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Evaluation of ecosystem services of irrigated agriculture: a policy option for a sustainable water management

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Abstract. Irrigated agriculture can generate pressures on water bodies and, consequently, potential environmental costs; likewise, agricultural water use can provide several ecosystem services (ES). Both pressures and benefits must be included in the economic analysis of River Basin District Management Plans (RBDMPs), for the environmental cost accounting of agricultural water use. In the RBDMPs, the main reference for environmental benefits and costs accounting is the Program of Measures (PoM), as set by the Water Framework Directive (WFD). This paper aims to provide a review of the main ES of irrigated agro-ecosystem and to clarify how the implementation of the actions that support them can constitute an opportunity to internalize the environmental cost charged to agricultural sector.

Keywords: agricultural water use, ecosystem services, water management, programmes of measures, River Basin District Management Plans.
JEL codes: Q15, Q25, Q56, Q57.

INTRODUCTION

At international level, agriculture is one of the largest users of water globally; among OECD countries, it accounts over 40% of freshwater withdrawals (OECD, 2018) generating pressures on water bodies both due to withdrawals and to the release of pollutants (IEEP, 2000). These pressures can determine environmental costs, which, according to the polluter/user pay principle (PPP), must be borne by the agriculture sector.

Nevertheless, the use of water in agriculture can generate positive impacts on environment (Rogers *et al.*, 1998; IEEP, 2000; Marsden Jacob Associates, 2003; Dwyer *et al.*, 2006; Zucaro, 2014). In fact, water, as an asset of Natural Capital, does generate several ecosystem services, ensuring the production of food, energy and many industrial products and other goods and services, as well as the integrity of ecosystems supplying habitat for all living beings, including humans.

During the last decades, EU water policy, starting for the introduction of the Water Framework Directive (WFD) 2000/60, introduced a policy based on an integrated and ecosystem-based approach to water resource planning and management. The Water Framework Directive (WFD) sets qualitative and quantitative water protection objectives, promoting the application of economic principles, methods and instruments for supporting the achievement of these objectives.

Starting from 2015, with the approval of the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) by the United Nations, it was recognized the unsustainability of a development model based only on the environmental level, and it was introduced an integrated vision of the various dimensions of development, based also on economic and social level (United Nation, 2015).

The WFD anticipated those principles, considering water resources as inputs of production process; in particular, through the economic instruments introduced by the Article 9 related to the polluter/user pay principle (PPP) and the full cost recovery, the legislation requires that the environmental objectives are achievable also through an adequate pricing policy able to take into account the effects in terms of environmental, economic and social sustainability. In this context, the principle of adequacy of cost coverage is combined with the objective of an efficient use of the resource with simultaneous reduction of pressures on natural resources.

The territorial reference for the implementation of the WFD are the River Basin District (RBD) and the water planning competences are responsibility of the River Basin District Authorities (RBDA). For water planning process, the Authorities, in accordance with Article 5 of WFD, must carry out an economic analysis considering all water uses and referred to each River Basin District, ensuring consistency across the DPSIR chain (Drivers-Pressures-State-Impacts-Responses). Through the economic analysis the objectives achievable in each planning cycle and the relative costs (financial, environmental and resource) are identified; in addition, the Programmes of Measures (PoM) associated to the River Basin District Management Plans (RBDMPs) and the environmental benefits produced are identified too. This means that, for all the activities that use water and/or impact on the state of the water and that could prevent the achievement of the environmental objectives set by the WFD, RBDA must identify pressures and impacts analysis.

The Programme of Measures (PoM) is the key tool for the implementation of the WFD, as it is designed to enable the Member States to respond appropriately to the relevant pressures identified at RBD level during the pressures and impacts analysis, with the objective of enabling the environmental objectives at river basin or water body level.

In Italy, the Ministerial Decree n. 39 of February 24th, 2015 issued by the Ministry of Environment establishes criteria to determine environmental and resource costs resulting from different water uses. Following the approach of the WFD CIS Drafting Group ECO2, the Guidelines of the Ministry of Environment establish how to estimate the environmental costs generated by water uses, starting from the pressures and impacts analysis of the economic analysis. In fact, the starting point is to identify pressures and impacts on water bodies generated by activities and, consequently, to identify measures to restore the target state of water bodies. It is necessary to find the combination of measures that give the best result in terms of effectiveness at the lowest price, guaranteeing, at the same time, socio-economic sustainability and economic-financial balance. For this reason, the measures to be included in the PoM should be evaluated through a Cost-Effectiveness analysis that provides a ranking of alternative measures based on their costs and effectiveness. Once the PoM has been established, the total cost of the measures represents the environmental cost generated by water uses, as it corresponds to the cost to be incurred for the removal or reduction of the damage generated by the activities. Subsequently, the portion of coverage of this cost must be attributed to each sector that uses water based on the information acquired from the economic analysis, in order to respect the polluter/use pay principle.

Each Programme of Measures shall include basic measure and, where necessary, supplementary measures. Basic measures are the minimum requirements to be complied with; supplementary measures are the measures designed and implemented in addition to the basic measures in order to provide for additional protection or improvement of water resources. If the measures are implemented and the related cost is sustained, resulting offset in the user accounting, the environmental cost can be considered internalized, so they do not configurate anymore as negative externalities. In this case, it is necessary to identify them and make them explicit in the economic analysis.

In this contest, ecosystem services are also mentioned by the Ministerial Decree 39/2015, and when they are configured as environmental benefits and it is possible to demonstrate the existence of relationships between environmental resources, economic systems and governance, they can be evaluated from an economic point of view and considered in the economic analysis.

This paper tries to answer the following questions: which are the ecosystem services associated to irrigation and how to include ecosystem services of irrigated agriculture in the economic analysis of the River Basin District Management Plans (RBDMPs) to include, in addition with pressures and negative impacts, also positive impacts and environmental benefits generated by water use for agriculture.

1. ECOSYSTEM SERVICES ASSOCIATED TO AGRICULTURAL WATER USE

Water is an asset of the Natural Capital, representing a key component in generating ecosystem services, defined as the benefits people obtain from ecosystems. Natural capital can be defined as the world's stocks of natural assets, which include geology, soil, air, water and all living things. The interaction of Natural Capital assets within of ecosystems generates the flows of ecosystem services, defined as the direct and indirect contributions of ecosystems to human well-being. According to the CICES Classification (Common International Classification of Ecosystem Services) the following types of ecosystem services can be distinguished:

- provisioning services: nutritional, non-nutritional material and energetic outputs from living systems, abiotic output;
- regulation and maintenance services: all the ways in which living organisms can mediate or moderate the ambient environment that affects human health, safety or comfort, together with abiotic equivalents;
- cultural services: non-material, and normally non-rival and non-consumptive, outputs.

CICES does not include supporting services that are ecosystem services necessary for the maintenance of all other ecosystem services. Differently from other ecosystem services classification, CICES provides a classification of potential final services. It is up to the user to decide whether in an application context, the service is to be regarded as final or not.

The interaction between the socio-economic system and the environmental system may also have the opposite direction. In fact, human activities may create pressure on the environmental system generating possible impacts on the conservation status of the Natural Capital. Policies play a key role in this context, as those not oriented towards sustainability may accentuate negative impacts; on the contrary, policies aimed at maintaining Natural Capital can limit negative impacts and ensure the generation of the flow of ecosystem services.

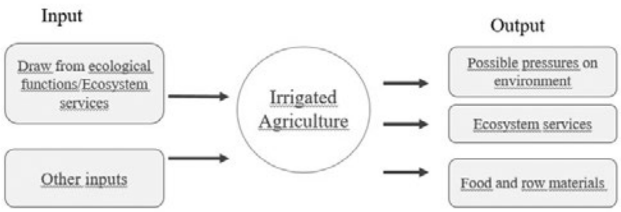
Water, as an asset of Natural Capital, generate several ecosystem services, ensuring the production of food, energy and many industrial products and other goods and services, as well as the integrity of ecosystems supplying habitat for all living beings, including humans.

Like other economic activities, agriculture uses ecosystem services of the surrounding area, generating pressure on environment. Inefficient withdrawals and utilization of water resource for agricultural purposes can have an impact on aquatic ecosystem quality and quantity, generating an environmental cost. Irrigation resource management is fundamental in determining the efficiency of water use. In this context, the Italian case has specific characteristics due to the presence of Reclamation and Irrigation Consortia, which manage collective irrigation. This type of irrigation ensures a higher degree of efficiency than self-supply irrigation, as the Consortia generally organize the distribution through irrigation exercises, management practice that is set, considering the different user requirements, both with regards to the crop requirements, and the specific moment of the intervention in the individual lands.

Nevertheless, agriculture can generate positive effects on the environment while using water. The relationship between irrigated agriculture and ecosystem services is represented in Figure 1: on one hand agricultural production processes use ecosystem services generated by the surrounding area, on the other hand agriculture, in sustainable management conditions, can provide ecosystem services to the society. Irrigated agroecosystems, as they are characterized by infrastructures and practices aimed at the use of water for agricultural production, generate benefits on the surrounding territory, at the level of Ecological Functional Unit (EFU) (Santolini, Morri, 2017), defined as the eco-geographic area characterized by the recognisability of the flow direction of the ecosystem services. The perimeter of an EFU allows to identify the place where the function is developed, in which the performance of the service can be evaluated and the places where the benefits can be appreciated. Therefore, the human activities in irrigation and drainage purpose have enabled the coexistence and interaction between water, vegetation and biodiversity, creating ecosystems capable of generating benefits on collectivity. Often these benefits are supplied in the form of positive externalities, as their value is not included in the company's costs and revenues system. In other cases, the supply of ecosystem services through the interaction of the Natural Capital assets is guaranteed through actions implemented with environmental purposes, attributable to water users in agriculture directly or indirectly. In this context Irrigation and Reclamation Consortia play a key role, as they are responsible for maintaining the territory.

Irrigated agriculture can provide provisioning, regulation and maintenance services and cultural services (Tab. 1). As it shown, ecosystem services are generated

Fig. 1. Relationship between irrigated agriculture and environment.



Source: our elaboration.

through some elements of irrigated agroecosystem, such as hydraulic-agriculture arrangements including ditches, wetlands, riparian vegetation and from irrigation practice. Infrastructures aimed at transporting water for crop irrigation have led to the creation of artificial water bodies capable of generating ecosystem services similar to those generated by natural water bodies. Proof of this is the inclusion of the objectives of protection and improvement of the artificial water bodies and strongly modified between the environmental objectives established by the WFD. Moreover, as mentioned above, the m.d. 39/2015 of the Ministry of Environment recognizes that some reconstructed aquatic systems are capable of performing functions that are configured as ecosystem services. The following paragraphs describe the main ecosystem services generated by the agro-irrigated ecosystem.

1.1. Habitat for species

Irrigated agro ecosystem provides habitats for plant and animal species through its artificial aquatic ecosystems, such as agricultural drainage ditches. Although these anthropogenic systems are habitats of lower quality than larger and more stable water bodies (such as rivers and lakes), in a context of a hyper exploited landscape where natural systems are rare, they may serve as complementary habitats (Herzon, Helenius, 2007; Rolke *et al.*, 2018). In many cases, irrigation canals host several communities of invertebrates (Verdonschot *et al.*, 2011; Hill *et al.*, 2016) fish and amphibians (Piha *et al.*, 2007; Romano *et al.*, 2014; Aspe *et al.*, 2016), birds (Fasola, 1986; Pomares *et al.*, 2015) and mammals (Defra, 2002).

Similarly, wetlands generated through historical water transfers and artificial basins in drought regions are recognized as suitable habitat for several species. A particular case of wetland is rice landscape that hosts many species of water birds. The rice fields are configured as temporary aquatic systems, flooded during the summer and kept dry during the winter, thus following an inverse cycle with respect to the natural wetlands. Therefore, they play an important role in replacing wetlands, particularly in drought periods (Fasola *et al.*, 1996). In some cases, such as in Italy, rice-paddies are recognized as Special Protected Zones areas of Natura 2000. The considerable amount of water used for submerging requires the presence of an irrigation network managed by the Reclamation and Irrigation Consortia, which becomes part of this cultivation system.

1.2. Aquifer recharge

High water consuming irrigation methods, such as submersion and sliding allow the return flows to the aquifer through deep percolation, enabling downstream uses. Several studies demonstrate that reduction of water application at the field scale does not necessarily imply total water savings (Ahmad *et al.*, 2007; Ward *et al.*, 2008).

Moreover, conveyance losses from uncoated canals can provide positive effect if they are «beneficial'losses», namely losses that are re-used or recycled to other beneficial uses either downstream of the water-supply system or within the water-supply system (Marsden Jacob Associates, 2003).

In addition to downstream uses, aquifer recharge service supports groundwater dependent ecosystems (GDEs) include aquifers, caves, lakes, wetlands, ecosystems of coastal lagoons where groundwater flow is needful for dilution of salinity etc. In the North of Italy, the

Tab. 1. Ecosystem services of irrigated agro-ecosystem.

Ecosystem service	Source	Classification
Provision of habitats	Ditches, riparian vegetation, wetlands, paddies	Regulation and maintenance
Water purification	Riparian vegetation, wetlands	Regulation and maintenance
Run-off control	Hydraulic arrangements	Regulation and maintenance
Aquifer recharge	Uncoated irrigation ditches, irrigation	Regulation and maintenance, provisioning
Landscape amenity and Recreation	Ditches, wetlands, irrigation	Cultural
Crop production and food chains maintenance	Irrigation for soil fertility improve	Provisioning, Cultural

Source: our elaboration.

issue of aquifer status is also related to the springs in the area of «Risorgive belt». These springs are important for their ecological function and landscape value (Bischetti *et al.*, 2012; Zucaro, Corapi, 2009). Their recharge is strictly dependent on the interrelation between surface and underground water circulation and from losses from uncoated canals and sliding and submersion irrigation (Gandolfi, 2017).

1.3. Water purification

Irrigation ditches and wetlands can also provide water purification service through aquatic and riparian vegetation that absorbs and reduces nutrients loads from diffuse and point sources water pollution. Several studies demonstrate that vegetated canals mitigate excess nitrogen (Pierobon *et al.*, 2012; Castaldelli *et al.*, 2015). This can occur through uptake and assimilation by plants and microbes, and through denitrification processes, removing permanently nitrogen (Balestrini *et al.*, 2004). Aquatic and riparian vegetation decelerates the flow and promote the sedimentation and the formation of an organic elective substrate for nitrogen reduction processes (Soana *et al.*, 2012). Macrophytes increases the contribution of organic carbon and nitrate to the denitrifying bacteria, creating the ideal setting for denitrification. Riparian vegetation acts as buffer systems between terrestrial human activities and aquatic ecosystems, removing water pollutants from surface runoff before getting into the water bodies (Webber, 2007).

1.4. Cultural and recreative service, hydraulic safety

Ecosystem services described in the previous are benefits provided to the collectivity indirectly. Irrigated agro-ecosystems generate also positive effects, such as cultural services and hydraulic safety, available from the community directly. Irrigation canals are capable of dispose of rainwater and fulfilling the function of maintaining the hydraulic security of residential areas and infrastructure. Moreover, the diversions from rivers for agricultural purposes have modelled the territory creating the typical landscape of irrigated agriculture. The ancient origin of canals and artefacts contribute to make these landscapes part of the cultural heritage of peoples. Irrigated agro-ecosystem has also a recreative function. The landscape of ditches and artificial basins, characterized by mirrors of water, vegetation and monuments, incentive for recreational use from the collectivity, also thanks to the hydraulic maintenance that improves the usability of the territory (Zucaro, 2014). Recreative activities in irrigated landscape include guided tours, fishing, birdwatching, cycling etc. Surrounding areas of ditches and artificial lakes are equipped with picnic areas, playgrounds, cycle-pedestrian paths (Costantini, Romano, 2010). A further socio-cultural benefit is represented by the quality of food production, generating also a provisioning ecosystem service. Irrigation has enabled the modern agri-food supply chain to achieve the high quality level that characterizes the Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG) products, otherwise not reachable if there was the need to use the foreign raw materials. Without irrigation, the quality level of production through other ways would be more expensive. These higher costs would be dumped on prices, with negative social consequences.

1.5. An example: Restoring and maintaining irrigated agroecosystems

The provision of ecosystem services through irrigated landscape requires the implementation of some actions aimed to maintain or restore the anthropogenic systems to ensure the flow of ecosystem services generated from the interaction between water, vegetation and soil. In fact, not every artificial systems of irrigated agriculture is capable of generating ecosystem services. A concrete lined ditch without vegetation cannot represent a biodiversity hotspot and within it, the water purification processes do not occur, neither water infiltration for aquifer recharge.

In addition, without an integrated approach, some processes can produce negative effects. For example, the water infiltration through deep percolation from ditches and fields can compromise status of groundwater if the quality of water infiltrated is poor. In this context, the role of territory management is crucial through the implementation of measure for water resources protection.

In Italy, irrigation Consortia, local water authorities in charge of managing and maintaining the irrigation network and the provision of irrigation water, play a key role in implementing these measures, through their financial resources including contributions of the farmers. Examples of measures are cleaning and resetting activities of irrigation canals beds; restoration and renaturation of irrigation canals in a state of degradation with river bed resurfacing, bank coverings with naturalistic engineering, measures to contrast the rising of the salt wedge, construction of fish ladders, measures to support aquifer recharge processes, phyto-purification, water bodies monitoring, measures for efficiency, improving including price policies etc. Also, compliance with legislative obligations such as the ecological flow release can be considered appropriate measures to achieve the environmental objectives of the WFD. In addition, sustainable agriculture is fundamental to ensure water quality and the flow of ecosystem services. In this context the compliance with obligation of the EU directives on water pollutants and the good agricultural practices promoted by the Community Agricultural Policy (CAP) are suitable measures for water quality protection. The compliance of these measures with the WFD environmental goals allows to consider their economic value in the economic analysis of water uses.

2. ECOSYSTEM SERVICES OF IRRIGATED AGRICULTURE EVALUATION METHODS

As mentioned above, ecosystem services of irrigated agro-ecosystems are often generated in the form of positive externalities, as the interaction between irrigation activity and environmentcauses a change in the human well-being without producing revenues for farmers or water distributors.

The ecosystem services generated by the irrigation agro-ecosystem are externalities, since these are benefits enjoyed by third parties as a result of the irrigation activity. The evaluation of externalities requires the use of alternative methods rather than the traditional one that is based on market price. Stated preference methods use survey techniques to estimate the willingness to pay for a marginal improvement or for avoiding a marginal loss. Revealed preference methods are based on observable choices that allow to directly obtain the resource value (Tietemberg, Lewis, 2012). The main methods of evaluating externalities of irrigation are listed below (adapted from Rosato, 2014):

- Avoided cost is based on the idea that if individuals are willing to support a certain spending to avoid the effects of a certain externality, then the monetary measure of the loss of welfare is at least equal to the amount spent. An example is the positive externalities produced by artificial reservoirs that is used to recreational activity too. The value corresponds to the amount of expenses saved to reach locations that are more distant.
- Substitution cost is based on expenditure that must be sustained to replace it with others, capable of performing the same functions or to provide the same utility. An example is the creation of wetland through historical water derivations. The value corresponds to the cost for the creation of constructed wetlands.
- Production functions method can be used when the externality changes the quantitative and qualitatively resources used as factors of production by agricultural or industrial companies. For example, if the irrigation of an agricultural area makes available additional volumes of irrigation water for a downstream area, the value of externality can be assessed based on the production increases obtained.
- The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. For example, if the properties located in a traditional irrigation area characterized by a pleasant and diversified landscape, have a value higher than what they would have if there were no irrigation, then the positive externality of the latter can be evaluated starting by the increase in the value generated.
- Travel cost method derives from the function of demand starting from the behavior of the visitors to the expenses required for going to a place. For example, if a place is visited for the presence of irrigation, the positive externality can be estimated starting from the expenses that the users are willing to pay for getting there.
- The contingent evaluation estimates the externality preferences through an interview with the user. During the interview it is asked what sum you are willing to pay for getting a certain advantage. For example, the interviewee is asked to be willing to pay for the presence of certain characteristics of the landscape given by irrigation.

The choice of method for evaluating each externality should consider the nature of the externalities and effects on the agents involved.

In some contests, to incentive the production of ecosystem services Payments for ecosystem services (PES) are provided; those are an example of production subsidies in their Pigouvian conceptualization (Sattler *et al.*, 2013). Generally, a PES scheme is defined as «voluntary, conditional agreement between at least one 'seller' and one 'buyer' over a well-defined environmental service or a land use presumed to produce that service (Wunder, 2007)». In the case of governmental payment, commonly referred to Pigouvian concept of PES, the role of the buyer is undertaken by the public sector, but it is distinct from the role of the beneficiary, that is represented by the society (or a part of the society). In this case, public sector takes on the role of intermediary, as it negotiates the terms and conditions of the PES scheme, since the direct beneficiaries of the ecosystem services delegate the PES implementation to the public sector. In the public PES schemes, the connection between ecosystem service payment and beneficiaries should be ensured through the correct use of budget funds, with a view to respecting the beneficiary pays principle (BPP). The implementation of PES schemes requires the monetary evaluation of positive externalities, in order to provide the appropriate incentives that ensure the optimal production of goods that generate ecosystem services. In irrigated agricultural context, PES may encourage farmers to adopt sustainable practices that allow to generate environmental benefits on artificial and natural water bodies. These practices can consist, for example, in maintaining traditional irrigation systems through vegetated uncoated ditches and artificial reservoirs.

3. SUPPORTING ECOSYSTEM SERVICES OF IRRIGATED AGRO-ECOSYSTEM AS POLICY OPTION

As described before, the economic analysis is the main tool for determining the environmental costs and benefits associated with the different water uses. According to WFD and m.d. 39/2015, through economic analysis it is possible to observe: the socio-economic state of the District, and to extrapolate the value of water resources for the sectors; the pressures deriving from the sectors; the measures designed to achieve the environmental objectives (good status of surface water and groundwater); the instruments for cost internalization (price, taxes, obligations).

The environmental cost recovery from agricultural sector, based on the analysis of withdrawal and polluting pressures on water bodies, requires the implementation of measures to achieve the objectives of the WFD to be included in the River Basin District Plans (RBDMPs). In particular, WFD establishes the inclusion of the basic measures (minimum legislative requirements) and, where necessary, supplementary measures; in accordance with the provisions of the European Commission on WFD reporting, measures must be grouped into Key Types of Measures (KTMs), defined as groups of measures identified by Member States in the PoMs which target the same pressure or purpose. There are twenty-five KTMs (Tab. 2), which are setting to include measures for improving water bodies quality and quantity, also referred to hydro-morphological condition.

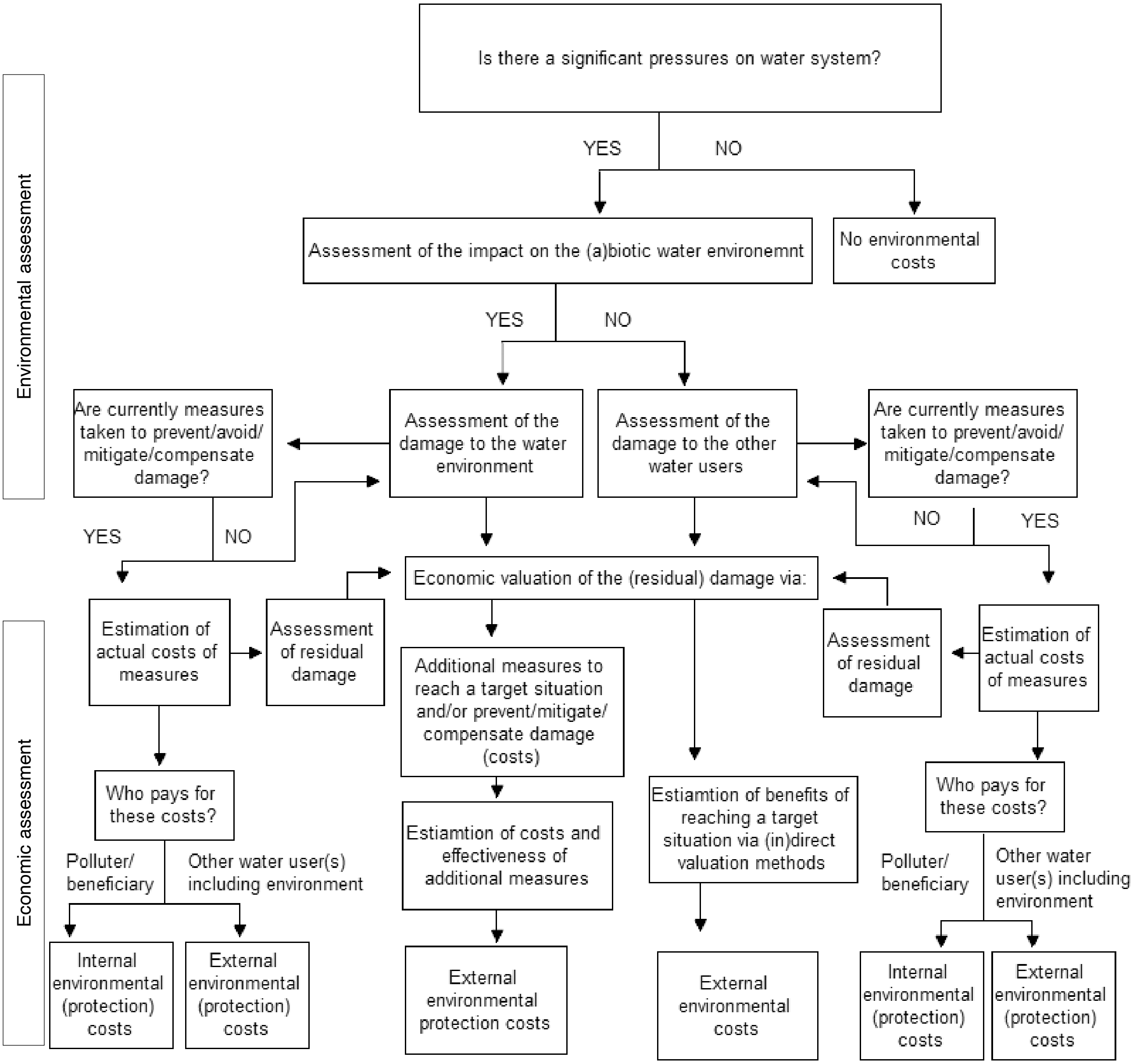
According to the framework of WFD CIS Drafting Group, the environmental cost resulting from negative impacts on water bodies can be considered internalized if the measures carried out to compensate damage are financed by users/polluters (Fig. 2). Ensuring the compliance with the PPP, the flow diagram is the main reference of the Guidelines of the Ministry of Environment's

Tab. 2. List of Key Type of Measures.

KTM number	KTM description
1	Construction or upgrades of wastewater treatment plants.
2	Reduce nutrient pollution from agriculture.
3	Reduce pesticides pollution from agriculture.
4	Remediation of contaminated sites (historical pollution including sediments, groundwater, soil).
5	Improving longitudinal continuity (e.g. establishing fish passes, demolishing old dams).
6	Improving hydromorphological conditions of water bodies other than longitudinal continuity (e.g. river restoration, improvement of riparian areas, removal of hard embankments, reconnecting rivers to floodplains, improvement of hydromorphological condition of transitional and coastal waters, etc).
7	Improvements in flow regime and/or establishment of ecological flows.
8	Water efficiency, technical measures for irrigation, industry, energy and households
9	Water pricing policy measures for the implementation of the recovery of cost of water services from households.
10	Water pricing policy measures for the implementation of the recovery of cost of water services from industry.
11	Water pricing policy measures for the implementation of the recovery of cost of water services from agriculture.
12	Advisory services for agriculture
13	Drinking water protection measures (e.g. establishment of safeguard zones, buffer zones etc)
14	Research, improvement of knowledge base reducing uncertainty.
15	Measures for the phasing-out of emissions, discharges and losses of Priority Hazardous Substances or for the reduction of emissions, discharges and losses of Priority Substances.
16	Upgrades or improvements of industrial wastewater treatment plants (including farms).
17	Measures to reduce sediment from soil erosion and surface run-off.
18	Measures to prevent or control the adverse impacts of invasive alien species and introduced diseases.
19	Measures to prevent or control the adverse impacts of recreation including angling.
20	Measures to prevent or control the input of pollution from urban areas, transport and built infrastructure.
21	Measures to prevent or control the adverse impacts of fishing and other exploitation/removal of animal and plants.
22	Measures to prevent or control the input of pollution from forestry.
23	Natural water retention measures
24	Adaptation to climate change.
25	Measures to counteract acidification

Source: European CWFD Reporting Guidance 2016.

Fig. 2. Flow Diagram to assess and classify environmental costs.



Source: WFD CIS Drafting Group ECO2- Information sheet - 2004.

approach. The method used by Guidelines, proposed by WATECO Group, is the Cost Effectiveness Analysis (CEA). CEA is a technique for identifying the least expensive option to achieve a specific physical goal (Balana *et al.*, 2016). Applying CEA in the context of River Basin Management Plans means to select measures based on their costs and effectiveness. This helps to exclude measures whose cost is out of proportion to the outcomes generated.

According to this approach, the internalization of positive externalities in the context of economic analysis can be assimilated to the setting of PES schemes, but instead of providing direct monetary transfers to farmers, those environmental benefits introduce costs reduction.

According to the legislation framework described, the first step to identify the environmental internalized costs is the identification of the measures already implemented. In fact, if the measures are implemented and the related cost is sustained, the environmental cost can be considered internalized, so they do not configurate anymore as negative externalities.

The aquatic ecosystems linked to irrigated agriculture capable of generating ecosystem services and their maintenance, play a role in this process; in fact, the actions that ensure the ecosystem services flows from water bodies can be considered as measures already implemented. In addition, identifying the funding source, it is possible to determine who/which sector pays for the cost of measures, and if the PPP is respected. Following this approach, a part of the environmental cost connected to irrigation and already internalized by the agricultural sector is the value of actions that maintain and improve ecosystem services from water bodies (included artificial ones of irrigation agro-ecosystem) financed through:

- public financial resources (for example through European Agricultural Fund for Rural Development (EAFRD) that respond to focus areas 4b (Improving water management) and 5a (increasing efficiency in water use by agriculture);
- financial resources of Irrigation Consortia;
- financial resources of farmers.

Examples of measures that can be implemented, whose related cost is sustained (so that the environmental cost can be considered internalized) through financial resources of the agricultural sector, are: costs related to the respect of obligations set by the legislation on sustainable use of pesticides and on nitrates; actions for soil management aimed to preserve water bodies quantity and quality, since pollution at the field scale can compromise status of groundwater due to percolation processes and to run-off; ecological engineering, nature-based solutions, green infrastructures, that can improve the flow of ecosystem services, the construction of riparian buffer strips on irrigation canals for water purification, wetlands construction for habitat, maintaining and restoration of uncoated canals for aquifer recharge (also maintaining adequate levels of waters) and for fish life, resurgences restoration etc. Most of those measures are implemented by Irrigation Consortia and are financed by Regional Rural Development Programmes (public funds) or by their own budget (private - farmers funds).

Other example refers to the Natural Water Retention Measures (NWRMs). Natural Water Retention Measures, multi-functional measures that aim to protect

Tab. 3. List of Natural Water Retention Measures.

A1	Meadows and Pastures	U1	Green roofs	N1	Basins and ponds	F1	Forest riparian buffers Forest riparian buffers
A2	Buffer strips and hedges	U2	Rainwater Harvesting	N2	Wetland restoration and management	F2	Maintenance of forest cover in headwater areas
A3	Crop rotation	U3	Permeable surfaces	N3	Floodplain restoration and management	F3	Afforestation of reservoir catchments
A4	Strip cropping along contours	U4	Swales	N4	Re-meandering	F4	Targeted planting for 'catching' precipitation
A5	Intercropping	U5	Channels and rills	N5	Stream bed re-naturalization	F5	Land use conversion
A6	*No till agriculture*	U6	Filter Strips	N6	Restoration and reconnection of seasonal streams	F6	Continuous cover forestry
A7	Low till agriculture	U7	Soakaways	N7	Reconnection of oxbow lakes and similar features	F7	'Water sensitive' driving
A8	Green cover	U8	Infiltration Trenches	N8	Riverbed material renaturalization	F8	Appropriate design of roads and stream crossings
A9	Early sowing	U09	Rain Gardens	N9	Removal of dams and other longitudinal barriers	F9	Sediment capture ponds
A10	Traditional terracing	U10	Detention Basins	N10	Natural bank stabilisation	F10	Coarse woody debris
A11	Controlled traffic farming	U11	Retention Ponds	N11	Elimination of riverbank protection	F11	Urban forest parks
A12	Reduced stocking density	U12	Infiltration basins	N12	Lake restoration	F12	Trees in Urban areas
A13	Mulching			N13	Restoration of natural infiltration to groundwater	F13	Peak flow control structures
				N14	Re-naturalisation of polder areas	F14	Overland flow areas in peatland forest

A= Agriculture; U=Urban; F=Forest; H= Hydro morphology.
Source: Synthesis document n°1 Introducing Natural Water Retention Measures: What are NWRM? NWRM project.

water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes. NWRMs can be applied in the RBMP framework under the Water Framework Directive (WFD) or the Flood Risk Management Plans (FRMP) under the Floods Directive (FD). Table 3 shows a list of NMRMs classified by sectors: Agriculture (A), Urban (U), Hydro morphology (N) Forest (F). Each measure can generate biophysical impacts and consequently some specific ecosystem benefits.

To consider the internalization of positive externalities in the context of economic analysis it is necessary to evaluate those actions, as they support the capability of irrigated-agroecosystems to provide ecosystem services. To assign an economic value it is possible to follow suitable methods from literature on ecosystem services evaluation, recalled before. From those reviews, substitution cost method seems to be the most suitable technique in terms of compliance with the WFD cost-based approach. The existence of elements of irrigated agro-ecosystem capable of explicating the same function of measure planned in RBDMPs allows to estimate the value of those elements. In this context, the Geo-referenced Information Systems (GIS) analysis plays a key role, since maps and models of ecosystem services allow to identify where ecosystem services are produced, to quantify changes in service provision over time and to describe the production of ecosystem services as a function of patterns of land use, climate and environmental variation (Maes *et al.*, 2011). Once the agro-ecosystem structures are identified the services provided through their interaction with the surrounding ecosystems should be quantified in biophysical terms. The value of these elements, estimated through the cost of corresponding measures, would constitute a part of internalized cost by agricultural sector.

4. CONCLUSIONS

The recognition of benefits provided by irrigated agro-ecosystem leads to considerate water use in agriculture not only as a source of pressures, but also considering the positive interaction between water resource and other elements of the territory, due to the distributive function of irrigation systems. These interactions should be supported through some suitable measures, equipping artificial ecosystems of the elements that support ecosystem services flow.

Economic analysis of water uses allows to combine environmental and economic issues related to water uses, following current environmental accounting approaches. The accounting of the impacts on water bodies as environmental cost, through the measures program, offers the possibility of highlighting the actions capable of improving water bodies' quality and quantity, also considering environmental value of aquatic ecosystems dependent on agricultural activity. In this context, it is important to adopt environmental accounting schemes not only at national level, but also at the level of water resource managers. These schemes would allow to report the data on the incoming and outgoing resource flows of the various sectors of use to estimate the significant pressures on water bodies, but also the financial resources allocated for the implementation of measures for the protection and improvement of the water bodies. In this way, it is possible to establish the contribution to environmental cost recovery of water resource for agriculture, considering not only the financial aspect given by the price paid using the resource but also the contribution in terms of the overall impact on water resource. In addition, the mapping of ecosystem services is fundamental for the evaluation of the measures already implemented. In this context, Geo-referenced Information Systems represent a suitable tool for identifying the elements of the agro-ecosystem and their interactions capable of improving the quantitative and qualitative state of groundwater and surface water.

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