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Research article

The economic value of ecosystem services of irrigation: a choice experiment for the monetary evaluation of irrigation canals and *fontanili* in Lombardy

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Abstract. The Water Framework Directive (WFD) has introduced economic principles for water resource management, including the environmental cost recovery on the basis of the polluter pays principle (PPP). Agriculture, as a potential driver of pressures on water bodies, can produce environmental costs. However, the use of water in agriculture can produce ecosystem services (ES), especially through the aquatic systems of the traditional irrigation agro-ecosystem. This work presents a case study of monetary estimation of some ES of aquatic ecosystems linked to irrigation, i.e. irrigation canals and fontanili in Lombardy (Italy). Through the choice experiment method, we obtained positive values of willingness to pay for the highest levels of ES analysed. This has an implication in the context of the economic analysis of water uses and the decision-making process within the interventions planning of irrigation efficiency improvement.

Keywords: irrigation, water framework directive, ecosystem services, choice experiment, economic analysis.
JEL codes: Q25, Q26, Q51, Q57.

HIGHLIGHTS

- The Willingness to Pay for the ecosystem services of traditional aquatic systems linked with irrigation is estimated through the choice experiment method
- Traditional irrigation network has an environmental and cultural value monetarily measurable
- Water saving measures should consider any loss of value of ecosystem services of aquatic systems linked with irrigation
- Water Framework Directive implementation should take into account territorial specificities

1. INTRODUCTION

To date, macroeconomic decision-making is still largely driven by information derived from the System of National Accounts (SNA). The most relevant indicator of the SNA is the Gross Domestic Product (GDP), which, although frequently used as an indicator of well-being, does not indicate the satisfaction of our complex society (Stiglitz, 2009). To fill this gap, several efforts have been made in recent years to implement accounting systems based on the natural capital approach. The Natural Capital Approach was introduced by Costanza and Daly in 1992 and indicates the stock of natural resources that produce wealth. The term Natural Capital refers to the analogy with the economic system, in which capital represents the stock that produces value flows. From the interaction within the stocks of Natural Capital derives the flow of ES, defined as the multiple benefits people obtain from ecosystems (MEEA). ES should be quantified in monetary terms to internalize so-called externalities, which generate allocation inefficiencies due to market failures. Environmental goods and services, being not rival and not excludable, generate costs and benefits for the community, which are added to the cost and private marginal benefit. This causes excessive supply (in the case of negative externalities) and, on the contrary, a modest production of public goods and services (in the case of positive externalities). Payments for ecosystem services (PES) play a fundamental role in encouraging the production of ES. A PES scheme is defined as a voluntary agreement between at least one "seller" of an environmental good/service and a "buyer" (Wunder, 2005, 2015) and they were introduced in Italy with l. 221/2015.

Regarding ES related to water resources and aquatic environments, monetary quantification is relevant for the implementation of directive 60/2000/EC (Water Framework Directive, WFD) economic principles. Art. 9 relates to the polluter/user pays principle (PPP) and adequate recovery of water services costs. This also includes environmental and resource costs, to be achieved through an appropriate pricing policy. Therefore, the legislation requires the quantification of the environmental and resource costs and the quota of contribution of water use sectors based on the economic analysis to be implemented in the River Basin District Management Plans (RBDMPs).

The WFD promotes the use of economic instruments, both in terms of cost recovery levers and requiring the monetary quantification of physical processes, such as environmental pressures and benefits. This involves some efforts to deepen knowledge of the economic and environmental aspects related to the use of water, including agriculture, which has many interactions with ecosystems.

The water cost recovery principle has been clarified by the European Common Implementation Strategy Working Group on Water and Economics (WATECO), which drafted a guide for the Assessment of Environmental and Resource Costs in the WFD. This document points out the breakdown of the total cost of water use into three main components: i) financial cost (including investment and operation and maintenance cost); ii) resource cost, i.e. the cost generated in scarcity conditions if an alternative use would generate a higher economic value; iii) environmental cost, which is the cost to recover the damage produced by pressures on the water resource. The WATECO guide also clarifies the process of internalization of environmental cost; in particular, environmental costs can be internalized if the measures aimed to compensate the damage are implemented and financed by the user/polluter. This can be considered an application of the cost-based methods for ES valuation (in particular the replacement cost). In addition to this cost-based approach, the Commission also proposes a benefit-based approach, which estimates the loss of well-being due to environmental damage or increased welfare if environmental damage is avoided, calculated through the willingness to pay by the community for the implementation of measures.

The information provided by WATECO guided the drafting of the Italian National Guidelines to determine environmental and resource costs resulting from different water uses (ministerial decree n. 39 of February 24th, 2015, issued by the Ministry of Environment) and the drafting of the Operational and Methodological Manual for the Implementation of Economic Analysis (directorial decree 574/STA of 6 December 2018).

In the context of economic analysis under WFD, it is important to consider the negative externalities of irrigation, which are due to withdrawals and water pollution through fertilizer and pesticides use (Racchetti *et al.*, 2019; Bouwer, 1987; Chen *et al.*, 2010)

However, it is also important to consider the positive externalities of agricultural water use. As recognized by the National Guidelines on water and resource cost, some aquatic systems, including those related to irrigation, can produce ES, also in the form of positive externalities (Natali, Branca, 2020). The *Manual* indicates including positive externalities of water uses in the socio-economic description of basin district and the context of quantification of water cost recovery contribution through measures of the Programme of Measures (PoMs). In particular, positive externalities directly affecting water bodies, replacing measures for the recovery of environmental damage, are a proxy of environmental cost. These can be assessed with both a cost-based approach and a benefit-based approach. Therefore, the quantification of ES in monetary terms is also useful for the proper implementation of economic analysis. The value of the benefits should be subtracted from the cost to the agricultural sector (according to the benefit-based approach) or be considered as an internalized environmental cost (cost-based approach).

The theme of ES of irrigation is often in contrast with the theme of irrigation efficiency, which plays an important role in the PoM and Article 9 of WFD, which requires the presence of water pricing policies encouraging efficient water use. In particular, the increase in traditional irrigation efficiency may reduce return flow (Kendy, Bredehoeft, 2006). The ecological structures of an irrigated agro-ecosystem capable of producing ES are mainly typical of traditional systems with a low level of hydraulic and irrigation efficiency. For example, uncoated irrigation ditches cause several leaks by infiltration and evaporation; furthermore, traditional irrigation practices, such as flooding and furrow irrigation, require large volumes of water, of which only a small part meets the needs of crops. Part of the trade-off between efficiency and ES of irrigation is developed in the conceptualization of effective water use, which takes into account the return flow into the aquifer available for "downstream" uses (Keller *et al.* 1996). Consequently, a system evaluated as poorly efficient at the field scale can be efficient at the basin scale, thanks to the return flows in the aquifer. This may make interventions for improving irrigation efficiency on a small scale because of increased volumes used at the basin scale (Grafton *et al.*, 2018; Kendy, Bredehoeft, 2006; Ward, Pulido-Velazquez, 2008). Water flow infiltrated into groundwater upstream and re-emerged downstream can be useful for other productive uses or can feed wetlands (Peck, Lovvorn, 2001).

The trade-off between efficiency and ES of aquifer recharge can be solved considering the "environmental use" of water in the context of water use efficiency as proposed by Brown *et al.* (2012), defined as the portion of water applied for environmental purposes, including water to produce and/or maintain wetlands, riparian or terrestrial habitats.

In recent years, measures have been taken in Italy to modernize irrigation networks, through conversion from open canal systems to pressure pipelines, as well as measures to convert irrigation techniques to more efficient systems, such as drip and sprinkler irrigation. Although these measures promote water saving, with environmental benefits in terms of protecting the quantitative status of water bodies affected by withdrawals, they can lead to alterations of some environmental functions of the agricultural landscape, especially in those strongly linked to the presence of irrigated water. Works linked to irrigation and the irrigated fields have created balances in terms of interchanges between water flows of natural and artificial freshwater systems and between underground and surface water circulation. They have also shaped the territory, characterizing it from an aesthetic-landscape point of view, providing the conditions for the formation and maintenance of habitats, supporting animal and plant biodiversity.

ES of the irrigated agroecosystem should be valued in monetary terms. This is also useful to take into account changes in their value as a result of policies for water saving, including interventions to increase irrigation efficiency.

Ultimately, the monetary quantification of ES is useful in two areas identified in the conceptual framework of this study: i) contribution to the quantification of the share of environmental cost to be deducted from the total cost to be borne by the agricultural sector in the context of economic analysis under WFD; ii) contribution to the analysis of possible environmental costs generated (paradoxically) by savings policies in agriculture.

This study aims to evaluate in monetary terms some ES of specific aquatic ecosystems linked to irrigation though choice experiment method, frequently used for monetary estimation ES, including aquatic ES (Khan *et al.*, 2019; Doherty *et al.*, 2014). This study differs from the analyses previously produced, because it applies the choice experiment to artificial water bodies linked to the irrigated agro-ecosystem, partly following the approach of other authors (Zucaro *et al.*, 2020; Aizaki *et al.*, 2006; Hasund *et al.*, 2010; Sayadi *et al.*, 2009).

With respect to the latter, this study identifies two specific aquatic systems as a source of ES, following a cascade approach (Haines-Young, Potschin, 2010). Furthermore, the monetary quantification of positive externalities is within the context of irrigation efficiency, which in cases such as that of the study area could paradoxically decrease the value of the flow of ES. Finally, political implications are considered within the context of economic analysis under the WFD.

2. STUDY AREA

Lombardy is historically rich in water, although in recent years it has faced frequent drought events. Water is traditionally derived by gravity from surface water streams; only in the last century lifting from surface water streams and extraction from groundwater have spread.

The territory was shaped by the extensive and dense canals network originating from the main rivers. Irrigation strongly characterizes the territory both of the valley, where the landscape is drawn by canals, irrigation ditches, and buildings of hydraulic engineering, and of the upstream area, though lakes control structures. All these works make the Lombard territory a symbol of the union between artificiality and naturalness.

A peculiarity of the Lombard territory is represented by the *fontanili*, which are springs of human origin, historically used as a source of water supply for irrigation.

The *fontanile* is a water intake in the non-emerging aquifer created to raise, collect, direct and use groundwater for irrigation purposes. It differs from the natural resurgence, which refers to the spontaneous surfacing. The *fontanili* were used for the irrigation of *marcite* (type of permanent grassland), which made it possible to have fresh fodder even during the winter season, and therefore to increase livestock production. The *fontanile* comprises two main parts: the head and the shaft. The head consists of an excavation in the ground to intercept the groundwater. The shaft consists of a ditch dug, starting from the head, to drain the surface water towards the fields or to irrigation canals. The *fontanili* are of great interest from the point of view of nature and landscape, so they are recorded at the regional level. In addition to the original irrigation function, they also perform a cultural, recreational and ecological function (Bischetti *et al*., 2012).

The *fontanili* are biodiversity hotspots; the temperature of the water remains relatively constant throughout the year, which ensures the maintenance of a cool summer microclimate. At the same time, it prevents the freezing of water during winter, favouring the development of vegetation even in colder periods. Waters of *fontanili* are crystalline, thanks to the purification processes that take place underground. The riparian strips around the *fontanili* offer niches ideal for nesting birds and represent important habitats for many reptiles and mammals. The feeding of *fontanili* is strictly dependent on the interrelations between surface and underground flow, in which irrigation plays a fundamental role. This is due to the existence, in the Lombardy plain, of two separate areas from the geological and pedological point of view: i) the area of the high plain, whose soil, being composed of pebbles and gravel, is highly permeable; ii) the low plain, in which the soils are formed by more impermeable materials. The volumes of water supply in the upper plain area, with both rainfall and irrigation, easily percolate into the subsoil, reducing the amount of water useful for crops. These volumes return to the surface, giving rise to spring phenomena where the coarse lithologies (high plain) meet the impermeable and fine-grained substrates, typical of the low plain. Springs and *fontanili* create a "band", the so-called "Band of Resurgence" that crosses the Lombard territory longitudinally, as well as the neighbouring regions. Therefore, the percolation processes of uncoated canals and fields irrigated through submersion and flow irrigation in the upstream area ensures the supply of *fontanili* in the downstream area (Gandolfi *et al*., 2006; Balderacchi *et al*., 2016).

3. MATERIALS AND METHODS

3.1. The ecological structures selection

For the analysis of the case study, sources of ES were selected focusing attention on ES linked to percolation processes, also given its importance in the study area in relation to the feeding of *fontanili* and natural springs. Considering the description of the study area, the agro-ecological structures able to favour these processes are irrigation canals on land and irrigated fields. Some information on the ES of irrigation canals can be derived from the literature, although these can refer to different territorial contexts.

As regards the landscape value, Hasund *et al.* (2010) conducted a choice experiment to estimate the WTP for public goods of the agricultural landscape in Sweden, including among the attributes the presence of canals, whose estimated value amounted to € 9.54 / year.

Regarding the biodiversity support, although these anthropogenic systems are lower quality habitats than larger and more stable water bodies (such as rivers and lakes), in a context where natural systems are rare, they can serve as complementary habitats (Herzon, 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; Loòpez-Pomares *et al*., 2015) and mammals (Defra, 2002).

Irrigation promotes the protection of biodiversity also through a contribution to the feeding of wetlands. In the national context, the contribution of irrigation to the feeding of *fontanili* in Northern Italy was highlighted (Balderacchi *et al*., 2016; Gandolfi *et al*., 2006) (see par. 3.2). Peck and Lovvorn (2001) estimated that the contribution of irrigation in terms of inflows in 74 wetlands being studied in North West America is equal to 65%.

Several studies have also been conducted to analyze the contribution of transport losses from uncoated canals to the aquifer recharge due to percolation processes. These, in fact, can generate positive effects if they are "beneficial losses", i.e. losses that are reused or recycled for other beneficial uses. Dagés *et al.* (2020) report the results of some measurements on a study area characterized by a dense canal network in a basin in the south of France in the autumn period. The results show a contribution of concentrated recharge from irrigation canals equal to 40-50% of the total recharge. Sèraphin *et al.* (2016) show that, in the study area considered (a basin in the south of France), the contribution of irrigation to the recharge of aquifers varies between 9% and 69% and is due to specific irrigation practices and the presence of uncoated canals. Through aquifer recharge, losses of irrigation canals feed wetlands, in particular during spring. Aquifer recharge presents problems related to the qualitative pressure on aquifers due to the percolation of polluting inputs. However, as regards the canals on land, this problem is limited, since the water pollution caused by runoff from the irrigated fields is mitigated by riverbed and riparian vegetation (Castaldelli *et al.*, 2015).

Therefore, for the case study analysis, vegetated uncoated irrigation canals were chosen. Thanks to the aquifer recharge ES, these are fundamental for the replenishment of *fontanili*, thus indirectly generating additional ES. In fact, *fontanili*, like springs, are Groundwater Dependent Ecosystem (GDE), so the presence of water in the aquifer, in turn, dependent on the exchanges between water flow processes in the Lombard high and low plain, is fundamental for their maintenance (Balderacchi *et al.*, 2016). Hence, also *fontanili* were chosen for the case study, both for their indirect services of the canals, and as another example of an aquatic system linked to irrigation capable of providing ES.

The ES choice was made considering benefits dependent on the water regime and, therefore, subject to changes caused by efficiency measures.

3.2. Method

The Choice experiment method (CE) was used to estimate the monetary value of the ES under analysis. This method has been used to estimate benefits of irrigation (Zucaro *et al.*, 2020; Hasund, Lagerkvist, 2011). Like contingent valuation, CE is based on the collection and analysis of questionnaires (Mazzanti, Montini, 2001). Compared to the contingent valuation, it can estimate the individual benefits of the environmental good characteristics, based on the assumption that any economic good can be represented by its characteristics ("attributes") and the different levels at which they occur. The purpose of the CE is to estimate the value of the changes in the demand of individuals for the different goods generated by different characteristics. This assumption is based on the economic theory of Lancaster (1966), which affirms the possibility of splitting the utility of the consumer in the utilities deriving from the individual attributes of an asset. From this derives the problem related to the impossibility of capturing the entire value of an environmental good, as there are elements of a subjective nature difficult to identify and quantify. The CE solves this problem in part, as the method is based on the stochastic utility approach (McFadden, 1973), which allows disaggregating the overall utility into two components, a deterministic and an error component.

The first step of the CE is the choice of attributes of the good under study. For each attribute, a vector of levels must be defined. Combinations of levels and attributes are the options respondents are asked to choose from. Using some models, it is possible to identify the weight that respondents place on the presented attribute with a certain level. This weight corresponds to the coefficients of the logit function that estimates the probability of individuals choosing a given alternative. For the estimation of coefficient, Random Parameter Logit Model (RPL) has been used, which, unlike the multinomial logit model, allows heterogeneity to be captured, as coefficients are indexed for each individual.

3.3. Data collection, survey structure and experiment design

To estimate the monetary value of the selected ES, a survey based on questionnaires sent electronically to a sample of Lombard citizens was conducted in the period March-December 2021. The non-probability sample, consisting of 222 units, was obtained through the "snowball" method, selecting units belonging to different contexts (schools, universities, reclamation consortia, social networks) having the characteristic of interest (being resident and/or domiciled in Lombardy) and asking them to indicate other units belonging to the same characteristic.

Attributes and levels used for the design of the experiment are listed in Table 1. For the attribution of levels, we investigated scenarios due to alterations in the water regime canals and *fontanili*. For biodiversity, we obtained information on the animal and plant species present in different conditions of water regime of the *fontanili* (Bischetti *et al.*, 2012). For canals, no information was found in relation to plant biodiversity; therefore, only the presence of aquatic animal species was considered.

Tab. 1. Attributes and levels used for the choice experiment.

Aquatic system	Attributes	Levels
Irrigation canals	Landscape	Semi-dry canal; canal at full capacity
	Animal biodiversity	High (presence of aquatic species), medium (aquatic species decrease); low
	Aquifer recharge	High; medium; absent
	Recreational activities	Possible; not possible
Fontanili	Landscape	Presence of a visible body of water; occasional presence of a body of water
	Biodiversity	Medium animal biodiversity (decrease in aquatic species), filamentous algae; high animal biodiversity (presence of aquatic species), aquatic vegetation; low animal and plant biodiversity
	Irrigation use	Yes; no
	Recreational activities	Possible; possible nearby; not possible

Two fractional factorial orthogonal designs were generated with SPSS® software. Two final sets of 18 profiles plus one (i.e. the "opt-out" alternative) each were selected.

Respondents were asked to choose between sets of four alternatives for twelve choice groups (six channel groups and six fountain groups). The hypothetical cost required for each alternative was presented in the form of an increase in the water bill, equal to 4, 12 and 20 € per month, depending on the alternative chosen (Tarfasa, Brouwer, 2013). The respondents were also offered the opportunity to choose none of the alternatives proposed against a zero increase in the bill.

For landscape of *fontanili*, images of a semi-dry canal and a full flow canal were presented, drawing from the websites of the Lombard consortia. For animal biodiversity, the information was derived with reference to the maintenance of a minimum vital outflow for the maintenance of aquatic species, which generally applies to natural water bodies (Puzzi *et al.*, 2005). For recreational aspects, the image of an accessible canal with a bike path was shown and a not accessible canal (Source Consorzio di Bonifica Chiese). For infiltration capacity, three scenarios were shown that present a high degree of infiltration, one medium and one low.

For *fontanili*, Bischetti *et al.* (2012) report data on the decrease in animal biodiversity following eutrophication and burial. In addition, the authors provide information on the vegetation present in partially buried springs, which is characterized by a massive development of filamentous algae. Therefore, the levels for biodiversity are: medium (decrease in aquatic species and the presence of filamentous algae); high biodiversity (presence of aquatic animal and plant species); low biodiversity.

For recreational aspects, the levels concern the impossibility of access, the possibility of enjoying the surrounding areas and the possibility of use for bathing. The images were taken from the Lombardy geoportal, which provides information on the *fontanili* census and from sites dedicated to tourism in the Province of Crema (area in which the most attractive *fontanili* are located). The attribute relating to the landscape has been defined on two levels that indicate the presence of a constant and visible body of water as opposed to the occasional presence of a body of water. Finally, the attribute that concerns the irrigation function is defined on the yes/no levels.

4. RESULTS

4.1. Socio-economic characteristics of the respondents

Table 2 summarizes some of the main characteristics of the 222 respondents, also through the comparison with census data of the population of Lombardy (Census ISTAT 2021). 36% of respondents are women, the average age is 37 years and most have a medium-high education (high school diploma and/or degree). The proportion employed is 57%, including employees, entrepreneurs and self-employed; the remaining 43% include, in part, students and pensioners. Finally, 9% of the sample, belong to environmental associations.

Tab. 2. Sample characteristics and comparison with the population.

Characteristic	Sample	Lombard population
Gender	women *36%*	Women *51%*
Age	37 years	45 years
Educational level	Medium-high *89%*	*52%*
Employed	*57%*	*68%*
Belong to Environmental association	*9%*	/

Source: survey and ISTAT census 2021.

4.2. Respondents' perception of irrigation and associated aquatic systems

Some information was requested about the general appreciation (and aversion) towards irrigation-related works. To support the choice, a set of options was presented using a 4-point Likert scale, in which indicating the degree of agreement with the claim submitted was asked. The options were numbered, assigning the lowest score to options indicating disagreement and the highest to those expressing a favourable opinion. A non-response was given a score zero. The results in Table 3 show that respondents have on average a positive perception of irrigated agricultural activity and related works; moreover, on average, they recognize the importance of irrigation for agricultural production and the economy of the territory.

4.3. Results of the choice experiment

Data was processed through the software NLogit ©, using two separate databases. The database of the fountains consists of 217 units. The random parameter logit (RPL) model was used for processing. The output of the models returns coefficients that, in the case of significance and positive sign, indicate that the level of the attribute associated is preferred regarding the level of the same attribute not included in the model.

The utility functions for the estimation of coefficients by means of the RPL model are as follows.

Tab. 3. Descriptive statistic of respondents' perception of irrigation and associated aquatic systems.

	Mean	Median	Mode	Standard deviation
The agricultural activity allows the territory to be enriched thanks to the watercourses necessary for irrigation)	3.37	4.00	4.00	0.83
Irrigation and related elements disfigure the landscape	1.78	2.00	2.00	0.88
Irrigation works are important for agricultural production and contribute to the territory	3.67	4.00	4.00	0.68

<u>Utility function for irrigation canal</u>:

$$U_C = OPTOUT + \beta_{BIOHIGH}BIOHIGH + \beta_{BIOMED}\mathrm{BIOMED} + \beta_{LANDSCAPEHIGH}LANDSCAPEHIGH + \beta_{RECRYES}RECRYES + \beta_{AQUIFHIGH}AQUIFHIGH + \beta_{AQUIFMED}AQUIFMED + \beta_{INCREASE}INCREASE$$

Where:
OPT-OUT = dummy for "None of the proposed irrigation canals"
BIOHIGH dummy for high biodiversity
BIOMED dummy for medium biodiversity
LANDSCAPEHIGH dummy for view of the full capacity canal
RECRYES dummy for the opportunity to carry out activities in the surrounding areas
AQUIFHIGH: dummy for high aquifer recharging capacity
AQUIFMED dummy for medium aquifer recharging capacity
INCREASE: monthly increase of water bill per household

<u>Utility function for *fontanili:*</u>

$$U_F = OPTOUT + \beta_{BIOHIGH}BIOHIGH + \beta_{BIOMED}BIOMED + \beta_{IRRIGYES}IRRIGYES + \beta_{RECRYES}RECRYES + \beta_{RECRNEAR}RECRENEAR + \beta_{WATER}WATER + \beta_{INCREASE}INCREASE$$

OPT-OUT = dummy for the option "None of the proposed irrigation canals"
BIOHIGH: dummy for high biodiversity
BIOMED dummy for medium biodiversity
IRRYES dummy for the possibility of use for irrigation
RECRYES dummy for the possibility of carrying out activities inside
RECRNEAR dummy for the possibility of carrying out activities in the surrounding areas
WATER dummy for the constant presence of a visible body of water
INCREASE monthly increase of water bill per household

4.4. Results for ecosystem services of irrigation canals

The estimates of the coefficients associated with the attributes of irrigation canals are represented in Table 4. The coefficient of the attribute for price is negative, which means that, as expected, the increase in the price decreases the utilities of the respondents. Furthermore, the "ASC" variable, which captures the effect of everything that was not considered in the model, is significant. All the coefficient of variables associated with the

Tab. 4. Output of RPL model for the estimation of coefficient of irrigation canals attributes.

	Coefficients	Standard error	z	Prob. |z|>Z*	95% Confidence Interval	
	Random parameters in utility functions					
BIOHIGH	1.99384***	.21462	9.29	.0000	1.57320	2.41448
LANDSCAPEHIGH	.49580***	.18322	2.71	.0068	.13670	.85490
RECRYES	1.57454***	.21946	7.17	.0000	1.14441	2.00467
	Non random parameters in utility functions					
ASC	.74394***	.20252	3.67	.0002	.34701	1.14088
ICREASE	-.11087***	.00846	-13.10	.0000	-.12746	-.9428
BIOMED	1.31918***	.13468	9.80	.0000	1.05522	1.58314
AQUIFHIGH	.27802***	.09077	3.06	.0022	.10012	.45593
	Distns. of RPs. Std.Devs or limits of triangular					
NsBIOHIGH	1.52536***	.15739	9.69	.0000	1.21688	1.83385
NsLANDSCAPEHIGH	1.27718***	.15431	8.28	.0000	.97474	1.57963
Ns RECRYES	2.12986***	.17824	11.95	.0000	1.78053	2.47920

***, **, * ==> Significance at 1%, 5%, 10% level.

highest levels of the attributes are positive and statistically significant. The output shows the presence of heterogeneity of preferences for the variables relating to high biodiversity, the possibility of carrying out recreational activities near the canals and the aesthetic aspect, whose coefficient is, in this case, positive and significant. The variable relating to the average recharging capacity is not significant, therefore not relevant in terms of the preferences of the respondents. McFadden's pseudo-R2 is equal to 0.23, considered an admissible value to establish the goodness of the model (Hensher *et al.*, 2005).

Through the estimated coefficient it is possible to estimate the WTP for attributes considered (Tab. 5). It corresponds to the ratio between coefficient of the price (INCREASE) and coefficient of the attribute.

Therefore, considering a scenario in which irrigation canals present high levels of each attribute considered, the WTP for the Lombard irrigation canals by the sample considered is approximately €40/ month per household.

Tab. 5. WTP for irrigation canals attributes.

Attribute	WTP (€/month)	WTP Confidence interval
High biodiversity	18	[15.7 24.1]
Medium biodiversity	12	[5.25 16]
Possibility to carry out activities	14.27	[11.4 20]
Aesthetic : full capacity canal	4.54	[1.4 8.5]
High aquifer recharge capacity	2.54	[1 4]

4.5. Results for ecosystem services of fontanili

Table 6 shows the results of the RPL model for the estimation of coefficient for attributes of *fontanili.*

Also in this case the coefficient linked to the increase of the price (*INCREASE*) is negative, confirming the hypothesis of consumer rationality; furthermore, the ASC variable has a significant coefficient. The output of the model indicates the presence of heterogeneity for high biodiversity, the irrigation function and the possibility of carrying out recreational activities in the *fontanili* and nearby. Instead, the coefficient associated with the visible presence of a body of water does not show heterogeneity and is not significant. McFadden's pseudo-R2 is equal to 0.17, which is a slightly out of the range value that ensures the goodness of the estimate, but is still considered acceptable (Doherty *et al.*, 2014).

WTP for attributes of fontanili, calculated through the ratio between the price coefficient and attributes coefficient, is shown in the Table 7.

Considering the scenario in which the attributes considered are provided at the highest level, the WTP for Lombard springs is approximately €30/month per household.

5. DISCUSSION OF THE RESULTS

The results show positive values for ES monetary value of the elements of the irrigation agro-ecosystem considered in the analysis.

With regard to irrigation canals, respondents show

Tab. 6. Output of RPL model for the estimation of coefficient for attributes of fontanili.

	Coefficients	Standard error	z	Prob. |z|>Z*	95% Confidence Interval	
	Random parameters					
BIOHIGH	1.14352***	.22552	5.07	.0000	.70150	1.58554
IRRIGYES	.68097***	.18629	3.66	.0003	.31584	1.04609
RECRYES	1.11199***	.13861	8.02	.0000	.84032	1.38365
RECRNEAR	.79619***	.19120	4.16	.0000	.42144	1.17094
	|Nonrandom parameters in utility functions					
ASC	.43004*	.26004	1.65	.0982	-.07962	.93971
INCREASE	-1.0089***	.00804	-12.55	.0000	-.11664	-.08513
BIOMED	.70763***	.12811	5.52	.0000	.45654	.95872
WATER	.19018	.19228	.99	.3226	-.18668	.56705
	Distns. of RPs. Std.Devs or limits of triangular					
NsBIOHIGH	1.40839***	.14894	9.46	.0000	1.11647	1.70031
NsIRRIGYES	1.39222***	.15155	9.19	.0000	1.09519	1.68925
NsRECRYES	.92894***	.13909	6.68	.0000	.65632	1.20156
NsRECRNEAR	.74374***	.17114	4.35	.0000	.40832	1.07917

***, **, * ==> Significance at 1%, 5%, 10% level.

Tab. 7. WTP for attributes of fontanili.

Attribute	WTP (€/month)	WTP confidence interval
High biodiversity	11,4	[7 15,8]
Medium biodiversity	7,1	[4,6 9,6]
Irrigation use	6,8	[3,2 10,5]
Recreational activities possible (bathing)	11,1	[8,4 13,8]
Recreational activities possible nearby	8	[4,2 11,7]

a positive WTP for the attributes related to biodiversity, aquifer recharge, landscape and recreational function. This justifies interventions of the irrigation and land reclamation consortia for the maintenance of irrigation canals aimed at preserving not only their capacity for water delivery, but also their ecological function, as well as the provision of recreational services.

The evidence also suggests particular attention should be paid to the conversion of traditional irrigation networks to pressure pipes or coated canals, since this would deprive the agro-ecosystem of elements of naturalness and ES that, as seen, have a value.

The biodiversity of the *fontanili* is particularly appreciated, showing a high WTP; similar results have been obtained for the possibility of using them for bathing.

An unexpected result regards the landscape attribute, represented by the continuous presence of a body of water in the *fontanile*. In this case, the coefficient is not significant, therefore this aspect is not taken into consideration by respondents in the choice between the alternatives proposed. This result, compared with the high WTP for activities, also nearby, is somewhat controversial, given the deep connections between aesthetic factors and choice of recreational places.

It is interesting to note that the respondents show a WTP for the possibility of productive use of *fontanili*, which is their original function that is instead disappearing nowadays. The appreciation of the community for the productive function suggests the importance of recovering and/or maintaining the original function of the *fontanili*, which support ecological processes dependent on the presence of water (nutrient purification, habitat for aquatic species, etc.). By adding the WTP for attributes it is possible to derive the consumer surplus generated through canals and *fontanili*. However, the value has been estimated only for some observable attributes through consumer preferences.

The interconnection between canals and *fontanili* (Gandolfi *et al.*, 2006; Balderacchi *et al.*, 2016) implies that the calculation of the monetary value of all ES included in the analysis can be attributed to irrigation canals. Indeed, in the case study analysed, ES of the *fontanili* can be considered as indirect ES of the irrigation canals. The interconnection between canals and *fontanili* also implies that variations in the aquifers recharge capacity of the canals, due, for example, to waterproofing, can lead to negative variations in the levels of ES of the *fontanili*, and, therefore, a lowering of their monetary value.

6. CONCLUSIONS

Water is increasingly becoming a scarce resource. Measures aimed at preserving water for future uses are an environmental and economic necessity. In terms of quantity, saving policies aimed at reducing withdrawals from surface and groundwater play a key role, in particular measures to improve irrigation efficiency, financed by huge resources deployed from public funds.

However, these measures do not take into account the return flow into the aquifer, which is available for "downstream" uses and other positive externalities. However, the excess water used for irrigation has not only a productive purpose, but also an environmental function. The case study analyzed in this paper is an example of this condition, since, in the study area, a fraction of water is useful for environmental purposes, including water to produce and/or maintain wetlands, riparian or terrestrial habitats.

The hypothesis of the capacity of an irrigated agro-ecosystem to produce ES, based on the literature review, has been reflected in the results obtained in this study regarding the WTP for uncoated irrigation canals and *fontanili*. Indeed, the results show a high WTP for the provision of services provided by these artificial aquatic systems. In particular, their biodiversity and recreational value are particularly appreciated. The WTP identified by canals and *fontanili* of the study area that have the highest levels of ES, respectively 40 and 30 €/month/household, reflects their approximate monetary value.

The aquatic systems considered are particular in relation to the theme of efficiency and ecological value, specifically, uncoated irrigation ditches are considered inefficient from the hydraulic point of view. They are often rich in vegetation, thanks to the presence of water, a factor that improves the aesthetic value of the landscape that, in turn, increases the attractiveness of the territory for tourist and recreational uses. As for surface water bodies, for which the maintenance of a minimum water flow is essential to provide the capacity of river ecosystems to offer ES, it is also essential to maintain an adequate water regime in the irrigation ditches for the development of vegetation and the related ES. Therefore, the volumes of water in the irrigation ditches play both a productive and environmental function, the latter in the form of positive externalities, quantified in monetary terms in this study.

This study also consider other ES of irrigation ditches supplied through the *fontanili*, following a cascade approach. This could be complemented by analyses involving the physical quantification of the ES considered, missing in this paper. The proposed case study refers to scenarios extrapolated from ecological and hydrological analysis on phenomena that occur in the study area that, however, do not allow physical mapping of the ES being studied according to the standards proposed by environmental accounting. This involves the need for ecological research of artificial aquatic environments such as those considered in the study presented. Therefore, it would be useful to map the artificial aquatic systems of an irrigated agro-ecosystem and investigate their ecological value. Indeed, not all irrigation ditches can provide ES, but only those rich in naturalness, which can improve biodiversity, landscape aesthetics and recreational attractiveness.

The implications of the monetary value of the environmental impacts of water use in agriculture concern the economic analysis to be implemented at the scale of the River Basin District. As seen, the main objective of the economic analysis is the identification of the environmental cost and the relative share of sectors of water use, to be internalized by some instruments. Therefore, the agricultural sector should contribute to the recovery of the environmental costs, through instruments such as compliance with requirements, taxes, irrigation fees and tariffs. However, the monetary value of the environmental benefits supplied by agricultural water use should be subtracted from the environmental cost of the agricultural sector. To ensure consistency in the assessment, the environmental cost should also be identified through a benefit-based approach, an option provided by the European Commission guidelines.

Since irrigated agriculture provides ES (with a positive monetary value), the measures aimed at the protection and enhancement of aquatic ecosystems linked to irrigation are relevant for the quantification of the environmental cost. Since these measures are financed through the consortium budget and/or other funds allocated to the agricultural sector, the cost incurred can be considered to be internalized, by the PPP principle.

Finally, the monetary values of the ES estimated in this study may provide useful guidance to include additional elements in a cost-benefit analysis with investments of projects for irrigation efficiency improvement. Generally, these analyses take into account investment costs, operation and maintenance costs, and benefits in terms of protection of upstream water bodies. The benefits of irrigation could be included taking into account the effective irrigation efficiency at basin scale (instead of classic irrigation efficiency). However, this would capture only the benefits of maintaining water for other uses. Nevertheless, as already mentioned, irrigation water performs other environmental functions which, without an appropriate monetary estimate, cannot be included in the analysis of the efficiency of water use. The results obtained are a useful tool to ensure the successful implementation of the WFD, which requires taking into account the different conditions within the territory, which need specific solutions (Sardaro *et al*., 2018).

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