season, both to cover demand-related costs—such as technical staff and electricity—and to provide appropriate incentives for efficient water use. Where applied, three-component tariff structures represent a further refinement, allowing fixed costs related to irrigated surface extension (such as network maintenance) to be distinguished from costs related to the number of users served, regardless of farm size, such as certain administrative and structural expenses.

Integrating technical and economic benefit in cost allocation

Besides the use of surface area to derive unit cost value per hectare, cost allocation also requires the estimation of user benefit, as prescribed by legislation. Combining technical and economic benefit assessments provides the most comprehensive approach, as it integrates indicators of water availability, infrastructure accessibility and adequacy, and irrigation needs with estimates of economic impact. However, technical indicators alone may serve as a first proxy for economic benefits where a positive correlation exists between technical service quality and economic outcomes. In such cases, reliance on technical benefit can simplify allocation procedures and avoid the introduction of additional elements linked to subjective estimation of income or gross production values.

Design principles for technical indicators

With regard to technical indices, the analysis suggests that the use of a broad and well-structured set of indicators improves both the objectivity and functional accuracy of pricing systems, better reflecting the cost impacts generated by individual users. However, indicator selection must follow clear conceptual criteria, consistent with two core objectives established by national legislation and the WFD: quantifying the benefit that each individual user obtains from the presence and use of irrigation systems, and providing adequate incentives for efficient resource use. A first guiding principle emerging from the empirical analysis is the need to combine indicators related to distribution network characteristics and water sources managed by consortia with indicators reflecting actual irrigation requirements at user level, whether measured directly or estimated indirectly. Network characteristics may be assessed both from the perspective of the consortium system, to quantify user benefit, and from the perspective of the on-farm irrigation system, to assess efficiency in resource use. Accordingly, it is advisable to combine indicators related to public infrastructure and water sources with indicators describing private irrigation systems, assigning higher contribution levels to users operating outdated or technologically inefficient equipment. Information on on-farm irrigation systems also enables more accurate adjustment of water needs where estimation is applied.

Direct measurement of water consumption — whether through meters or, in future, through Earth Observation technologies — **remains the most effective method for estimating irrigation requirements**. Where technical or economic barriers exist, or where satellite-based measurements are subject to excessive uncertainty, direct measurement may be temporarily replaced by proxy indicators such as pedo-cultural characteristics and crop-hectare methods. However, these substitutes should be continuously updated based on systematic monitoring of crop plans and on effective field checks conducted by consortia. Their transitional nature derives from their limited ability to capture aspects related to efficient resource use, as they are based on theoretical rather than actual water consumption.

Risks of distortions from mixed indicator use

Finally, it should be noted that the combined use of direct and indirect consumption indicators — applied respectively to variable and fixed cost components — may give rise to distortive outcomes where fixed costs are allocated on the basis of estimated consumption (such as crop-hectare proxies) rather than on the basis of the infrastructural characteristics of the irrigation systems available. Such approaches risk weakening incentives for efficient water use and should therefore be applied with particular caution.

The issue of individual self-abstraction remains unaddressed

Finally, this process of rationalisation and partial harmonisation of irrigation contribution calculation methods at national level **would not resolve the challenge of applying the principles of Article 9 of the WFD to self-abstraction**, which lies outside the pricing mechanisms applied by consortia and, in most cases, is subject only to abstraction concession fees.

ANNEXES

ANNEX I - LIST OF CONSORTIA ADOPTING BOTH TECHNICAL AND ECONOMIC BENEFITS

	Region	Consortium Name
1	Emilia-Romagna	Emilia-Centrale
2	Emilia-Romagna	Parmense
3	Emilia-Romagna	Renana
4	Lombardy	Garda Chiese
5	Molise	Piana di Venafro
6	Apulia	Centro Sud Puglia
7	Sardinia	Sardegna Centrale
8	Sardinia	Sardegna Meridionale
9	Veneto	Acque Risorgive
10	Veneto	Adige Euganeo
11	Veneto	Bacchiglione
12	Veneto	Delta del Po
13	Veneto	Piave
14	Veneto	Veronese

ANNEX II - LIST OF CONSORTIA ADOPTING A HIGH NUMBER OF INDICATORS (≥4)

	Region	Consortium Name
1	Lombardy	Dugali,Naviglio,Adda Serio
2	Lombardy	Oglio - Mella
3	Apulia	Centro Sud Puglia
4	Emilia-Romagna	Emilia-Centrale
5	Emilia-Romagna	Renana
6	Veneto	Acque Risorgive
7	Sardinia	Ogliastra
8	Tuscany	Alto Valdarno
9	Tuscany	Toscana Costa
10	Emilia-Romagna	Burana
11	Lombardy	Terre dei Gonzaga in Destra Po
12	Emilia-Romagna	Romagna Occidentale
13	Lombardy	Mincio (2° grado)

ANNEX III - LIST OF CONSORTIA ADOPTING WATER CONSUMPTION MEASUREMENT

	Region	Consortium Name
1	Lombardy	Dugali, Naviglio, Adda Serio
2	Lombardy	Oglio - Mella
3	Apulia	Centro Sud Puglia
4	Sardinia	Ogliastra
5	Tuscany	Alto Valdarno
6	Tuscany	Toscana Costa
7	Emilia-Romagna	Burana
8	Lombardy	Terre dei Gonzaga in Destra Po
9	Sardinia	Sardegna Centrale
10	Basilicata	Basilicata
11	Apulia	Gargano
12	Sardinia	Gallura
13	Sardinia	Oristanese
14	Sardinia	Nord Sardegna
15	Veneto	Adige Euganeo
16	Campania	Bacino Inferiore del Volturno
17	Campania	Vallo di Diano e Tanagro
18	Campania	Velia - Bonifica del Bacino dell'Alento
19	Marche	Consorzio di Bonifica delle Marche
20	Trentino-Alto Adige	Monte - Salorno
21	Umbria	Val di Chiana Romana e Val di Paglia

ANNEX IV - LIST OF CONSORTIA WHICH DO NOT APPLY ANY OF THE FOLLOWING INDICATORS: IRRIGATION METHOD, PEDO-CULTURAL FEATURES AND MEASUREMENT OF WATER CONSUMPTION

	Region	Consortium Name
1	Lombardy	Est Ticino Villoresi
2	Abruzzo	Centro - Bacino Saline - Pescara - Alento - Foro
3	Abruzzo	Interno - Bacino Aterno e Sagittario
4	Campania	Paestum
5	Lombardy	Media Pianura Bergamasca
6	Veneto	Veneto Orientale
7	Umbria	Tevere - Nera