Design of an incentive-based tool for effective water saving policy in agriculture. DOI: 10.1016/j.agwat.2022.107866

Abstract

This study proposes a novel agri-environmental payment scheme aimed at saving irrigation water. The design incorporates an outcomes-based reward system, ensuring effective savings of water volumes in on-farm uses. A choice experiment (CE) was conducted with 259 farmers, in a pilot study of a water-stressed region with Mediterranean climate. Values for each attribute were estimated using the Random Parameter Logit Model. The environmental payment scheme resulted as receiving good acceptance by the interviewees. The size of economic incentive has the highest relevance in the farmers' choice behaviour, followed by duration of the commitment. Among the attributes tested, water savings effort receives the lowest score. In general, the findings show that farmers are willing to save water in response to the tested payment scheme. Based on the significance of covariates, however, the variable of the farm's crop specialization is critical in the farmer's choice. The main findings suggest that it is advisable to target the payment scheme based on crop profitability, territorial dimension, and taking into account the groundwater salinity map.

Keywords: irrigation; farmer's preference; payment scheme; choice experiments; willingness to accept

1. Introduction

Worldwide, water resources are becoming increasingly scarce, while locally, demographic growth and climate change can threaten water security and ecosystem services. Given that agricultural withdrawals account for the largest share of water use (Carpenter et al. 2011), any reduction in resource use for irrigation can magnify the impact on total water availability. The issues of how to improve water use in agriculture and thereby enhance water saving, however, is controversial (Grafton et al. 2018).

In this regard, whatever the specific measures put in place, an effective water saving policy requires truly manifest incentives, significant effort from farmers, and the support of governments of national and/or regional levels. Incentives, backed by the public and private sectors, are intended to induce behavioural change in farmer's choices. The literature reports three major kinds of incentives for on-farm adoption of sustainable practices (Piñeiro et al. 2020): market regulation, non-market regulation and cross-compliance incentives.

Raising the in-price is a long-standing market incentive, claimed as an effective way to achieve water savings, improve water allocation and encourage conservation. While irrigation water pricing has been promoted by national and international governmental organizations (e.g. Water Framework Directive of European Commission), its effectiveness in actual practice is quite controversial (Berbel and Expósito 2020). This is particularly true in the presence of multiple uses of collective facilities, or where use of on-farm groundwater pumps could cause conflicting or unintended effects (Portoghese et al. 2021). Moreover, in the case of volumetric water pricing, lack of metering for irrigation water can undermine the effective implementation of in-price incentive schemes (Lika et al. 2017).

Regulatory incentive measures are those providing the assignment of water rights or permits that limit (open) access to water resources. The rights are generally issued by a centralised agency, also responsible for monitoring, enforcement, and eventually sanctioning uncompliant users. When abstraction points are known and water uses fully metered, a system of individual abstraction quotas can be implemented. Regulatory incentives suffer the general shortcoming common to command -and -control approaches. Indeed, enforcing regulations entails the control of water access and the metering of water uses. The will of governments to enforce rigorous regulations may be doubtful (Molle and

Closas 2020), and it is generally difficult and costly to implement point-to-point monitoring of usage of irrigation water, particularly in the case of groundwater irrigation (Foster et al. 2020; Ursitti et al. 2018). Even when governments have tried to devote special attention to control of groundwater withdrawals, these difficulties have still been causal in the failure of most regulatory initiatives (De Stefano and Lopez-Gunn 2012).

Cross-compliance incentives link direct payments with farmers' compliance to basic standards concerning water-related issues, in this case mostly voluntary. A Good example of a cross-compliance measure would be the agri-environmental payment schemes that allow farmers to obtain subsidies, conditional on adhering to certain practices. Throughout the European Union (EU), Agri-environmental schemes (AESs) have largely focused on biodiversity, and only to a lesser extent on soil conservation, water pollution, and climate issues. The 2014-2020 EU Rural Development Programme was an example that included the proposal of specific payment schemes supporting adoption of climate-smart agricultural practices. The planned agri-environmental schemes directly tackling agricultural water savings, however, have received very limited uptake (Pagliacci et al. 2020; Rouillard, 2020). A further consideration is that other measures protecting biodiversity and reducing nitrogen or pesticide pollution, such as crop diversification, crop rotation, and conversion of cereal crops into permanent grasslands, could indirectly reduce abstraction pressures on water. Water quantitative issues have been more widely addressed in the EU through the introduction of economic incentives, including within the Rural Development Programme, aimed at promoting on-farm adoption of more efficient irrigation technologies (Kail et al., 2015). However, scientific evidence (Grafton et al., 2018) has long and substantially shown that increasing irrigation efficiency rarely delivers the presumed (saved) availability of water. This is because, from the farmers' perspective, rather than pursuing water savings, the aim is to maximise economic returns. Unless water savings are economically convenient (e.g. in contexts of very high extraction costs), then the demand for irrigation water will continue to increase. Furthermore, in the case of groundwater resources with large numbers of independent users, none are encouraged to preserve the resources, since others might continue to use them equally, in which case water savings would not achieve exclusive individual benefits (so-called "tragedy of the commons").

Given this context, the current research intends to outline the design of a new agri-environmental payment scheme aimed at saving irrigation water, in particular an outcome-based reward system for reduction of on-farm water use, ensuring effective savings of volumes. A choice experiment (CE) is conducted with farmers, for elicitation of their preferences concerning a new scheme. The research identifies the level of payment that would make farmers willing to reduce on-farm water use, in consideration two main design attributes of the agri-environmental scheme: *i)* the targeted amount of on-farm water saving, and *ii)* the duration of farmers' participation in the compensatory scheme.

The research is expected to attain twofold results: i) revealing which policy attributes are relevant in enhancing farmer's uptake of schemes aimed at saving irrigation water; ii) estimation of the potential for irrigation-water savings from economic incentivisation, in view of farmers' willingness to accept such schemes. This latter information is highly relevant to policymakers interested in designing effective water -saving policy for the agricultural sector, through incentive-based instruments, and in planning programmes of measures aimed at achieving good ecological status for water bodies. In this regard, it should be noted that in the EU, water-resource management is entering a new phase, expected to feature combinations of various tools and instruments, among these: voluntary agreements, adoption of technologies, trading in water rights, multi-actor governance, planning and control measures (Berbel and Expósito, 2020).

The study reports on the results from an explorative case study in the Puglia region of south-eastern Italy. Within the Italian context, this area was chosen in view of its long history of joint use of surface and groundwater resources (Portoghese et al. 2021). The findings of this research, however, are not limited to the pilot study area, and indeed the policy implications extend to broader national and international contexts.

The following sections of the paper report first on data gathering and methodology, then provide the main findings. These are followed by a deeper discussion on the results, and finally some concluding remarks with discussion of policy implications.

2. Data and research methodology

2.1 Case study description

Currently, 2,886,000 hectares of Italian land are irrigated, representing 24% of the total used for agriculture (FAOSTAT, 2020), yet the irrigation function on this relatively small share consumes almost 50% of national water resources. Across all national territory, the average annual rainfall is 942 mm, making Italy a country of Mediterranean climate class that is rich in water resources. However, both water availability and irrigation uses are unevenly distributed among the national regions, related to the fact that northern and inland areas have a continental wet climate, while southern coastal areas face semi-arid conditions.

In Italy, almost 65% of irrigated land is served by collective pipeline networks (Zucaro et al. 2011), meaning that farmers can rely on external infrastructure for delivery to their field boundaries. Collective supply is managed by local water user associations, called Reclamation and Irrigation Consortia, and generally sourced from river basins regulated by dam systems. The area of the irrigation network is determined based on reservoir capacity, while the amount of water available is dependent on the rain and snowfall patterns of previous seasons. The tariffs for irrigation services are determined by the individual consortia, meaning that, viewed at the national level, the tariff scheme is a jigsaw of different solutions. In the case of non-networked water supply, irrigation services are managed by the farmer end user, who may obtain water by direct diversion from rivers and/or drawing from aquifers, bearing all the relative costs. The regulation of access to water resources is by the issue of permits by the governments of the Italian regions (20 in all), for which renewal generally requires sizable fees. Although the national administrative systems therefore do provide an environmental tax for water abstraction, the lack of systematic metering means that in effect, the tax is calculated based on areas of irrigable land, rather than the actual amounts abstracted (Berbel et al. 2019).

The current case study concerns the region of Puglia, in south-eastern Italy (the heel of the boot), characterised by dry warm-to-hot summers and wet mild-to-cool winters, with average annual rainfall of about 600 mm. Officially, the region has 238,000 ha of irrigated land, operated by 63,909 farms, representing 18.5% of total farmland and 23.5% of total farms (ISTAT 2010). The large part of irrigated land, however, is operated by the 27% of farms holding more than 5 ha of this type. The region has extensive network infrastructure, operated by six Reclamation and Irrigation consortia, named Gargano and Capitanata (in the province of Foggia), Arneo (Brindisi), Stornara and Tara (Taranto), Terre d'Apulia (Bari), and Ugento Lì Foggi (Lecce). In spite of this infrastructure, almost 65% of irrigated land is operated by farmers' self-supplied groundwater services (Ursitti et al. 2018). Moreover, the region is characterised by striking differences across the provinces. Foggia, for example, achieves the highest share of irrigated land serviced by collectively delivered surface water, while for Lecce almost 80% of total is served by on-farm abstraction of groundwater.

Overall, more than 80% of the region's irrigated land is permanently operated in highly specialised production, especially olive tree**s** (for oil) and grape, followed by fresh vegetables and processing tomatoes. Puglia is the leading region in national production of olive oil and table grape, and accounts for a full third of processing tomato.

Average irrigation volume for Puglia is estimated of 655 million m^3 (Lupia et al., 2013), however groundwater abstraction increases considerably in periods of severe drought (Portoghese et al. 2021; Zingaro et al. 2017). In many areas where groundwater is the main source, pumping rates exceed the natural recharge rate, leading to ongoing water-table drawdown and well depletion, as well as a situation in which the regional "groundwater vulnerability map" reports severe seawater intrusion in coastal areas (2015-2021 Update to Territorial Monitoring, Decree of the Regional Government of Puglia, 16/07/2019).

In view of the goals of the EU Water Framework Directive for good ecological management of all surface water, the regional government aims to increase the supply of reclaimed urban wastewater for agricultural uses. In this regard, the past decade has seen the planning of sizable expenditures for either installing or upgrading a total of 93 tertiary wastewater treatment systems within Puglia (Giannoccaro et al. 2019). Meanwhile, on the demand side, the region has also implemented policy[1] for reducing water use, especially groundwater use for irrigation, in particular through establishing systematic metering of the actual water volumes extracted by farmers. Such policy also obviously implies the need for systems of rigorous control over groundwater access, for prevention of illegal abstraction.

The current research analyses the potential of an incentive-based instrument, as a means of providing policy makers with a broader selection of measures for achieving the desired aims of agricultural water management.

2.2 Design of incentive-based tool

The study applies a choice experiment (CE) to elicit the farmers' willingness to save irrigation water, and in particular, identify the level of payment that would make them willing to reduce on-farm water use. CE relies on hypothetical scenarios, constructed in consideration of the main attributes and respective levels of the research subject.

The literature on the design of agri-environmental schemes (AES) points out the positive effects of incentive mechanisms in increasing farmer participation. In an extensive review on the attributes of contracts encouraging adoption of agri-environmental practices, Mamine et al. (2020) identifies two significant clauses of contract design: commitments and economic incentives. Numerous studies apply the choice experiment model in analysis of farmers' willingness to accept AES, in which the schemes feature a trade-off between commitments (e.g. provision of effort, duration) and payments (e.g. Espinosa-Goded et al. 2010; Villanueva et al., 2017; Sardaro et al., 2019). A main issue emerging is the heterogeneity in farmers' willingness to engage in an AES. Consequently, some authors have recently pointed out that targeting is a key issue in improving the effectiveness and efficiency of AES (Bartolini and Vergamini 2019). Vergamini et al. (2020) have also observed that in this regard, for AES where payments are linked with outcomes, there have been very few studies analysing the effective performance of farmer's participation.

In view of this literature, the design of our CE scheme assumes that for farmers to receive payment, they must deliver (measurable) outcomes, specifically savings of irrigation water at farm level. In other words, irrigators will receive an economic reward only for the actual on-farm water saved. Concerning the time commitment under the scheme, we consider that in rural development programmes, adopters of AES have typically signed five-year contracts, but also note that more than with other schemes, those concerning use of irrigation are more significantly affected by meteorological features such as temperature and rainfall pattern. The duration of the commitment can affect the farmer's decision, and therefore we consider this as a relevant feature in the design of the scheme. Furthermore, to obtain monotonicity in outcomes, the scheme lays out amounts of payment that increase proportionally with the level and duration of provision. In this way, for each attribute, the scheme provides farmers with a broad set of different choice levels at different payments.

The design of the AES thus considers two main attributes: *i)* the targeted amount of on-farm water saving (i.e. provision of effort), and *ii)* the duration of farmers' participation in the compensatory

[1] Consistent with the national regulatory updates for the quantification of volumes (Decreto MiPAAF del 31 Luglio 2015) and recovery of environmental and resource costs (Decree of Ministry of Environment no. 39/2015), respectively translated into regional laws (Regolamento n.2 del 28 febbraio 2017 della Regione Puglia e Deliberazione della Giunta Regionale n. 976 del 20 giugno 2017).

scheme (Table 1). Levels for each attribute were elicited after conducing two focus groups with farmers, technicians and, experts from irrigation water agencies in Apulia region.

Using a D-optimal experimental design, four choice sets were drawn up, each including three alternatives and the "no choice" option. The experimental design aimed at avoiding difficult mental tasks for respondents involving potential issues of incentive compatibility. As reported in Barreiro-Hurle et al. (2018) discrete choice experiments, as a norm, are designed with five attributes (including the monetary attribute) and on average 3.6 levels per attribute (17 levels). The number of alternatives per choice card (including status quo, SQ) ranges from two to five, however these are usually grouped in three alternatives.

A pre-test pilot trial was carried out with eight farmers, with the incentives framed on a per hectare equivalent basis, rather than euros per cubic metre, since during a focus group it had emerged that farmers were more familiar with such equivalents. Moreover, at this time, the participants had also strongly disputed the potential of achieving on-farm water savings of 50%.

Figure 1 shows an example of a payment card in the case of on-farm water use up to 1,500 m^3/hectare/year. We set 2017 as the reference year for on-farm water use, given that this had been the latest very dry season for the region.

In addition to the influence of climatic conditions, on-farm irrigation volumes can depend on, among other variable: the nature of the irrigation systems, crop requirements, soil type. As a consequence, choice sets should be constructed accordingly, with individual specific SQ. In most of the scientific literature, discrete choice experiments rely on average or 0 SQ value. Only a few papers deal with this issue (e.g. Guerrero-Baena et al. (2019), in the context of valuation for water use, and Salazar-Ordoñez et al. (2021), in the context of AESs).

To account for a broad range of current irrigation volumes, we laid out 12 payment cards ranging from 500 to 6,000 m^3/hectare/year, however each farmer was only shown the payment card with the volume closest to their current usage of on-farm irrigation water. The issue of individual specific SQ was tackled directly in the survey, by making the farmer immediately aware of the monetary reward (m^3/hectare/year) earn in each of the AES alternatives.

Table 1. Attributes and levels of the choice experiment.

Attributes	Levels
Water saved (% with respect to 2017 on-farm water volume)	0% (SQ); 10%; 20%; 30%;
Time (Number of years with on-farm saving in the coming 5 years)	None (SQ); 1 year out of 5; 3 years out of 5; 5 years out of 5;
Incentive (Economic reward for saved volume - €/m^3)	0 €/m^3 (SQ); 0.12 €/m^3; 0.24 €/m^3; 0.36 €/m^3; 0.48 €/m^3.

OPTION A	**OPTION B**	**OPTION C**	**"NO CHOICE" OPTION**
Water saved: **30%**	Water saved: **10%**	Water saved: **20%**	Water saved: **0%**
Participation: **5 year**	Participation: **3 year**	Participation: **3 year**	Participation: **0 year**
Incentive: **216 €/hectare/year**	Incentive: **18 €/hectare/year**	Incentive: **72 €/hectare/year**	Incentive: **0 €/hectare/year**
☐	☐	☐	☐

Fig. 1. Example of choice set.

2.3 Surveying

A questionnaire was designed to collect data from farmers on a range of topics, including through the choice experiment. The questioning was structured as follows:

A - Preliminary information: farmer's awareness of current and foreseeable problems regarding the availability and quality of irrigation water in the region of Puglia; knowledge of regulations on access to water resources; presence and type of access to water resource for the interviewee's farm.

B – Farm characteristics: information concerning the geographic location (e.g. altitude, distance from the nearest inhabited centre), structural (e.g. irrigated and non-irrigated area, land tenancy) and organisational characteristics (i.e. type of management) of the farm.

C - Types of crops and breeding: distribution of the cultivated area among the different crops grown; species of animal husbandry; adoption of environmental certifications (e.g. organic, integrated pest management); adoption of innovations in recent years (mechanical, managerial, varietal, and commercial).

D - Technical data concerning the irrigation practice: general information (e.g. distribution system, water sources); annual use of irrigation water; characteristics of the water service; quantitative and qualitative evaluation of the irrigation service; operational costs of irrigation.

E - Technical data concerning wells: characteristics of any wells present on the farm (depth, diameter, flow rate, etc.).

F - Cost of land: information regarding the value (rental, purchase-sale prices) of the specific farmland.

G – Willingness to accept compensation to reduce usage of irrigation water: the respondents were presented with a choice experiment, asking them to choose between three alternative options of AES, in addition to the current situation, called "No choice option".

H - Personal information: socio-demographic and professional characteristics of the farm manager.

The sampling procedure was based on the identification of the most intensively irrigated areas of the region, i.e. "hot spot" irrigated areas. In particular, the procedure was to calculate the share of irrigated Utilized Agricultural Area (UAA) at the level of the municipalities (Italian Agricultural Census, 2010) and then select those with the highest shares, for which the sum of irrigated UAA would equal 66% of regional irrigated UAA.

The experiment was conducted on a sample of 300 farmers from the hot-spot areas, with the number selected for each hot-spot proportion to the municipal share of irrigated UAA. In each area, the farms were selected on the basis of the criteria: farmland size, types of crops grown, type of irrigation services (i.e. collective, self-supplied).

A team of six trained members carried out the survey from December 2018 to February 2019, by means of face-to face interviews in the municipalities. The survey obtained fully answered questionnaires from 259 respondents.

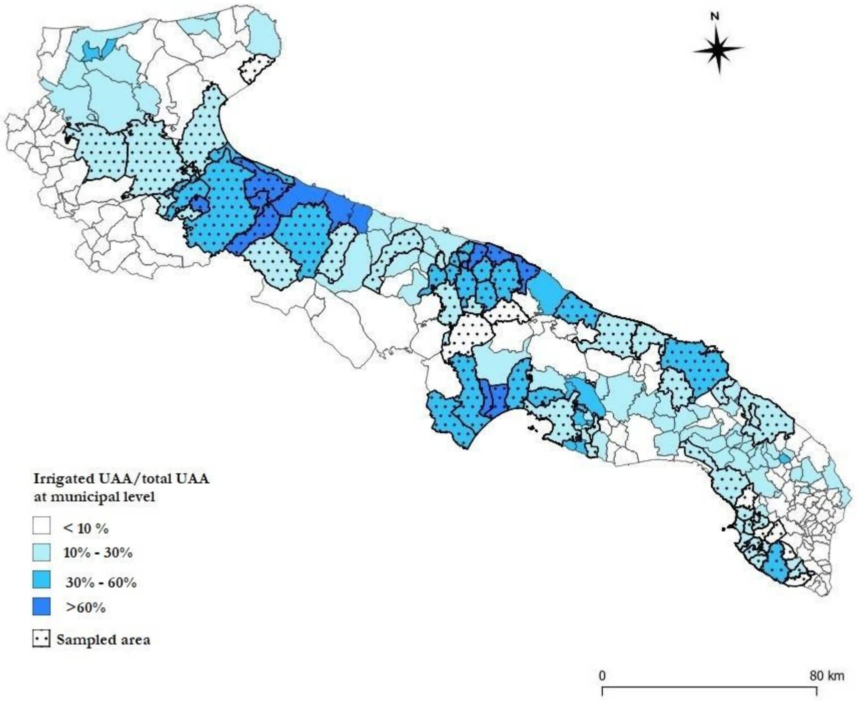

Fig. 2. Hot-spot irrigated area of sampling

The characteristics of the universe of irrigators in the targeted region (Puglia) and those of the sample are shown in Table 2.

Table 2. Sample representativeness

Structural features	**Sample**		**Apulia**[+]	
Farms [N.]	259		62,178[1]	
Volume supplied by collective services (%)	28		35	
Volume self-supplied (%)	72		65	
Annual irrigation volume [m^3/ha]*	2,026		2,4710	
Irrigated UAA (average) [ha]	18.94		3.84	
Irrigated UAA (median) [ha]	9.60		5.2	
Irrigated area per crop	**[ha]**	**%**	**[ha]**	**%**
Olive tree	1.262,45	25	81.737,33	34
Vineyard	1.323,54	27	63.088,32	26
Vegetables	1.139,77	23	46.925,35	20
Orchards	277,18	6	12.230,90	5
Criticus	365,17	7	7.948,54	3
Other crops	586,3	12	26.615,28	11
Total	**4.954,41**	100	**238.545,72**	**100**

Source: our elaboration from ISTAT census (2010)
[+] Farms with land size less than 0.99 ha are excluded
*191 respondents knew their on-farm irrigation volume

Although the sample size is small relative to the large number of irrigated farms in the region, the main features of irrigated agriculture are fairly fitted. Of the different features, the sample shows larger deviation in the extent of irrigated land, being more heavily weighted to large-sized farms, while irrigated area of olive tree is underweighted, given that this crop is more commonly cultivated by smallholders. Overall, however, the sample is a good representation of the Apulian patterns of irrigated crops, on-farm irrigation volume and irrigation services (i.e. self-supplied and collective).

2.4 Econometric modelling

The CE theory is based on the concepts of Lancaster (1966), according to which the farmer's utility deriving from a new payment scheme for saving irrigation water is the sum of the utilities related to the characteristics of the scheme. Furthermore, the Random Utility Theory underlying the stochastic utility models (Turnstone, 1927) states that farmers express their individual preferences in order to maximize utility under the income constraint. Therefore, the choice analysis requests the solution of a utility maximization problem concerning a set of alternatives. Considering an individual *n* who chooses the alternative able to ensure the greatest utility among the *J* possible alternatives at a choice opportunity *t*, the utility function is given by the following expression (Train, 2009):

$$U_{njt} = V_{njt} + e_{njt}, \quad n = 1, \dots, N;\ j = 1, \dots, J;\ t = 1, \dots, T \tag{1}$$

where V_{njt} is the deterministic component, while e_{njt} is the random component, specifically defined as an independent and identically Gumbel distributed (IID) component. Given a finite set of *J* alternatives, farmer *n* performs a series of pairwise comparisons between them, so as to identify the alternative that maximises their utility. In particular, the alternative *i* will be preferred to *j* if $U_{nit} > U_{njt}$, $\forall j \neq i$. Due to the stochastic nature of the utility function, the maximisation problem can be solved in probabilistic terms. Therefore, considering a set of *J* alternative, the probability that a farmer *n* chooses the alternative *i* is given by:

$$P_{nit} = Prob\ [(V_{nit} + \varepsilon_{nit}) > (V_{njt} + \varepsilon_{njt})] > 0, \quad \forall j \neq i,\ \forall J \tag{2}$$

whose estimation can be made using a discrete choice model (McFadden, 1986). Assuming a linear utility function in parameters for the deterministic component, the expression (1) can be reformulated as:

$$U_{njt} = \beta_n\ x_{njt} + \varepsilon_{njt}, \ \ n = 1, \dots, N; \ \ j = 1, \dots, J; \ \ t = 1, \dots, T \tag{3}$$

where $\boldsymbol{\beta}_n$ is a K × 1 vector of parameters to be estimated, concerns utility and corresponds to *K* choice characteristics; x_{njt}, instead, is the K × 1 vector of choice characteristics concerning the alternative *j* at the choice opportunity *t* carried out by the farmer *n*. Farmers may present similar attitudes in presence of different choice sets, leading to correlation phenomena, therefore to the violation of the assumption related to the independence of irrelevant alternatives (IIA). To relax this assumption, the expression (3) introduces a $\boldsymbol{\beta}_n$ vector of specific parameters for farmers, following a $g(\boldsymbol{\beta}|\boldsymbol{\theta})$ distribution whose vector $\boldsymbol{\theta}$ indicates mean and variance. This specification allows the formulation of the Random Parameter Logit Model (RPLM), able to capture the heterogeneity of unobserved factors that are common to groups of farmers and are able to influence choices (Mamine and Minviel, 2020). The probability that a subject *n* chooses the alternative *i* at the choice opportunity *t* is calculated as (Train, 2009):

$$P_{nit} = \int \frac{\exp(V_{nit})}{\sum_j \exp(V_{njt})} f(\beta)\, d(\beta) \tag{4}$$

where the distribution *f(·)* of the random parameters *β* is specified by researcher. In this regard, a normal distribution for the price variable (INCENTIVE) and a triangular distribution for the remaining attributes were used for the form of the density functions of parameters (Greene and Hensher, 2003). Final models were obtained using 1,000 Halton's draws (Halton, 1960). An alternative specific constant (ASC) was also included in the model, to capture preferences for the "no-choice" option. Finally, Willingness To Accept (WTA) was calculated as the ratio between each non-monetary attribute and the attribute relating to price, namely:

$$WTA_k = \frac{\beta_k}{\beta_I} \quad (5)$$

where WTA_k is the willingness to accept for the *k* attribute, β_k is the estimated coefficient for the *k* attribute and β_p is the estimated coefficient for the incentive attribute. The 95% confidence intervals were calculated using the method proposed by Krinsky and Robb (1986), and the WTA was estimated through the delta method.

3. Results

3.1 Sample statistics

Overall, the surveyed farms totalled 9,176 hectares of farmland, including 7,049 of irrigable land, of which 4,954 were irrigated in 2017 (accounting for 2% of total irrigated area of Apulia). On average, the farm size reported is 35 hectares, of which 18.94 were irrigated in 2017. Of the irrigated farms, 59% rely on self-supply services from groundwater (on-farm wells). The Total water volume for irrigation amounted to 6.414 million m^3, while average irrigation volume was 2,026 m^3/ha (Table 3).

The farmers of the sample are mostly male (80%), and their average age is 51 years. For 72% of respondents, farming is the main economic activity; for the remaining 28%, off-farm employment is more important.

Table 3. Main features of surveyed farms

Irrigation services	**Number of farms**	**Irrigable land** (ha)	**Irrigated land over last 3 years** (ha)	**Irrigation water use*** (Mm^3/year)	**Irrigation volume*** (m^3/ha)
Only Collective	72	1,200	936	1.88	2,114
Self-supplied and Collective	187	5,849	4,018	4.553	1,993
Total	*259*	*7,049*	*4,954*	*6.413*	*2,026*

*191 respondents knew their on-farm irrigation volume

Olive tree is the most frequent irrigated crop, followed by table grape and vegetables. A sizable number of farms also crop processing tomato under irrigation.

Half of the respondents expressed concerns over the status of the quality of water bodies and the quantity of water within the region of Apulia. Moreover, almost 60% expect increasing water shortages in the near future. Nevertheless, among those who have on-farm access to groundwater, only 42 out of 187 respondents recognised that their farms were already affected by salinity. The awareness of quantitative issues is higher, since 48% of groundwater users self-reported that they were already affected by well depletion. Almost 20% of farmers, largely those who rely on self-supplied irrigation groundwater, did not know how much irrigation water they use[2].

[2] For these respondents CE was conducted setting as SQ the standard irrigation requirements (m^3/ha/year)- as provided by local technicians- of most relevant on-farm irrigated crop.

3.2 Estimated model

When respondents appeared unwilling to participate at all in the AES, also known in CE as serial non-participation, protest answers were distinguished from legitimate zero bids by means of follow up questions to check farmers' motivations. In investigating willingness-to-accept (WTA) in relation to incentive-based schemes contexts, very few studies have provided coherent guidance on identifying protest responses, however the concern in such cases is mainly that of distinguishing protest behaviour from "very high taking" (Villanueva et al., 2017). At the close of CE section of the survey, therefore, serial non-participants were provided with close-ended answers for indication of possible motivations underlying their choices.

Of 69 serial non-participants, those providing legitimate zero bid answers included 38 respondents who "lack enough information", and 12 who "believe the incentives are much too low". Another three reasons, generally seen in literature for identification of protests and also considered as protest in the current CE, are: "Do not think such measures are a good solution" (14 respondents), "It's a problem of the state" (3 respondents), and 'Do not trust Regional government actions" (2 respondents). A total of 19 observations were excluded by the econometric regression, in line with other analyses in the literature (Villanueva et al., 2017; Alcon et al. 2019). It is worth mentioning that among those who claim that they have little information, 23 did not know their on-farm water use or cost for irrigation. In general, the farmers surveyed did not behave strategically in their responses.

Average values per attribute were calculated at each level, using the lowest level as baseline reference. In the model, the alternative-specific constant (ASC) takes the value zero when one alternative of AES is selected and 1 when the current status is selected.

Table 4 Reports the results of the random parameter logit model. All attributes are significant and the ASC is significant with negative sign, meaning that the "no-choice" option is less convenient for farmers. Random parameters in the utility function show no linearity. The size of *Incentive* has the highest relevance in the farmers' choice behaviour, followed by *Time*. Water savings effort (*Save*) receives the lowest score among the attributes tested. Overall, the environmental payment scheme is well accepted by the interviewees.

To capture the heterogeneity of unobserved factors common to groups of farmers and able to influence choices, a set of covariates was also tested. All significant variables introduced as covariates are reported in Table 5.

Some of the heterogeneity in farmers' choices is explained by covariates found to be significant in econometric regression. It is worth mentioning the salinity issue, in particular that respondents who acknowledge already experiencing detrimental effects from salinity were more likely to accept the environmental scheme. Variables such as *metering*, *mulching* and r*eservoir* are all related to farmers already with good accounting services for irrigation water, and the presence of all of these features makes it more likely that farmers will be willing to accept payment schemes aimed at saving on-farm irrigation water. In contrast, farmers whose crop pattern includes processing tomato or table grape are less likely to accept any incentive for reducing on-farm irrigation volumes.

Table 4. Estimates of RPML (without protesters).

CHOICE	Coefficient (SD)	Sign.	SE
Random parameters in utility function			
Save_10% (percentage of water saving)	*Baseline*		
Save_20% (percentage of water saving)	-0.17438 (1.97603)	***	0.04426
Save_30% (percentage of water saving)	-0.37855 (2.69560)	***	0.08194
Time_1_years (years of commitment)	*Baseline*		
Time_3_years (years of commitment)	-1.21032 (4.97761)	***	0.34880
Time_5_years (years of commitment)	-1.85503 (4.57330)	***	0.43040
Non-random parameters in utility functions			
Incentive (€/m^3)	4.81008	***	0.96394
ASC	-0.50382	***	0.12471
Heterogeneity in mean, Parameter:Variable			
Save_20%:Metering	1.65669	***	0.46739
Save_20%:Mulching	0.60265	***	0.17519
Save_20%:Education	0.52528	**	0.20405
Save_20%:Olive groves	1.56112	***	0.42887
Save_20%:Tomato/Table grapes	-0.91820	***	0.22019
Save_20%:Storage	1.68945	**	0.73423
Save_20%:Salinity	0.33031	***	0.12732
Save_20%:Collective network	0.70626	**	0.32397
Save_30%:Metering	1.19790	**	0.58618
Save_30%:Mulching	0.21042	***	0.04793
Save_30%:Education	0.25971	***	0.06625
Save_30%:Olive groves	1.57622	***	0.59982
Save_30%:Tomato/Table grapes	-0.10967	***	0.02662
Save_30%:Storage	3.56216	***	1.10484
Save_30%:Salinity	0.53141	***	0.20380
Save_30%:Collective network	0.33691	***	0.09851
Time_3_years:Metering	1.12603	**	0.51683
Time_3_years:Mulching	1.11816	*	0.67494
Time_3_years:Education	0.61473	***	0.21075
Time_3_years:Olive groves	0.36923	***	0.07660
Time_3_years:Tomato/Table grapes	-1.31962	***	0.35762
Time_3_years:Storage	1.45513	*	0.82900
Time_3_years:Salinity	0.44208	***	0.16576
Time_3_years:Collective network	0.58096	***	0.16228
Time_5_years:Metering	1.08901	**	0.46229
Time_5_years:Mulching	0.20397		0.45046
Time_5_years:Education	0.72795	***	0.20374
Time_5_years:Olive groves	0.30455	***	0.06358
Time_5_years:Tomato/Table grapes	-0.31228	***	0.09052
Time_5_years:Storage	1.91566	***	0.69394
Time_5_years:Salinity	0.56977	***	0.12698
Time_5_years:Collective network	0.41776	**	0.19341
Log likelihood function -998.33459			
Restricted log likelihood -1330.84259			
Chi squared [38 d.f.] 665.01598			
Significance level 0.00000			
McFadden Pseudo R-squared 0.2498477			
Estimation based on N = 960; K = 44			

*** Sign. 1%; ** Sign. 5%; * Sign. 10%.

Table 5. Main statistics of covariates.

Variable name	Description	Mean	Std. Dev.
Metering	1 if on-farm volumetric device is used for irrigation metering; 0 otherwise.	0.19	0.39
Mulching	1 if mulching technique is applied; 0 otherwise.	0.27	0.44
Education	1 none; 2 primary school; 3 middle school; 4 High school; 5 University degree.	3.75	0.85
Olive groves	1 if olive grove belongs to the on-farm crop pattern; 0 otherwise.	0.59	0.49
Tomato/Table grapes	1 if tomato or table grapes belongs to the on-farm crop pattern; 0 otherwise.	0.31	0.46
Reservoir	1 if farmer has built on-farm reservoir system; 0 otherwise.	0.07	0.25
Salinity	From 1 to 5, where 1 = salinity did not reduce yield or product quality; 5 = salinity reduced yield or product quality.	1.79	1.48
Collective service	1 if irrigation water comes only from collective services; 0 otherwise	0.28	0.45

Table 6 reports the average marginal WTA estimates at different levels of each attribute respective to baseline. WTA values range from 0.03625 to 0.07870 €/m^3 at 20 and 30 percent water savings, respectively. While *time* attribute reports higher monetary values ranging from 0.25162 to 0.38565 €/m^3 for three and five-year periods of commitment, respectively.

Table 6. Estimates of marginal Willingness-to-accept

Coefficient	€/m^3	Sign.	SE
Save_10%	*baseline*		
Save_20%	0.03625	***	0.00837
Save_30%	0.07870	***	0.01378
Time_1_years	*baseline*		
Time_3_years	0.25162	***	0.05156
Time_5_years	0.38565	***	0.09074

*** Sign. 1%; ** Sign. 5%; * Sign. 10%.

4. Discussion of results

Based on the CE findings, *incentive* is confirmed to be the most relevant attribute in the case of agri-environmental schemes aimed at achieving savings of irrigation water. Duration of commitment (i.e. *time*) emerges as an attribute equally as relevant as monetary compensation. This distinguishes the research results from those reported in Vergamini et al. (2020), which assumed the duration of the AES time window as a five-year period. As extensively reported in previous studies (Giannoccaro et al. 2015), the value of irrigation water in fact changes over time, depending on climatic conditions. The least relevant attribute relates to the extent of savings, or "savings effort" (i.e. *save*). Furthermore, in respect of the levels of choice, neither *Save* nor *Time* show linearity in marginal WTA values.

The survey data can serve as a basis for designing policy in more detail, by estimating potential water savings associated with the implementation of the proposed AES type. We assume that farmers will save on their annual water use according to the AES framework. The supply curve is estimated taking the product of each farmer's response (i.e. preferred savings effort, duration and incentive), multiplied by their current on-farm water use (m^3/ha). This gives the available average annual volume at any given price. The aggregated curve is drawn by summing the amounts that farmers are willing to save at each price. Figure 3 shows the savings in water supply.

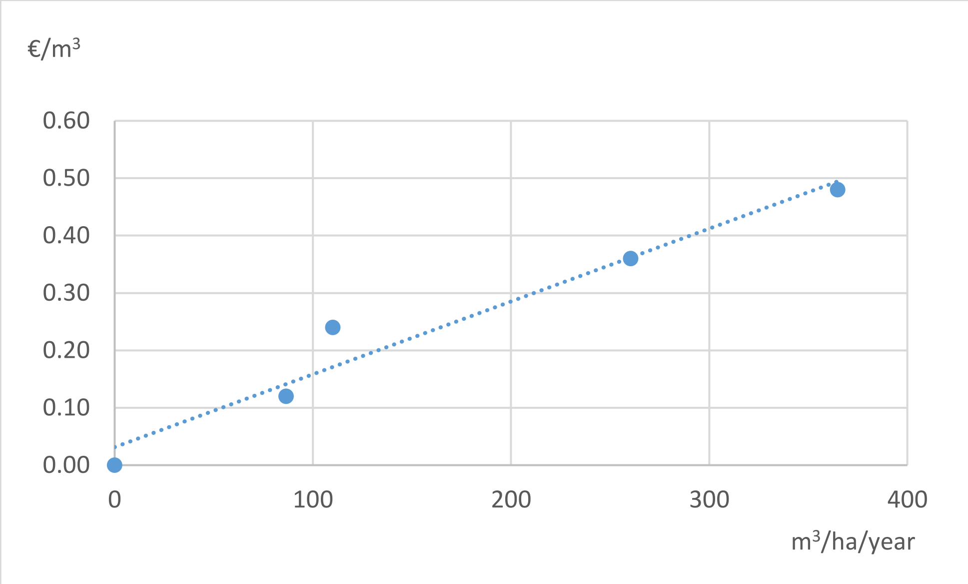

Fig. 3: Farmers' willingness to save water

Keeping in mind that for the sampled farms, average yearly water use is 2,026 m^3/ha, for savings of 300 m^3/ha (15% of current water use) farmers call for 0.40 €/m^3. Annually, this sums up 120 €/ha, while it does not take into account transaction costs of participation in such a scheme.

In general, the findings show that there is room for implementing the proposed type of economic incentives, perhaps within the upcoming EU 2023-2027 Rural Development Programme. However, based on the significance of covariates, the crop specializations of the farm are critical in determining the farmer's choice (Sardaro and La Sala, 2020). Farmers whose crops receive high added value from irrigation (e.g. table grape, processing tomato) are not willing to enrol in the proposed AES. While in irrigated olive tree (for oil), deficit irrigation (below crop-level requirements) is already largely practiced (Expósito and Berbel 2016), for processing tomato or table grape, only marginal reductions in season-by-season water allotments would be possible (Gatta et al. 2015). Also in this regard, the Pagliacci et al. (2020) reported very low adoption of an AES for 25% reduction of irrigation volumes on corn and tobacco crops, the most water -intensive crops of the Veneto region (north-eastern Italy). Targeting payments on the basis of crop profitability would therefore be advisable, as well as differentiated spatial payment in the manner proposed by Bartolini and Vergamini 2019. Other potential shortcomings concern the possibility of adverse selection in the case that the farmer withdraws less profitable resources, such as salt water, as already reported in the Australian market (Zuo et al. 2014). Indeed in the current research, those farmers who have already experienced groundwater salt intrusion report higher probability of adhering to the AES. A number of variables related to the opposite context, of good practices of on-farm irrigation management (i.e. mulching, on-farm water metering) are linked to higher willingness to uptake the proposed AES instrument. Furthermore, the presence of an on-farm reservoir also plays a key role in the farmer's decisions on irrigation management.

The proposed incentive-based instrument is shown to have potential for savings in irrigation water, with magnitudes of impact at the regional level, but can also have other advantages and beneficial effects. The payment scheme is not compulsory, which makes monitoring and control actions easier for the Regulator (Montginoul et al. 2016), but there is also the further beneficial effect of encouraging greater diffusion of on-farm volume metering. The proposed AES can also serve *in* gathering *in-situ* data on irrigation water volumes (Foster et al. 2020), and of course such schemes cannot be drawn on by unauthorised water users, meaning that the AES should also incentivise voluntary disclosure of farmers' water use.

The current research has been conducted on the scale of a large region with great variability in irrigation water services (collective and self-supplied), water sources (surface and groundwater), as well as on-farm irrigation use (current irrigation volumes). This also results in high standard deviation for coefficients of the attributes. Further research should be carried out in the context of single crop patterns and single types of irrigation service, thereby allowing identification of a specific SQ for all the relative respondents. Improvements could also be made in the sense of reducing alternative choices, making it easier for farmers' trade-off reasoning.

5. Conclusions

Crop irrigation uses vast amounts of freshwater, and therefore saving water for reallocation to other sectors (among others including the natural environment) has become an aim in policy agendas, worldwide. The importance of the issue becomes critically clear during periods of drought.

The current research conducts a pilot study eliciting responses to the design of a new agri-environmental payment scheme aimed at saving irrigation water, in a water-stressed region with Mediterranean climate. According to the findings, the farmers are willing to save water in response to the tested payment scheme. Importantly, however, the research shows that such schemes should be set up differently than has been the practice, in particular by allowing for flexible duration of commitment.

In seeking to comply with the Water Framework Directive (WFD) regulation, Italy faces critical challenges in accounting for water uses in agriculture. In 2015, the Italian Ministry for Agricultural Policy opened the way for accounting of usages of irrigation water (Guidelines for the Regional regulation of means of quantification of water volumes used in irrigation; Decree of 31 July 2015) but until now, such accounting has not been achieved, least of all in Puglia. In this regard, the proposed AES is not compulsory, which makes monitoring and control actions easier for the Regional Government. Indeed, volumetric metering is a prerequisite to entering in the payment scheme under the instrument. Moreover, the AES also provides economic incentive to farmers for voluntary disclosure and rectification of illegal access to groundwater.

In the proposed instrument, the incentives are constructed in the manner of an outcomes-based reward system, thereby ensuring true savings in volumes. Moreover, as with incentives based on market regulation, the instrument achieves useful data collection, such as on the monetary value of water saved by the farmers. On the other hand, a potential weakness is that the proposed instrument appears less effective in coping with intensive value-added water usage on crops such as processing tomato and table grape. There could also be potential adverse selection, in cases where water quality is already suffering, for example with higher salt content.

This economic instrument should not be seen as panacea for the problems in managing irrigation water usage. The aim here is to provide policy-makers with a broader range of instruments for application, in contexts of agricultural water management.

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