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KNOWLEDGE IN ACTION

Faculteit Bedrijfseconomische Wetenschappen

master handelsingenieur

Masterthesis

Evaluating farmers preferences for irrigation with treated municipal wastewater in the Apulia region, Italy: using a discrete choice experiment.

Stef Verlaak

Scriptie ingediend tot het behalen van de graad van master handelsingenieur, afstudeerrichting technologie in business

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This master thesis was written during the COVID-19 crisis in 2020-2021. This global health crisis might have had an impact on the (writing) process, the research activities, and the research results that are at the basis of this thesis.

Evaluating farmers' preferences for irrigation with treated municipal wastewater in the Apulia region, Italy: using a discrete choice experiment.

ABSTRACT

The Mediterranean region is characterized by frequent droughts leading to the depletion of existing natural water resources. The agricultural sector is one of the largest water consumers and highly depends on natural water resources for irrigating their lands and crops. The reuse of treated municipal wastewater for crop irrigation could mitigate water shortage and protect natural water sources. In water-scarce regions treated wastewater might be the only alternative for irrigation in the future. This paper uses a discrete choice experiment method to evaluate farmers' preferences to use treated municipal wastewater for irrigating their land. The sample consists of 120 farmers and the study area is a water-scarce region in Italy, namely the Apulia region. Four attributes were identified to describe the relevant characteristics for treated wastewater reuse: quantity, price, restrictions, and availability. The attributes' coefficients and willingness to pay for treated wastewater reuse as irrigation are estimated via a conditional logit. The results show that water price, water quantity, and restrictions significantly affect farmers' choices. A higher price and high restrictions are not preferred by the farmers, for an increase in the water quantity they are willing to pay more. Water availability does not affect the farmers' choices.

Keywords: discrete choice experiment – conditional logit – treated wastewater – agriculture – irrigation - Italy

SAMENVATTING

Het Middellandse-Zeegebied wordt gekenmerkt door frequente droogtes die leiden tot uitputting van bestaande natuurlijke watervoorraden. De landbouwsector is één van de grootste waterverbruikers en is sterk afhankelijk van natuurlijke watervoorraden voor irrigatie van hun land en gewassen. Het hergebruik van gezuiverd stedelijk afvalwater voor irrigatie van gewassen kan het watertekort verminderen en natuurlijke waterbronnen beschermen. In waterschaarse regio's is gezuiverd afvalwater in de toekomst misschien het enige alternatief voor irrigatie. Deze paper maakt gebruik van een discrete keuze-experimentmethode om de voorkeuren van boeren te evalueren om gezuiverd stedelijk afvalwater te gebruiken voor irrigatie van hun land. De steekproef bestaat uit 120 landbouwers en het studiegebied is een waterschaarse regio in Italië, namelijk de regio Apulië. Er werden vier attributen geïdentificeerd om de relevante karakteristieken voor het hergebruik van gezuiverd afvalwater te beschrijven: hoeveelheid, prijs, beperkingen en beschikbaarheid. De coëfficiënten van de attributen en de bereidheid om te betalen voor hergebruik van behandeld afvalwater als irrigatie worden geschat via een voorwaardelijke logistisch model. De resultaten tonen aan dat de waterprijs, de waterhoeveelheid en beperkingen een aanzienlijke invloed hebben op de keuzes van boeren. Een hogere prijs en zware beperkingen hebben niet de voorkeur van de boeren, voor een toename van de waterhoeveelheid zijn ze bereid om meer te betalen. De beschikbaarheid van water heeft geen invloed op de keuzes van de boeren.

1. INTRODUCTION

Climate change is expected to have an impact on water resources and agriculture (Falloon and Betts, 2010). Depending on the region, this may result in extreme climate events like floods due to more frequent and intense rainfalls or droughts due to a lack of water (Field et al., 2012). Drought is characterized by dry (precipitation deficit) and hot (warm temperatures) weather conditions (Mishra and Singh, 2010; Dai et al., 2018). The agricultural sector is the most affected by climate change threatening global food security since crops and livestock highly depend on rainfall and temperature (Cai et al., 2015). A visible consequence of drought is the decrease of surface water (Brown, 2017). The demand for groundwater will increase when surface water is scarce, which may lead to the depletion of the aquifer (Cai et al., 2015). Besides the effects on water quantity, also water quality for agriculture might be impacted by climate change, with increasing water salinization (Werner et al., 2013). Furthermore, several studies showed that drought, high temperatures, and declining water availability have a negative impact on crop yields (Lobell and Field, 2007; Kang et al., 2009; Roberts et al., 2013).

In most countries, most of the agricultural water withdrawal is represented by irrigation (Siebert et al., 2010). An increase in irrigation requirements is expected due to climate change (Döll, 2002). Yoshikawa et al. (2014) assessed irrigation on a global scale and showed that it is unexpected that existing water sources will be sufficient for irrigation in the future. Sources for irrigation water are groundwater, extracted from springs or by drilling wells (Manga, 2001), and surface water, withdrawn from rivers, lakes, wetlands, or oceans (Lewandowski et al., 2020). Besides surface water and groundwater, the reuse of wastewater is an alternative water supply source for irrigation in agriculture (Toze, 2006). The major types of wastewaters include domestic blackwater and greywater (Masi et al., 2010), industrial wastewater (Ranade and Bhandari, 2014), and stormwater runoff (Furlong et al., 2017). All can be reused, but require different types of treatments before reusing it.

The main benefits of utilizing treated wastewater for irrigation are the potential to decrease the pressure on freshwater sources and reduce the necessity for fertilizers due to the significant concentration of organic and inorganic nutrients in wastewater (Jaramillo et al., 2017; Meli et al., 2002). Wastewater has high supply reliability because its availability is relatively constant over time (Friedler, 2001). The main obstacle to reuse wastewater is the potential risk to health and the environment since it may contain hazardous substances (Garcia and Pargament, 2015). The European urban wastewater treatment directive 91/271/EEC regulates the adequate treatment of wastewater before discharging it in natural water bodies (European Union, 1991). Due to the presence of potentially toxic elements, treated wastewater requires additional treatment before using it for agricultural purpose (Pereira et al., 2002). An additional challenge for treated wastewater reuse for irrigation is keeping the cost low. By decentralizing the treatment, a reduction in storage and transportation costs could make the reuse of treated wastewater more economically viable (Angelakis and Snyder, 2015). However, public perception seems to be the main barrier for reusing treated wastewater scheme implementation (Wade Miller, 2006). Khanpae et al. (2020) showed that farmers are willing to adopt treated wastewater if they consider it profitable, non-polluting, suitable for consumption, and health risks can be avoided.

In Europe, water scarcity due to frequent droughts occur the most in the Mediterranean region (Lionello et al, 2006). Vautard et al. (2014) estimated that due to global warming precipitation is expected to decline in summer up to 20% in Southern Europe, this region presumably will encounter increased warming compared to the global average. Furthermore, it is expected that minimum streambeds in the region will be reduced by up to 40% and intensive water consumption via irrigation will aggravate streamflow drought conditions (Forzieri et al., 2014).

Fader et al. (2016) showed that due to climate change most crops in the Mediterranean countries require additional water per area. Therefore, irrigation will be of vital importance for the agricultural sector in this region and it is expected that the Mediterranean area will be confronted with a growing demand for irrigation water between 4 and 18% (Fader et al., 2016).

In Italy, several studies have been conducted to assess the use of treated wastewater for irrigation (Lopez and Vurro, 2008; Barbagallo et al., 2012; Barbagallo et al., 2001; Verlicchi et al., 2012; Verlicchi et al., 2018), which represents a promising path for saving good quality water resources for drinking, especially in Southern regions. The Apulia region (South of Italy) has the lowest average precipitation (appr. 600mm) and the smallest amount (136 m^3/capita/year) of available water sources within all Italian regions (Lopez et al. 2010).

Despite a large amount of locally available treated municipal wastewater (more than 100 million m^3/year), only 5 million m^3 are recovered yearly (Arborea et al. 2017); inadequate infrastructures for storage and distribution, restrictive legislation, and scarce information about the environmental impacts (Moretti et al., 2019) limit the use of treated municipal wastewater in agriculture.

Lonigro et al. (2015) compared the effects between irrigation via well water and treated wastewater on agriculture, the results showed that irrigation via the latter provided higher crop yields with lower use of fertilizers and environmental pollution.

Giannoccaro et al. (2019) evaluated the technical and economic feasibility of municipal wastewater reclamation for irrigation purposes in the region and found that economic viability constrains municipal wastewater reuse to about 60% of the technically feasible volume.

This is the first study to investigate farmers' willingness to use treated municipal wastewater as an alternative type of crop irrigation in the Apulia region. To achieve this objective, we conducted a discrete choice experiment (DCE) among farmers in the Apulia region and assessed the impact of water quantity, water price, legal restrictions, and water availability attributes on their choice to use treated municipal wastewater for irrigation through hypothetical scenarios.

The remainder of this paper is structured as follows. In section 2, we outline the research method, including the background on DCE, study design, and a description of the study area. We present the results and discussion in section 3. Finally, section 4 holds the conclusion.

2. METHOD

2.1 Discrete choice experiment and econometric model

Instead of observing individuals' behaviours, a stated preference (SP) method evaluates people's preferences in a hypothetical market (Lancsar and Louviere, 2008). Discrete choice experiments (DCEs) are SP techniques used to elicit and predict people's stated choice behaviour. Everyone is requested to make choices based on a series of choice sets (Louviere and Hensher, 1982). Those choice sets are a set of hypothetical alternatives consisting of a different combination of values for multiple attributes (Louviere and Woodworth, 1983). DCEs were initially introduced in marketing but have been used in other disciplines such as applied economics (i.e., especially transportation) and health (Lancsar and Louviere, 2008).
Adamowicz et al. (1994) were pioneers in using SP methods for the valuation of environmental amenities. In the past decades, the use of DCEs has expanded and has developed into a favoured SP method for environmental valuation and decision making (Hoyos, 2010).

In environmental economics, DCEs are typically designed containing two or more choice options and a non-designed status quo option (Louviere, 2006). To obtain more realistic results, an unforced option is added to avoid that respondents are forced to choose between alternatives that are not best resembling their preferences (Scarpa et al., 2006). Determann et al. (2019) describe the three types of unforced choices that are commonly used in DCEs: opt-out (i.e., the option not to buy the good/service), neither of the alternatives (i.e., the option to not choose any alternative) or status quo (i.e., the option to choose the current situation over the hypothetical alternatives). In this study, the status quo option was used as an unforced choice.

Discrete choice modelling is derived from two theoretical concepts. Lancaster's characteristics demand theory states that a consumer evaluates a good as a combination of characteristics and the total utility of the good is the summarization of all characteristics' values (Lancaster, 1966). Furthermore, Thurstone's law of comparative judgment introduces the concept of random utility (Thurstone, 1927), which has been further developed by McFadden into the conditional logit (CL) model (McFadden, 1973). This model is the workhorse in discrete choice models, and it is considered good practice to estimate this model first before continuing with more advanced models, which is outside the scope of this paper.

In a random utility model, the utility (U_{ij}) represents an individual *i* choosing alternative j. Individual *i* decides in favour of alternative j when he expects to derive the highest utility from this alternative compared to any other available alternative. This latent utility is partitioned into two separate components, the deterministic (or observable) part (V_{ij}) and a random unobserved and stochastic error component (ε_{ij}) as shown in equation (1):

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

The observable component V_{ij} is replaced by a linear and additive product of the set of characteristics for alternative j presented to individual i (X_{ij}) in choice set t (which for brevity is omitted) and the coefficients representing the marginal utilities that the average individual gets for changes in an alternative's attributes (β_j). In addition, the utility specification for the hypothetical alternatives may include an alternative specific constant (ASC), as reflected in equation (2). This constant captures the effect of all the attributes missing in the design. The attributes can be coded via dummy coding or effects coding. The benefit of effects coding is that the base level of a variable has no confoundment with ASC and represents a value with a unique utility (Hensher et al., 2015):

$$U_{ij} = \text{ASC} + X_{ij}\beta_j + \varepsilon_{ij} \quad (2)$$

Several econometric models can be applied to estimate the discrete choice model, we chose the conditional logit (CL) model developed by McFadden (1973). McFadden showed that the derivation of the CL model while assuming the error terms to be independent and identically distributed (IID) over the alternatives with an extreme value type-I (Gumbel) distribution, results in the closed-form expression for P_{ij} as shown in equation (3). P_{ij} represents the probability that alternative *j* maximizes the utility for individual *i*, i.e., alternative *j* has the highest utility among all alternatives within the choice set for individual *i*.

$$P_{ij} = \frac{e^{X_{ij}\beta_j}}{\sum_{n=1}^{J} e^{X_{ij}\beta_j}} \quad (3)$$

Train (2009) describes that the coefficients (β) in the CL model are estimated using a log-likelihood (LL) function as shown in equation (4), where $y_{ij} = 1$ if individual *i* chooses alternative *j* and zero otherwise.

$$LL(\beta) = \sum_{n=1}^{N} \sum_j y_{ij} \, ln \, P_{ij} = \sum_{n=1}^{N} \sum_j y_{ij} \, ln \frac{e^{X_{ij}\beta_j}}{\sum_{n=1}^{J} e^{X_{ij}\beta_j}} \quad (4)$$

Hoyos (2010) describes that when the attribute price is included, the willingness-to-pay (WTP) can be estimated. This is the maximum price that an individual is willing to pay for a service or good. As presented in equation (5), the marginal WTP can be calculated by dividing the coefficient value of an individual attribute (β_j) by the coefficient value of the price attribute (β_{price}). This value is multiplied by -2 if the attribute has two levels and -1 if the attribute has more than two levels when effects coding is used (Hu et al., 2004).

$$WTP = -I \, x \left(\frac{\beta_j}{\beta_{price}}\right), \; I = \begin{cases} 1 \text{ for more than two levels} \\ 2 \text{ for two-level attributes} \end{cases} \quad (5)$$

2.2 Study design

2.2.1 Identification of attributes and their levels

As a primary step in the design of the choice experiment, the applicable attributes, and their corresponding levels for the valuated good or service were identified. The good in this study is the use of treated municipal wastewater for irrigation in the agricultural sector. Four attributes were identified to describe the relevant characteristics for treated wastewater reuse: quantity, price, restrictions, and availability (Table 1). The first three attributes and their corresponding levels were identified based on literature (Saldías et al., 2016; Saldías et al., 2017; Ndunda and Mungatana, 2013). The attribute availability is introduced in this study for the first time. A group of ten farmers was asked to rank the alternatives and to indicate whether higher or lower levels are more preferred.

The attribute "treated wastewater quantity" referred to the increased amount of water available for irrigation compared to the current water availability (in m^3). Three levels were proposed to complement the current water availability: 20%, 35%, and 50%.

The "treated wastewater price" attribute referred to the higher market price per m^3 of treated wastewater reused for irrigation purposes. Since this water price reflects the additional costs for wastewater treatments, it is assumed to be higher for treated wastewater compared to freshwater, the conventional irrigation water sources in the case study area. Three levels were suggested: 10%, 20%, and 30% increase in water price.

The attribute "restrictions" referred to the restrictions put in place to maintain human health and food safety when using treated wastewater for irrigation. They concern about the crop type, irrigation technology, and irrigation management. The attribute "restrictions" is coded like Saldías et al. (2017). The levels range for the condition where very strict to low restrictions are in place:

- "High" refers to a condition where raw consumption of irrigated crops is not allowed; irrigation methods are periodically inspected, and the water usage is carefully monitored (including longer periods between irrigation and harvesting and avoiding direct contact between water and crops).
- "Moderate" implies that irrigated crops that will not be consumed raw (including fruits) are allowed, those irrigation methods are occasionally inspected, and frequent observation of the water usage is enforced.
- "Low" implies no restrictions on crop consumption, no restrictions on irrigation methods, and frequent observation of water usage.

Finally, the attribute "treated wastewater availability" referred to the potential limitations in treated municipal wastewater availability following the high demand for irrigation water in the case study area, especially during the summer season. Again, three levels were identified for this attribute according to different priorities in the water distribution scheme: treated wastewater available according to the irrigated surface (priority is given to farmers with the highest amount of irrigated land), treated wastewater available according to a bargained distribution scheme and treated wastewater available at any time.

In addition to the levels mentioned above, the respondents were offered the opportunity to choose for the status quo (SQ), representing the current status of the attributes (i.e., respectively the current water quantity, the current average water price, the current legal restrictions to be complied within the country/region and the amount of available water according to the current distribution scheme.

Table 1. Attributes and corresponding levels.

Attributes	**Levels**
Treated wastewater quantity	+20%, +35%, +50% vs. status quo (SQ)
Treated wastewater price	+10%, +20%, +30% vs. SQ
Restrictions	High, Moderate, Low vs. SQ
Treated wastewater availability	Irrigated surface, bargained scheme, at any time vs. SQ

2.2.2 Experimental design

As a next step, the set-up of an experimental design is required and allows to model combinations of the attributes' levels into different scenarios that can be presented to the respondents. This experiment has four attributes with three levels each, giving a total of 81 different scenarios that can be combined. Presenting all hypothetical DCE scenarios (i.e., the full factorial design) to the respondents is often not feasible, therefore it is advisable to create a reduced choice sample via an experimental design method (Rockers et al., 2012). The statistical efficiency of the design is measured in terms of D-efficiency, guaranteeing to minimize the variation for estimated parameters by reducing the estimation of the standard errors (Kuhfeld, 2007). The benefit of Bayesian D-efficient (or DB-efficient) designs is that the uncertainty about the true parameters has been acknowledged by specifying a prior preference distribution (Traets et al., 2020). Therefore, a DB-efficient fractional factorial design was used to create the experimental design in this study taking the advantage of the information about ranking and wide distributions to reflect uncertainty about the true values.

Via the SAS-based software JMP 24 scenarios were generated for the experimental design and were split into four versions of six choice sets. Each choice set contains two scenario options and the status quo as an unforced choice.

2.2.3 Questionnaire

Besides the six hypothetical choice sets, the survey included another 28 questions with a socio-demographic and agricultural background, distributed among five sections: (A) Your farm, (B) Your experience with water availability, (C) Your main sources of irrigation water, (D) Environmental issues and (E) Your willingness to adopt alternative water sources.

The survey was first pilot-tested with some native speakers because it was translated from English into Italian before distribution. Afterwards, the questionnaire was conducted in 2019 amongst randomly selected farmers identified among participants to technical conferences and meetings organized by advisory services and trade associations operating in the Apulia region, Italy. There was a random assignment of the participants to one of the four choice set versions and towards minimizing the order effect the different choice sets were presented in a random order (Kjær et al., 2006). To obtain a higher quality of responses and reduce the amount of missing data, researchers at the Department of Agricultural and Environmental Science of the University of Bari (Apulia region, Italy) supported filling out the questionnaire together with the farmers. They explained the objective of the research and the meaning of the attributes and levels in the DCE. Furthermore, they provided additional information and clarification on the other questions.

For the elicitation of preferences in this study "subjective probability elicitation" was used. Here respondents are asked to state (subjective) probabilities of selection across mutually exclusive alternatives in an experimental choice set, rather than indicating only the preferred one (Scarpa et al., 2020). An example of a choice set is shown in figure 1.
For further data analysis in this study, the collected choice probabilities for the different alternatives have been simplified into a stated choice between the alternatives.[1]

The following guidance was provided to the respondents on how to deal with the DCE questions:

> *"Below, you will be shown* ***6 hypothetical choice situations*** *(i.e., question 1 to 6) in which you are asked to* ***indicate the probability of selecting each alternative*** *(i.e., option A, option B, or the status quo) based on the attributes (e.g., treated wastewater quantity) and levels (e.g., 20% increase in available water) given in that situation. The probabilities must* ***sum to 1, the highest probabilities indicate you are more likely of choosing that alternative****. All* ***attributes not included*** *in the table can be* ***considered identical*** *and should therefore not influence the likelihood of selecting an attribute. Selecting the* ***status quo*** *means that you do* ***not wish to purchase treated urban wastewater****. This implies that the volume of irrigation water you can use stays the same as in the previous irrigation season, its cost stays the same, and you remain exempt from the restrictions and distribution system put in place for those that do wish to use treated urban wastewater. In* ***each situation*** *the attribute levels will be different from the previous, forcing you to make* ***new trade-offs****. Therefore, please do not consider the answers given in the previous situation in the next situation. Each situation should be considered* ***independently****."*

[1] For some cases there was a tie in the answers (e.g., both options A and SQ were assigned a probability of 50%), in a randomized way one of both alternatives was chosen.

Suppose the following alternatives are available **NOW**, please read **all** the features of **each** option and then **indicate with what probability you would select that alternative**.

Attribute	Option A	Option B	
Treated wastewater quantity	Increased water available during the irrigation season relative to your current situation 20%	Increased water available during the irrigation season relative to your current situation 35%	Status quo
Treated wastewater price	Increase in water price relative to your current situation 10%	Increase in water price relative to your current situation 10%	
Restrictions	• irrigation of crops which are not eaten raw allowed • sporadic inspections on the irrigation technique • regular monitoring of water use Moderate	• no restriction on crops • no restriction of irrigation methods • regular monitoring of water use Low	
Treated wastewater availability	Treated wastewater is distributed according to: At any time	Treated wastewater is distributed according to: Irrigated surface (Priority is given to farmers with the highest amount)	

	Option A	Option B	Status quo

Figure 1. Example choice set.

2.3 Study area

In this paper, we focus on Italy as a study area, more specifically the Apulia (Italian: Puglia) region, an area in the southeast of Italy bordering the Adriatic and Ionian Sea (Figure 2). The region comprises 19,540.49 km² of land and had a population of 4,008,296 residents at the end of 2019 (UrbiStat, 2019). The region is currently divided in 6 provinces: Bari, Barletta-Andria-Trani, Brindisi, Foggia, Lecce, and Taranto. The Apulia region is characterized by a Mediterranean climate with hot, dry summers and mild wet winters (Seager et al., 2019).

Figure 2. Study area: the Apulia region in Southern Italy (Biscotti et al., 2018).

As shown in figure 3a, the Apulia region has the lowest average precipitation (appr. 600mm) and the smallest amount (136 m^3/capita/year) of available water sources within all Italian regions. Despite the water scarcity, figure 3b shows that around 80% of the land is used for agriculture (Lopez and Vurro, 2008; Marini et al., 2019).

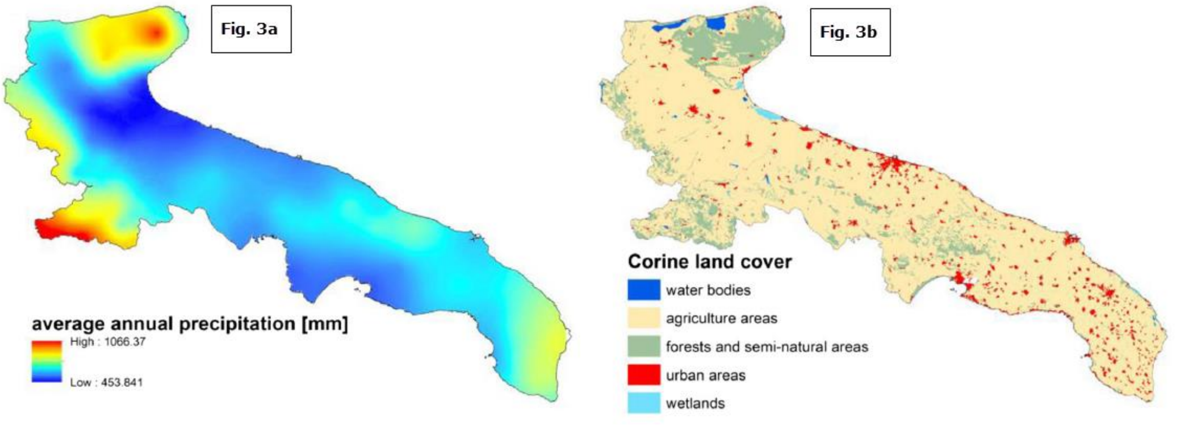

Figure 3a. Average annual precipitation distribution for the Apulia region between 1960 and 2012 (Marini et al.,2019). **Figure 3b.** Corine land cover map for the Apulia region (Marini et al.,2019).

The main cultivated crops: permanent crops such as olive and grape, fresh-cut vegetables, and processing tomatoes account for around 80% of the irrigated land which spread over around 87,500 small farms (< 5 hectares) in the region (Arborea et al., 2017).

Despite a large amount of locally available treated municipal wastewater (more than 100 million m3/year), only 5 million m^3 are recovered yearly.

Improving the treatment of urban wastewater could increase the available irrigation water in the region by 60 million m^3/year, which represents around 10% of the water demand for irrigation (Arborea et al., 2017). However, inadequate infrastructures for distribution and storage, restrictive legislation, and scarce public acceptance are constraining the reuse of treated municipal wastewater in agriculture (Moretti et al., 2019). Additionally, the region is threatened by the potential exploitation of aquifers. Indeed, groundwater represents two-thirds of irrigation water, exploited almost everywhere by many public and private small users and the lack of effective monitoring and control systems foster an unrestrained extraction of groundwater by farmers to compensate for the lack of irrigation water during the dry seasons (Arborea et al., 2017).

3. RESULTS AND DISCUSSION

3.1 The sample and the choice shares

In total 120 respondents (out of 130) submitted the completed questionnaires. With six choice sets each and three options per choice set, this results in 2,160 observations for statistical analysis. First, we describe the agricultural and socio-demographic characteristics of the sample, this is also summarized in table 2. Most respondents are agricultural managers (50%), followed by full-time farmers (22.5%), part-time farmers (17.5%), and others (6.67%). On average the amount of land that is currently used for farming among all respondents is 21.7 ha (min. 1ha; max. 120ha). Approximately 12.5 ha (58%) of this cultivated land was irrigated during the last irrigation season, whereas 12.5% of the farmers indicated that they do not use any irrigation for their land.

Seven different types of crops were produced on the farms during the last season, namely: cereals (e.g., wheat, spelt), vegetables, fruit trees (e.g., olive, almond, citrus), energy crops (e.g., sunflowers, rapeseed), fodder crop (i.e., annual, or perennial grasses), roots-plants (e.g., potatoes, sugar beet) and ornamental plants.

Most of the farms (71%) apply monocultural production systems, whereas 29% of farms produce two or more crops in the same season. Fruit trees are the most grown crops (87.5% of the farms in the sample) followed by cereals (28.3%), fodder crop (10%), vegetables (8.3%), energy crop (3.3%), roots-plants (3.3%) and ornamental plants (less than 1%).

All crops in the sample are irrigated using conventional water. It is observed that fruit trees and vegetables are irrigated the most, accounting for 98% and 70% of overall crops in the sample, respectively. All other crops are barely (cereals 5.9%) or not at all (energy crops, fodder crops, roots-plants, and ornamental plants) irrigated.

For irrigated crops, the average yield was 18,978 kg/ha whereas the respondents' best estimate for the average yield on the same land but without irrigation was 7,402 kg/ha.

The fertilization plans used for the crops can be summarized into four categories: organic (35.3%), chemical (41.8%), a combination of organic/chemical (1.8%), and none (21.1%)

The main water source for irrigation amongst farmers in the Apulia region is groundwater (83.3%). Whereas surface water is used by 5% of the sampled farms. None of the respondents is currently using treated wastewater as their main source of irrigation water. The 58% of the farmers that irrigate with groundwater extract the water via a privately owned well. On average 2,413 m³ of groundwater was used for irrigation during the last season at an average cost of around 0.46 €/m³. When asked about their willingness to irrigate land with treated wastewater, 36.7% of the farmers responded that they would irrigate all their land, 31.7% would consider irrigating their land partially, 2.5% none of the land, and 29.1% was indecisive.

The monthly net household income after taxes is categorized as follows: 22.5% of the respondents earn less than €1,000 per month; 59.2% between €1,001 and €2,000 per month; 15.8% between €2,001 and €3,000 per month; 1.67% more than €3,000 and 1 person (0.83%) did not respond to the question.

Furthermore, the farmers were asked to share their experiences with water availability. We received the following responses: on average the irrigation season lasts 4-5 months; 65% of the respondents felt that there was a frequent to very frequent lack of water during the last irrigation season; 53.3%

of the respondents felt that there was a long to very long period with a lack of water during the last irrigation season; 92.5% agrees or strongly agrees that water availability for irrigation is getting worse over time; 90.8% agrees or strongly agrees that a lack of water for irrigation is becoming a serious risk for their farming activities.

In addition, the respondents gave their opinion about environmental issues, 90% to 95% of them answered that it is important to reduce water pollution, improve water availability for agriculture, combat climate change (including desertification, water, and soil salinization), and safeguard natural freshwater ecosystems.

Table 2. Descriptive statistics of the sample.

Characteristics	**Value**	**Sample (n=120)**	
Current work situation	Full-time	22.5%	
	Part-time	17.5%	
	Agricultural manager	50%	
	Others	6.67%	
	Question not answered	3.33%	
Land (average)	Cultivated	21.7 ha (min. 1ha; max. 120ha)	
	Irrigated	12.5 ha (=58% of the average cultivated land)	
	No irrigation used	12.5%	
Crops (produced* | irrigated)	Cereals	34/120 (28.3%)	2/34 (5,9%)
	Vegetables	10/120 (8.3%)	7/10 (70%)
	Fruit trees	105/120 (87.5%)	103/105 (98%)
	Energy crops	4/120 (3.3%)	0/4 (0%)
	Fodder crop	12/120 (10%)	0/12 (0%)
	Roots-plants	4/120 (3.3%)	0/4 (0%)
	Ornamental plants	1/120 (0.8%)	0/1 (0%)
Yield irrigated crops (average)	With irrigation	18,978 kg/ha	
	Without irrigation**	7,402 kg/ha	
Fertilizers	Organic	35.3%	
	Chemical	41.8%	
	Organic/chemical	1.8%	
	None	21.1%	
Water source for irrigation	Surface water	5%	
	Groundwater	83.3% (58% via a private well)	
	Treated wastewater	0%	
	Others	2.5%	
	Question not answered	9.2%	

Characteristics	Value	Sample (n=120)
Farmers' willingness to irrigate land with treated wastewater	100% of the land	36.7%
	25%-60% of the land	31.7%
	None	2.5%
	Question not answered	29.1%
Groundwater use for irrigation	Average amount	2,413 m^3
	Average cost	0.46 €/m^3
Monthly net household income after taxes	< €1,000 per month	22.5%
	€1,001 - €2,000 per month	59.2%
	€2,001 - €3,000 per month	15.8%
	> €3,000 per month	1.67%
	Question not answered	0.83%

*29% of the farms produce multiple crops; **best estimate from the respondents.

A first analysis of the choice sets revealed that 19.2% of the respondents chose the status quo for all six choice sets. On the other hand, 35.8% of the respondents did not select the status quo in any of them. Overall, the status quo option was chosen for 40.8% of the choice questions. Status quo bias was investigated by Samuelson and Zeckhauser (1988), this cognitive bias associates every change from the current baseline (or status quo) as a loss. One additional question was added after the DCE questions to follow up on the respondents' reason for selecting consistently the status quo alternative and identifying possible protest motives. The protestors were those who agreed with the statement: "I do not trust the water management authority". Based on this it was identified that 4.2% were protest responses and the other 15% genuine reasons (or true zero values) to stay with the current situation. The number of protest responses was too low to find a link between those farmers. Excluding those five protesters brought the final sample on 115 respondents. After evaluating both statistical models with and without protesters it turned out that the exclusion had no significant impact on the results, nevertheless we continued our further analysis with the reduced sample.

3.2 The model results and their interpretation

As explained in section 2.1, the conditional logit (CL) model from McFadden is used to estimate the model for 2,070 choices elicited from 115 farmers. The explanatory variables used in the model are ASC, quantity, price, restriction, and availability. The quantitative attributes (i.e., treated wastewater quantity and price) were coded based on their respective levels. Effects coding was used for the qualitative attributes (i.e., restrictions and treated wastewater availability). This coding method allows non-linear effects in the attributes' levels but dispenses with the disadvantages of dummy coding, namely the perfect confounded base attribute level with the grand mean of the utility function (Hensher et al., 2015). The base level in effects coding receives a value of minus one, in this study we used the levels low restriction and availability at any time as the base levels. Additionally, the alternative specific constant (ASC) was added to estimate the change in utility associated with choosing the status quo option (Holmes and Adamowicz, 2003). The level for the status quo is represented by zeros for every attribute.

An ASC with a negative coefficient indicates that the status quo option gives less utility to the respondents compared to the hypothetical alternatives.
The attributes price (p = .001) and quantity (p < .001) are found to affect farmers' choices statistically significantly. A high negative value for the price is derived, this indicates that the farmers are unlikely to pay more for using treated wastewater for irrigation. The positive value for the quantity attribute indicates that the average respondent prefers higher quantities of available treated wastewater.
The levels high (p < .001) and moderate (p = .036) for attribute restriction are significant as well, but the coefficients are lower compared to price and quantity, indicating that the participants assign lower utility to the restrictions. There is only a small difference in the farmers' perception of low and medium restrictions. The high restriction has a negative sign, so it is disliked compared to low/medium restriction attributes.
The attribute availability (existing of levels: irrigated surface, bargained scheme, at any time) is not statistically significant and seems to have no relevance in the choice of using treated wastewater for the farmers in this study. Table 3 shows the detailed results of the conditional logit model.

Table 3. Conditional logit estimation results.

Attributes	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
Constant (ASC)	-0.734	0.246	-2.98	0.003	-1.217	-0.251
Quantity	2.840	0.545	5.21	0.000	1.772	3.909
Price	-2.579	0.786	-3.28	0.001	-4.119	-1.038
Restriction1	-0.465	0.091	-5.11	0.000	-0.644	-0.287
Restriction2	0.161	0.077	2.10	0.036	0.011	0.312
Availability1	0.121	0.100	1.20	0.228	-0.076	0.317
Availability2	0.006	0.101	0.06	0.953	-0.191	0.203

Model statistics	
Log-likelihood	-721.986
Observations	2,070
LR chi² (7)	72.11
Prob > chi²	0.000
Pseudo R²	0.048

3.3 WTP estimates

Table 4 shows the WTP estimates, which are calculated based on the estimated coefficients shown in table 3. The WTP value for quantity suggests that farmers are willing to pay €1.101 per m³ of treated wastewater to have more water available compared to the current water quantity.
The effects coded attributes show the WTP for changing from the excluded base level to their respective level (Genius et al., 2012). If using treated wastewater implies higher restrictions, the farmers would expect a compensation of €0.180 per m³. Moderate restrictions have a positive WTP of €0.063 per m³ for treated wastewater. As mentioned above the attribute availability is not significant, so WTP values neither.

Table 4. Willingness to pay (WTP) estimates in €/m³ of water.

	Quantity	Restriction1	Restriction2	Availability1	Availability2
WTP	1.101	-0.180	0.063	0.047	0.002
ll*	0.356	-0.302	-0.006	-0.034	-0.075
ul**	1.847	-0.059	0.132	0.127	0.079

*lower limit; **upper limit.

3.4 Discussion

Arborea et al. (2017) observed that olives and grapes are the most widespread crops in the Apulia region, this is in line with our findings shown in section 3.1 (both crops are classified as fruit trees in our study and representing 87.5% of the produced crops). They estimated that vegetables, grapes, and olives account for 80% of the irrigated land in the region, compared to 98% for fruit trees and 70% for vegetables in our study. Furthermore, the authors found that 66% of the farmers in the Apulia region extracted their irrigation water from groundwater and that half of them have on-farm wells. We have similar results for the use of privately owned on-farm wells (58%), but a higher number of farmers using groundwater for irrigation (83.3%). Most farmers taking part in our study come from the provinces of Bari, Barletta-Andria-Trani, and Taranto that cover the highest share of irrigated land in the region, this could explain the differences in results.

Lanz and Provins (2015) identified that selecting the status quo is not unusual in DCE's, in their study 14% of the respondents chose the status quo for all choice sets and overall the status quo option was selected for 60% of the choice questions (compared to 19.2% and 40.8% in our study). In addition, they state that a statistically significant and positive sign for the ASC can be interpreted as status quo bias. Since our ASC is negative and the amount of protest responses is low, there is no status quo bias in our study.

Table 5 shows the studies used to compare our results with. All studies investigated farmers' preferences for irrigation with treated wastewater via a discrete choice experiment. Different valuation methods were used for analysis, i.e., conditional logit (CL), latent class (LC), or random parameter logit (RPL). To compare the WTP results it is important that effects coding was also used since dummy and effects coding lead to different coefficient estimates and therefore different values for the WTP (Hasan-Basri and Karim, 2013).

A significant and negative water price attribute suggests that the farmers' preference for alternative water sources decreases when the price increases. Having access to water via private wells on their land and extracting groundwater at a low cost could be a reason that they do not want to pay extra for wastewater treatment.

High restrictions, which include severe restrictions on crops, periodically inspected irrigation methods, and carefully monitored water usage are not preferred by the farmers. They might expect that wastewater is properly treated and has a good quality before using it on their land and therefore should not lead to higher restrictions. Moderate restrictions have a small positive value, which can be explained that most of the farmers in our study grow fruit trees, and the consumption of those crops after irrigation with wastewater is allowed under moderate restrictions. Due to this reason, there is barely a difference between low and moderate restrictions for the farmers in our sample.

As a first comparison we review the results of the studies eliciting farmers' preferences for irrigation with wastewater in Cape Town, South Africa (Saldías et al., 2016) and Hyderabad, India (Saldías et al., 2017). Analyzing their data via a CL and LC model they observed a negative preference for an increase in water price and high restrictions, which is in line with our findings.

In addition, the water quantity attribute was also evaluated in the study in Hyderabad. In contrast to our findings, water quantity was not significant in their study, but this could be explained that in this part of India water is not scarce but rather more polluted, whereas water scarcity is more common in the Apulia region. Treated wastewater quantity is also an attribute in the study that evaluated the welfare effects of improved wastewater treatment in Nairobi, Kenya (Ndunda and Mungatana, 2013), they analysed the results via a CL and RPL. Their results show a positive WTP for increasing the quantity of treated wastewater. We found the same indication that farmers from the Apulia region are willing to pay for treated wastewater if the available water quantity increases. This can be linked to the responses on the farmers their experiences with water availability that we described in section 3.1: 92.5% agrees or strongly agrees that water availability for irrigation is getting worse over time; 90.8% agrees or strongly agrees that a lack of water for irrigation is becoming a serious risk for their farming activities.

Another study in Cyprus, in the Mediterranean as well, assessed the economic viability of treated wastewater to replenish a depleting aquifer that is used by farmers for irrigating their land (Birol et al., 2010). Via a CL the attributes water quantity and price were estimated and with a significant positive coefficient for quantity and a negative coefficient for the price, the results are in line with our findings. Their WTP for water quantity was CYP 0.028 per m^3 (€0.05/m^3), which is less compared to the €1.101 per m^3 that we calculated. A possible reason for this difference could be that the study in Cyprus took place 10 years before ours and drought periods have increased in the meantime. Furthermore, higher water availability or a lower income for the farmers in Cyprus could explain the difference, but those comparable figures are not available for the Cyprus study.

To the best of our knowledge The attribute "treated wastewater availability" is introduced in this study for the first time and not used yet in any comparative study. The attribute is nonsignificant and indicating that the respondents were indifferent towards the availability scheme (availability via irrigated surface, bargained scheme, or at any time) for irrigation with treated wastewater. Possibly the farmers in the Apulia region do not see any potential limitations in treated municipal wastewater availability while they expect there will be sufficient treated wastewater compared to the natural water sources. This is only an assumption and a further follow-up with the farmers is suggested to better understand their indifference to this attribute.

Water quality was often chosen as an attribute in the comparative studies and statistically significant. The current irrigation water in those study areas was more polluted compared to the Apulia region, so that could explain the choice.

Based on our findings and the results from comparative studies it would be a suggestion to add water quality instead of water availability as an attribute for future studies. Additionally, it is advisable to add more socio-demographic characteristics like household size, age, education, or gender in addition to the monthly income. This could be valuable for estimating a model with interactions.

Table 5. Comparative studies.

Reference	**Study area**	**Wastewater reuse**	**Population**	**Valuation Method**
Ndunda and Mungatana (2013)	Nairobi, Kenya	Irrigation agriculture	Farmers	DCE (CL* & RPL**)
Saldías et al. (2016)	Cape Town, South Africa	Irrigation agriculture	Farmers	DCE (CL* & LC***)
Saldías et al. (2017)	Hyderabad, India	Irrigation agriculture	Farmers	DCE (CL* & LC***)
Birol et al. (2010)	Cyprus	Replenish aquifer (for irrigation agriculture)	Farmers	DCE (CL*)

**CL=Conditional Logit; **RPL=Random parameter Logit; ***LC=Latent Class.

The CL model is also estimated with interactions between ASC and three other variables that have been described in table 2. The main effects are comprehensively described in section 3.2 and the results of the interactions model are limited reported below, while most of those results are either nonsignificant or too many observations got dropped. The first variable is related to the question "What is your current work situation?". For this interaction, the number of observations dropped to 1,998 and only the work situation "other" (representing 144 observations) is significant (Coef. 2.217; 95% CI = 0.992, 3.442; $p < .001$). It indicates that those farmers (i.e., mainly students and professors) are willing to irrigate their land with wastewater, but the sample is too small to draw further conclusions. Furthermore, there was an interaction with the variable "How much land would you be willing to irrigate with treated urban wastewater?". This resulted in a higher pseudo-R^2

(0.124), but the fit is still on the low side. Only 1,530 observations are left and besides the answer “100% of the land” (Coef. 0.803; 95% CI = 0.003, 1.603; p = .049), all other levels are nonsignificant. The last interaction included the question "In which category is your monthly net household income after tax?" and contains 2,052 observations, but all levels of income are nonsignificant. This preliminary evidence for observed heterogeneity could be the basis for further research in gaining more insights into preference heterogeneity across the farmers.

Christiadi and Cushing (2007) explain that a limitation of the CL model is the independence from irrelevant alternatives (IIA) assumption. It implies that when individuals choose between two alternatives, the probability ratio will not depend on the attributes or availability of the other alternatives. The mixed logit models (e.g., the random parameter logit (RPL)) fully relax the IIA assumption, those models allow parameter estimates to vary across individuals.
As a further research step, it could be interesting to run a mixed logit model and compare it with the results of the CL model. Furthermore, the subjective probability choices from the original design could be used instead of the simplification of stated choices for further analysis.

4. CONCLUSION

Water scarcity due to droughts is a challenge and affecting the water demanding agricultural sector. In many regions, natural water resources are the main source of crop irrigation. The reuse of treated municipal wastewater could be a promising alternative to deal with water shortage and protect natural water sources. This is the first study to investigate farmers' willingness to use treated municipal wastewater as an alternative type of irrigation in the Apulia region, Italy. The sample consists of 120 farmers and the research method is a discrete choice experiment, which is a good method for eliciting preferences. Although currently none of the interviewed farmers in the Apulia region is using treated wastewater as their prime irrigation water resource, the majority is not reluctant to use it in the future.

Four attributes, with three levels each, describe the relevant characteristics for treated wastewater reuse: "treated wastewater quantity" (+20%, +35%, +50%), "treated wastewater price" (+10%, +20%, +30%), "restrictions" (high, moderate, low), "treated wastewater availability" (irrigated surface, bargained scheme, at any time). The results in this paper show that the farmers in the Apulia region are not willing to pay a higher price for irrigating their crops with treated wastewater unless they obtain higher water quantities in return. If irrigation with treated wastewater would cause high restrictions on the human consumption of certain crops, the farmers expect a lower price for the treated wastewater compared to the current water price. Treated wastewater availability has no relevance in the choice of using treated wastewater for the farmers in this study.

It needs to be taken into consideration that this study only evaluates farmers' preferences for the use of treated wastewater. To obtain more precise numbers for policymakers, a full cost-benefit analysis for wastewater treatment programs should be conducted in addition. The results of such a study can be used to motivate the future introduction of wastewater treatment projects.

In other parts of Europe, with more moderate climates, water is less scarce compared to the Mediterranean. Nevertheless, we also face in Flanders (Belgium) more often long and intense periods of drought, depleting the aquifer and impacting agriculture. The reuse of treated wastewater in agriculture and other areas could conserve good quality water resources for different practices that require high-quality water (Thoeye et al., 2005). Mesa-Perez and Bethel (2020) showed that in Flanders the amount of treated wastewater is exceeding the need for water for agricultural purposes. Recently an experiment has been set up by VUB (University), Aquafin (water treatment plants), and Boerennatuur (agricultural organization) to use treated wastewater as a source for irrigation in Flanders (Agropolis, 2021). A similar study as ours could be an added value to evaluate the farmers in Flanders their willingness to use and pay for treated wastewater in agriculture. Based on the gathered experiences in this study, the attributes price, quantity, and restrictions seem useful, the attribute water availability could be changed by water quality. Additionally, it is advisable to add more socio-demographic characteristics for estimating a model with interactions. Furthermore, a mixed logit model could be estimated in addition to the conditional logit.

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