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An Analysis of Farmers’ Propensity to Use Reclaimed Wastewater in Agriculture

Antonella Tassinari and Adele Coppola *

Department of Agricultural, Forestry, Food and Environmental Sciences (DAFE), University of Basilicata, 85100 Potenza, Italy; antonella.tassinari@unibas.it
* Correspondence: adele.coppola@unibas.it

Abstract

In the Mediterranean Basin, increasing water scarcity, exacerbated by climate change, necessitates the use of alternative water resources in agriculture. This study analyses farmers’ propensity to use reclaimed wastewater for irrigation in Basilicata, a region in southern Italy. Through a survey of 167 farms and the application of a logit model, this work quantifies the role of the main factors influencing farmers’ propensity to use this new resource. The results identify several key drivers and barriers. A higher level of education and participation in Producers’ Organisations make wastewater use approximately ten times (odds ratio equal to 9.84) and five times (odds ratio equal 4.96) more likely, respectively. Furthermore, an adequate knowledge of the relevant legislation nearly quadruples (odds ratio equal to 3.57) the likelihood of adoption. In contrast, concerns related to worker health and groundwater pollution are strong deterrents, reducing the odds of adoption by 90% and 87%, respectively. Concerns about product quality also significantly decrease the propensity to adopt (odds ratio equal to 0.25). The findings underscore the need for integrated interventions that enhance farmers’ awareness and knowledge of the characteristics and impacts of new practices, thereby fostering the innovative and sustainable management of water resources.

Keywords: wastewater irrigation; propensity to use; risk perception; logit model

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1. Introduction

Water scarcity is impacting many geographical areas, especially the Mediterranean Basin. In this area, climate change, characterised by prolonged drought, reduced annual rainfall, and heatwaves, is expected to intensify in the coming years compared to the global average. These changes could have significant consequences for water and food availability, as well as the well-being of the population [1]. In Europe, the estimated economic losses due to droughts amount to around EUR 9 billion/year, with Italy accounting for EUR 1.4 billion [2,3]. The growth of the world’s population and the resulting rise in food demand suggest that irrigated areas are expected to expand considerably, leading to increased agricultural water requirements and a higher pressure on natural resources [1] for many autumn–winter and spring crops, when water needs are not fully met, putting additional pressure on natural water reserves and raising costs for farmers [1,4]. To effectively address droughts and water scarcity, it is crucial to adopt a proactive approach and implement specific measures, as purely emergency interventions are technically and economically ineffective. The use of reclaimed wastewater is an economically, politically, and environmentally beneficial solution, as it meets agricultural water demand and reduces the pressure on natural water resources [4,5]. This approach aligns with the principles of the circular economy, focusing on reduction, reuse, and recycling, thereby facilitating an effective transition from waste to resource [6]. Using wastewater for irrigation, properly treated and controlled to ensure microbiological and physicochemical quality, is already a common practice in some areas facing water shortages and provides benefits for both the water supply and the recovery and utilisation of the nutrients within it [7]. The European Union has established minimum water quality requirements for the reuse of reclaimed urban wastewater in agriculture through Regulation (EU) 2020/741, aiming to facilitate and economically encourage this practice while also ensuring public health and environmental protection.

In recent years, in Italy, some regions have permitted the recycling and reuse of urban wastewater for agricultural purposes; however, this practice is still not widespread, and wastewater reuse for irrigation is mainly at the stage of experimental projects and demonstration pilots [4,8]. Despite the considerable advantages, there are still barriers to its acceptance and related investments. These include a lack of specific regional regulations, insufficient incentives for implementation, health and production quality issues, and deficiencies in infrastructure [4]. Furthermore, farmers' willingness to adopt these practices is influenced by their perceptions of the risks associated with the product quality, market difficulties, and the potential health effects for both producers and consumers [4,9–12]. Risk perceptions can vary considerably among individuals and, along with environmental concerns [12,13] and the availability of clear and sufficient information [4,10], can significantly influence the likelihood of using reclaimed wastewater for irrigation. Understanding how and to what extent these factors influence farmers' behaviour is a crucial topic.

This study aims to examine the likelihood of farmers using reclaimed wastewater for irrigation through a field survey conducted on a sample of irrigated farms in Basilicata. It primarily addresses the following research questions: (1) Are farmers inclined to use wastewater for irrigation? (2) What socio-demographic, economic, and motivational factors influence their propensity? (3) How can we act on these factors to enhance the use of reclaimed wastewater in irrigation?

Basilicata is an interesting study area because it is a southern Italian region heavily impacted by climate-related emergencies and drought, where a specific regulatory framework for wastewater use and an appropriate risk management plan are still lacking. In this context, there is no institutionalised large-scale reuse network for irrigation, making it crucial to analyse the factors that can either promote or hinder the use of this resource at the farm level. This analysis can help to build an effective intervention framework aimed at encouraging wastewater reuse at the regional level. More generally, the results of this empirical analysis can help address the existing knowledge gap concerning the role of driving factors and barriers acting on the farms' willingness to adapt to changing contexts, which is vital for agricultural competitiveness [14].

After a reviewing of the factors influencing the adoption of innovative agricultural practices (Section 2), Sections 3 and 4 describe the methodology used in this study and the results obtained. Finally, Section 5 presents the discussion and concluding remarks.

2. Factors Affecting the Adoption and Diffusion of Innovations in Agriculture

Building on the Theory of Reasoned Action by Ajzen and Fishbein (1975) [15], the Technology Acceptance Model by Davis (1985) [16], and Rogers' Innovation Diffusion Theory (1995) [17], the literature on innovation has explored several factors influencing the adoption and diffusion of innovations. They include socio-demographic, economic, and structural characteristics, as well as information, knowledge, attitudes, and risk perception. Their effect has been analysed to predict different innovative behaviours.

Wastewater reuse for irrigation represents a genuine eco-innovation in terms of its process, as the effects related to its technical aspects, such as treatment, transport, and distribution operations, are still under investigation, and there is a lack of comprehensive understanding regarding the benefits and hazards associated with this practice. In this context, the propensity of farmers to adopt reclaimed wastewater for irrigation can be analysed in the light of innovation adoption models. A literature review on the factors affecting innovative choices can help identify the specific drivers related to adopting reclaimed wastewater for irrigation.

2.1. The Socio-Demographic Factors

Research indicates that a farmer's age, experience, education, and gender are the main socio-demographic characteristics influencing the adoption of innovations.

Even if there are conflicting views on its contribution to the propensity to innovate, several studies have shown that age inversely affects innovation adoption, with younger farmers being more inclined to promote and implement agricultural innovations [18,19]. This may be due to their longer planning horizons and lower risk perceptions compared to older farmers. Conversely, some scholars relate age directly to experience and skills gained over time, identifying a favourable and significant association with innovation adoption [20,21]. Indeed, while more experienced farmers are often more likely to adopt innovations due to the considerable knowledge they accumulate over the years [22–24], on the other hand, a greater agricultural experience may also correlate with well-established management techniques, making the transition to new farm organisations and production processes more complex [25].

Education is another significant factor in the decision to innovate [26]. A low level of education is often identified as a barrier to adopting innovations [27]. In the agricultural sector, more educated farmers tend to have a higher ability to understand the pros and cons of innovative investments [20,25,28]. According to this view, education facilitates the acquisition of information and skills from multiple sources, enables a rapid association between benefits and new practices and technologies, and significantly reduces the associated risk perception [26,29].

The impact of gender on the propensity to adopt innovations is another topic of discussion due to its controversial effects. Different effects stem from the contexts in which innovations are proposed and the types of innovations [30,31]. In the agricultural sector of less developed countries, many women in farm management roles display a significantly higher propensity to adopt technical and management innovations, despite the fact that they sometimes have limited skills compared to men [32]. In more developed contexts, such positive attitudes of women toward innovation can be attributed to a strong propensity for inter-firm collaboration [30] and greater concern about unsustainable practices, including their long-term effects [33].

2.2. Economic and Structural Factors

Farm income and size are key determinants for adopting innovations [26,31]. These factors are directly and indirectly related to the investments required to introduce an innovation.

Innovative practices and techniques often imply high operational costs, especially in the initial stages of implementation, so that only the most productive farms can bear the related economic burden [21,34,35]. Additionally, higher income levels allow firms to face prolonged periods of economic recovery associated with innovative investments [36]. Therefore, innovative farms are frequently characterised by higher incomes, which, in turn, are also linked to larger farm sizes [21]. A different view emerges in other studies, which have found that farm income negatively affects innovation adoption, primarily due to the associated high risk perception [37].

Similarly, farm size plays a crucial role in the acceptance and adoption of innovation [26,38]. Some scholars argue that larger farms have more economic resources to invest, can reorganise more effectively, and are better equipped for addressing existing problems and implementing the solutions that innovations entail [19,25,29]. From this perspective, small farms would have fewer economic resources, face more significant difficulties in accessing credit, and require more incentives to implement innovations [25,39]. The role of size is not exclusively related to income level. Some studies have highlighted how smaller farms can implement technical and management innovations more rapidly, as they are more flexible and can consequently adjust their activities more easily to remain competitive in the market [40–42]. On the other hand, larger farms can face greater difficulties in implementing innovations. These difficulties stem from the need to extend cultivation practices, technical inputs, and process changes across the entire farm, which can be complex and costly [43].

Another relevant issue for innovation adoption is the relationship between on-farm and off-farm income. Indeed, farmers with an additional income from off-farm sources are more likely to adopt innovative practices and technologies, as the greater financial security reduces their risk aversion [44]. Besides the implications in terms of income, off-farm work can enhance the flow of information and knowledge, which are crucial in the diffusion of innovation.

2.3. The Role of Information and Knowledge Factors

Information and knowledge play a crucial role in determining whether an innovation will be adopted. Rogers' Theory of Innovation Diffusion [17] highlights the importance of information flow and communication channels in facilitating the spread of new practices and processes. Rogers also focuses on how different interpersonal relationships and networks act in the transmission of knowledge within a social system.

Empirical studies have examined how information and knowledge affect innovation adoption by considering either the level of knowledge or the "change agents" [17] who are effective in communicating information.

In agriculture, the level of knowledge is often measured by the degree of education and vocational training, which were found to be positively correlated with the adoption of new technologies [45,46]. Chuang et al. (2020) [47] showed that the availability of well-structured training courses can encourage farmers to adopt new technologies, while low adoption rates were linked to inadequate information, resulting in a lack of innovation-specific knowledge.

In addition to in-house knowledge and expertise, the flow of information from outside the company is relevant in the process of disseminating innovations [17,48–50]. In this sense, collaboration, networks, and interactions with extension agents help improve knowledge and skills about a specific innovation, contributing to an increased likelihood of its adoption [28,29,33,51–53]. Therefore, communication and information sharing are essential for improving farmers' overall knowledge, which is crucial for informed decision-making.

2.4. The Risk Perception

Recent studies have examined the role of psychological and attitudinal factors influencing the adoption of innovations, including the perception of risks associated with these innovations. Perceived risks are often related to uncertainty and a lack of confidence in the new [54]. The extent of the perceived risk associated with a specific innovation may depend on factors such as access to information, strength of knowledge, and experience in the field [55–57]. The presence of accurate information and a deeper knowledge of the pros and cons of an innovation translate into a higher acceptance level. The understanding of the benefits associated with an innovation results in lower perceived risks or a greater tolerance towards them [58].

Perceptions of risk will differ based on the type of risk, individual attitudes, and the social context [59].

In agriculture, the perception of risks related to new products, processes, and production techniques has been studied with reference to financial, environmental, and health risks [5,60]. The significant upfront costs associated with acquiring new technologies often generate concerns about whether farmers will recoup their investment, which can deter farmers from implementation [60]. Deh-Haghi et al. (2020) [5] showed how farmers' perceptions of health risks are hindering factors in the adoption of innovations. The fear of contamination and disease associated with the use of reclaimed wastewater for irrigation generates negative perceptions of this resource, limiting the adoption of such techniques [61–63].

Risk perception is also related to the individual's attitude toward risk. The more risk-averse a farmer is, the more likely he will stick with traditional production systems and will limit complex innovations, characterised by high maintenance costs and unpredictable market demands [64], thus resulting in a delayed adoption of innovations [65].

2.5. Factors Affecting the Diffusion of Reclaimed Wastewater for Irrigation

The review of the main factors influencing the adoption of innovations can help as a basis for selecting the aspects for analysing which factors can affect the willingness to use reclaimed wastewater for irrigation.

Socio-demographic characteristics, such as age, experience, and education level, can be highly relevant in significantly influencing the propensity to use a new resource. However, the controversial findings resulting from many empirical studies suggest that the interactions among these factors require careful consideration. On the contrary, the farmer's gender appears to play a limited and indirect role in a developed context, as it mainly acts through participation in networks and social relationships.

Based on previous studies, the farm's income and size are less relevant factors when a new practice does not require significant investments. This is true for adopting reclaimed wastewater for irrigation, as its use does not necessitate substantial changes in equipment or extensive financial commitments. Therefore, the size should not specifically affect the introduction of this new practice.

Instead, more crucial is the role of information, knowledge, and risk perception. The literature highlights that an adequate, continuous, and up-to-date flow of information, supported by collaborative networks—both between peers and with experts in the field—is essential for raising awareness and fostering a willingness to adopt innovations. In the case of treated wastewater, the fragmented and limited availability of information represents a significant obstacle. Clear and reliable information could significantly contribute to reducing perceptual barriers and enhancing confidence in this resource. Additionally, reclaimed wastewater is still a relatively unknown resource, whose effects and benefits are not immediately evident. Consequently, the perception of the potential risks associated with its use can greatly influence the willingness to accept and adopt this innovation. This underlines the need to conduct specific empirical research on this aspect.

3. Data and Methods

3.1. The Study Area

The present study was conducted in Basilicata, one of the regions in southern Italy highly affected by climatic alterations and frequent drought phenomena. According to rainfall data for the last decade from the Ministry of Agriculture, Food Sovereignty and Forestry (MASAF), the average rainfall in Basilicata is around 650 millimetres per year, mainly concentrated in the autumn and winter months. However, due to climatic anomalies and exceptional weather events, these data appear unstable and vary considerably from one period to another and from one area to another. Basilicata is a region with a strong agricultural vocation and boasts a wide range of irrigated crops. According to the 2020 Census by the National Institute of Statistics (ISTAT), there are 8842 irrigated farms in the region. The most productive areas in the region are in the Matera province, where there are 22,800 irrigated hectares, accounting for 76% of the regional irrigated area. This study focused on farms located in this province (Figure 1). These areas are the region's main arid and semi-arid areas and are more sensitive to water scarcity challenges.

Figure 1. The study area.

3.2. The Sample

A field survey was conducted to gather primary data and information on farmers' propensity to use reclaimed wastewater for crop irrigation and the factors that may influence its use. A questionnaire was administered to 167 farmers through face-to-face interviews. Participation in the survey was voluntary and driven by the farmers' strong interest in the subject among farmers. The survey took place from April to August 2024. Therefore, the analysis is based on a convenience and non-probability sample. This represents a limitation of the work, as the self-selection of participants may introduce bias into the survey results, and these results cannot be generalised to all irrigated farms in the study area. Nevertheless, the work provides helpful insights into farmers' propensity to utilise unconventional water and rethink traditional irrigation management practices to ensure environmental sustainability and agricultural productivity.

The questionnaire was divided into four sections. The first section collected farmers' socio-demographic information, including age, experience in the sector, level of education, agricultural training, and both on-farm and off-farm income. The second section gathered data on farm characteristics, including production yields and the destination of outputs, with a dedicated subsection focused on irrigation, water use, and consumption. The third section contained questions for identifying farmers' primary sources of information and their level of knowledge of wastewater and current regulations. Specific questions were asked to assess the propensity and willingness of farmers to use reclaimed wastewater on their farms. The final section explored motivational aspects, such as farmers' perceived advantages and disadvantages that might influence their willingness to use wastewater, as well as their risk perceptions regarding potential hazards to human health, the environment, production quality, and product marketing.

The sample accounts for a total Utilised Agricultural Area (UAA) of 6765.7 hectares, and 5472.7 hectares of irrigated land (81% of UAA and 24% of the province's total irrigated land). Fruit (35% of UAA) and horticultural crops (17.8% of UAA) are prevalent, followed by intensive crops such as kiwi (7.6%) and strawberry (6%). Most farmers simultaneously cultivate multiple crops, trying to limit monoculture and apply diversification strategies. For 87% of the interviewed farmers, farm activity is the primary source of income, and 43.7% of the respondents reported annual incomes exceeding EUR 50,000, while 31.7% of farmers have incomes between the EUR 28,000 and EUR 50,000 range.

Moreover, 90% of the respondents use the drip irrigation systems to ensure optimal and efficient water delivery, thereby minimising waste and runoff losses. Additionally, 32% of the sample confirmed using advisory services for irrigation systems. Water mainly comes from the Irrigation Consortium, with about 86% of farmers relying on this source. However, around 83% of the respondents stated that they have encountered several utilisation issues, including water scarcity and distribution inefficiencies. Most farms (72.5%) monitor their irrigation water consumption using metres. On average, water consumption accounts for 3870 m^3, varying according to the crops. Horticultural crops, strawberries, and kiwis have the highest seasonal water requirements (around 4250 m^3 per hectare on average), followed by fruit crops (3778 m^3). Tables 1 and 2 summarise the main characteristics of the sample.

Table 1. Main characteristics of the sample (descriptive statistics).

Variable	Mean	Standard Deviation
Age (years)	52.3	17.3
Experience in the sector (years)	23.0	16.3
Utilised Agricultural Area (UAA)	40.5	43.0
Irrigated UAA	32.7	34.2
Total Agricultural Area	46.8	48.8
Water cost (EUR/mc)	0.70	0.07
Water consumption (mc)	3870.0	1256.5

Table 2. Main characteristics of the sample (frequencies).

Variable	% of the Sample
Education level	
Higher education (upper secondary and tertiary education level)	57
Lower education (primary and middle school)	43
Agricultural education (specific training in agriculture)	
Yes	44
No	56
Income class	
Up to EUR 28.000	24.6
EUR 28.000–EUR 50.000	31.7
EUR 50.000 and more	43.7

Table 2. *Cont.*

Variable	% of the Sample
Irrigation system	
Microirrigation	90
Other systems	10
Origin of water	
Irrigation Consortium	86
Other source	14
Use of consulting services	
Yes	32
No	68
Participation in Producers' Organisations	
Yes	50
No	50

3.3. Methods

The empirical analysis was divided into two steps.

In the first phase, we performed an exploratory and descriptive analysis to examine the relationship between farmers' propensity to use wastewater for irrigation and various socio-demographic, economic, and motivational factors. We utilised both parametric and nonparametric statistical tests, depending on the types of variables, to obtain information on data distribution and identify which variables might have some relationship with the propensity to use wastewater.

In the second step, a logit model was used to estimate how selected independent variables influence the likelihood of using reclaimed wastewater.

In the binary logit model, the dependent variable y can take only two values (0 or 1), with the conditioned probability of y given by the following (Greene, 1997) [66]:

$$Prob(y = 1|x) = \Lambda(\beta' x)$$

where Λ is the logistic cumulative distribution function; x is the vector of explanatory factors; and β is a vector of coefficients associated with the explanatory factors.

The marginal effects of the changes in the explanatory variables on the probability of y are estimated by the following:

$$\frac{\partial Prob(y = 1|x)}{\partial x} = \frac{e^{\beta' x}}{1 + e^{\beta' x}}$$

In our model, the dependent variable y = 1 if the farmer stated a propensity to use reclaimed wastewater for irrigation; y = 0 otherwise, and the vectors of the independent variables include the following:

(1) Farm size, in terms of Utilised Agricultural Area (continuous variable: hectares);
(2) Education level: 0 = primary or middle school level of education; 1 = upper secondary level or tertiary education level;
(3) Knowledge of legislation on wastewater: 0 = no knowledge; 1 = some level of knowledge;
(4) Use of irrigation consulting service: 0 = no use of consulting service; 1 = use of consulting service;
(5) Participation in Producers' Organisations (0 = NO; 1 = YES);
(6) Perception of the possible risks associated with wastewater use, such as the following:
    - Worsening product quality (0 = NO; 1 = YES);
    - Danger to farmers' health (0 = NO; 1 = YES);
    - Risk of groundwater pollution (0 = NO; 1 = YES).

The selection of independent variables to include in the model was based on a preliminary analysis of the correlations between them to prevent potential multicollinearity issues. As socio-demographic characteristics are concerned, the main problem relates to age, experience, and educational level: age and experience often overlap, and younger farmers are frequently more educated. The correlation index and mean tests have confirmed that Pearson's correlation between age and experience is equal to 0.913, and the Mann–Whitney U tests on age and experience in years by education levels (test statistics equal to 416.5 and 532.5, respectively; Sig. < 0.001) demonstrate the strong relationship between these variables. Consequently, among these factors, only the education level was included in the logit model. Indeed, the education level is conceptually more relevant when investigating innovation adoption because it means a greater ability to apply new practices and adapt new knowledge and information to specific contexts. A high correlation also characterises some economic and structural factors. The Kruskall–Wallis test proved that the distribution of the farm size significantly differs across income classes (test statistics equal to 50.621; Sig. < 0.001), with a direct link. Therefore, we included in the logit model only the Utilised Agricultural Area, which is a continuous and more reliable variable.

We performed several tests on the logit model to check for multicollinearity among the independent variables, assess the goodness-of-fit of the model, and evaluate its discrimination ability. Multicollinearity can lead to unstable coefficients and standard errors, making multicollinearity tests crucial for the model validity. The Variance Inflation Factor (VIF) measures how much the variance of a regression coefficient increases due to the correlation among the predictor variables in the model. Higher VIF values (typically above 5) indicate a problematic collinearity among predictors. The VIF can be calculated for each predictor, while the average VIF provides an overall indication of multicollinearity across all predictors in the regression model. To evaluate the goodness-of-fit of the model, common tests such as the likelihood ratio test (LRT) and the Hosmer–Lemeshow Test were applied. The LRT compares a fitted model against a null model that includes only the intercept, evaluating whether the predictors collectively improve the model fit significantly. The Hosmer–Lemeshow Test compares the observed and expected frequencies using a chi-square statistic, and a non-significant p-value (e.g., >0.05) indicates an acceptable fit. Finally, the AUC, the area under the Receiver Operating Characteristic (ROC) curve, can be used to quantify the overall model discrimination ability on a scale from 0.5 (random guessing) to 1.0 (perfect classification).

4. Results

4.1. Farm's and Farmer's Characteristics and Propensity to Use Reclaimed Wastewater

Most farmers (60.5% of the sample) state that they favour using reclaimed wastewater to irrigate crops. The propensity to use alternative water sources is related to their more extensive availability than conventional water (for 65% of the farmers who favour using reclaimed wastewater), the possibility of reducing fertilisers due to the possible presence of organic residues in the recycled water (for about 48.5%), and the lack of other water sources (for about 42.6%). About 70% of the farmers believe that adopting this resource requires adapting traditional irrigation systems, and 64% think that using wastewater for irrigation can be dangerous. They think wastewater irrigation can be dangerous due to the possibility of accumulating undesirable substances in the production (63% of the sub-sample) and the deterioration of product quality (44%). Additionally, approximately 30% believe that using this water source may harm natural habitats and contribute to groundwater contamination. Therefore, most farmers are favourable to using wastewater for irrigation, but they are still concerned about the risks this resource may entail. Water scarcity issues appear to be prevailing in shaping their attitudes.

The relationship between specific farms' and farmers' characteristics and the propensity to use wastewater for irrigation was verified through parametric tests, the t-test and chi-square, according to the continuous/categorical variables. Tables 3 and 4 show the main results.

Table 3. Analysis of mean differences by wastewater use propensity group: results of t-tests.

Variable	*t*-Test	Sig.
Age (years)	11.001	<0.001
Experience in the sector (years)	10.803	<0.001
Utilised Agricultural Area (UAA)	−0.690	0.246
Irrigated UAA	−1.399	0.082
Water consumption (mc)	−0.330	0.371

Table 4. Analysis of the relationship between main discrete factors and wastewater use propensity: results of chi-square tests.

Variable	χ^2	Sig.	Cramer's V	Sig.
Knowledge of legislation (no/yes)	42.655	<0.001	0.505	<0.001
Income class (up to EUR 28,000/EUR 28,000–50,000/more than EUR 50,000)	8.746	0.013	0.229	0.013
Education level (higher/lower level)	77.502	<0.001	0.681	<0.001
Agricultural training (no/yes)	37.603	<0.001	0.475	<0.001
Use of consulting services (no/yes)	23.550	<0.001	0.376	<0.001
Participation in Producers' Organisations (no/yes)	20.200	<0.001	0.348	<0.001
Product quality concern (no/yes)	24.077	<0.001	−0.380	<0.001
Groundwater pollution concern (no/yes)	17.336	<0.001	−0.322	<0.001
Workers' health concern (no/yes)	38.507	<0.001	−0.480	<0.001

No significant differences exist in the propensity for using wastewater in relation to the farm's size, the irrigated area, and the seasonal water consumption. This highlights how structural aspects do not play a relevant role when new practices or processes do not really imply financial commitments and burdensome changes.

On the contrary, the propensity differs significantly according to the age and experience of the farmers. Pearson's chi-square (χ^2) and Cramer's V tests revealed a statistically significant association between education level and the propensity to use wastewater. Farmers with higher levels of education and agricultural vocational training are more likely to use wastewater for irrigation, provided it is permitted by regional regulations (Table 4). These results confirm the importance of formal education as a factor promoting the adoption of innovation, consistent with what is highlighted in the literature [20,58].

Moreover, the propensity to use wastewater was found to be significantly associated with participation in the Producers' Organisation, the use of irrigation advisory services, and the knowledge of current regulations on wastewater use. This aligns with studies focusing on knowledge and information as primary factors for the diffusion of innovations [17] and the action of specialised organisations and agents to encourage individuals to adopt new practices and technologies [29,49,52].

Further aspects refer to farmers' perceived concerns and issues regarding the quality of products irrigated with wastewater, the health of workers directly involved in using this water source, and the environmental impacts on the farm agroecosystem. Concerns about the deterioration of product quality resulting from wastewater use and the perception of environmental and health risks were found to be significantly (and inversely) associated with the propensity to use this resource.

4.2. Factors Affecting the Propensity to Use Wastewater

The logit model estimates the impacts of selected variables on the propensity to use wastewater for irrigation. The Variance Inflation Factors are lower than 2 for all the variables (Table 5) and suggest that there is not a multicollinearity problem. As the models' goodness of fit is concerned, the Hosmer–Lemeshow Test highlights that the model fits the data well ($\chi^2(8) = 9.05$, $p = 0.3384$). The value of the likelihood ratio chi-square is 40.62 and confirms the model's goodness of fit. The accuracy of the model was further supported by the area under the ROC curve, which was equal to 0.9499, suggesting a high discriminatory power in distinguishing between the positive and negative classes. The classification matrix employed to evaluate the model's performance indicated an overall accuracy of 86.2%, with a sensitivity of 89.1% and a specificity of 81.8%. These results highlight a well-balanced classification performance, demonstrating the model's considerable precision in correctly predicting both the propensity and the non-propensity to use treated wastewater.

Table 5. Multicollinearity VIF test.

Variables	VIF
Utilised Agricultural Area	1.07
Education level	1.78
Knowledge of legislation	1.31
Use of consulting services	1.26
Participation in Producers' Organisations	1.07
Product quality concern	1.24
Workers' health concern	1.30
Groundwater pollution concern	1.17
Average VIF	**1.27**

The results of the model are presented in Table 6. As expected, the level of education, knowledge of the legislation, and participation in Producers' Organisations are found to affect the farmers' propensity to use wastewater positively. On the contrary, the likelihood of using wastewater decreases if farmers are concerned about the quality of products, the workers' health, and groundwater pollution, and when farm size increases. As already underlined, the effects of farm size are rather controversial, and this factor can favour or hinder the adoption of new practices/products according to the innovation characteristics and the action of other motivational or socio-economic factors. In our study, the farm's size has a negative effect. This finding aligns with previous studies, such as those of Läpple and Van Rensburg [42] and Khalid et al. [53], suggesting that smaller farms may have more flexibility in implementing new practices, and organisational and managerial changes can be more complex when the size increases.

Table 6. Results of the logit model.

Variables	Coeff.	Std. Error	*p* Value	[95% Conf. Interval]		Odds Ratio
Utilised Agricultural Area	−0.122	0.004	0.024	−0.228	−0.001	0.987
Education level	2.286	0.605	0.000	1.099	3.472	9.835
Knowledge of legislation	1.272	0.511	0.013	0.269	2.275	3.568
Use of consulting services	0.958	0.754	0.204	−0.523	2.437	2.606
Participation in Producers' Organisations	1.600	0.536	0.003	0.548	2.652	4.955
Product quality concern	−1.396	0.571	0.014	−2.515	−0.278	0.247
Workers' health concern	−2.304	0.599	0.000	−3.479	−1.130	0.099
Groundwater pollution concern	−2.028	0.685	0.003	−3.373	−0.682	0.131

Log likelihood = −47.291; Wald chi2 (8) = 40.62; Prob > chi2 = 0.0000.

The odds ratios provide information on how much significant variables affect the propensity to use alternative water sources. A higher level of education leads to more than a 9-fold increase in the likelihood of wastewater use. This confirms the relevance of formal education as a promoter of innovation adoption, which is consistent with previous studies [20,28,58]. Several aspects help explain why education can positively influence the willingness to use wastewater for irrigation. More educated farmers can be more able to understand both the benefits and risks of this resource, recognise the value of wastewater as a source of nutrients, and better utilise external information flows. Overall, education can enhance a farmer's problem-solving ability and determine a proactive attitude toward innovations.

The degree of information and knowledge of reclaimed water regulations also showed a significant influence on the propensity to use wastewater. The knowledge of regulations increases the likelihood of farmers to use wastewater by a factor of 3.5. Very relevant is the effect of participation in the Producers' Organisation, which increases the likelihood of wastewater use by about 5-fold. These findings can be related to what Rogers (1995) [17] says about "change agents" and the information and knowledge flow among peers. In fact, the Producers Organisations can play two main roles. On one hand, they can actively promote the adoption of innovations to improve the efficiency and quality of the associates' production. On the other hand, they facilitate the exchange of knowledge among farmers and act as the main communication channel in conveying information from outside.

On the contrary, the current use of advisory services does not significantly affect the probability of adopting wastewater irrigation. This contrasts the findings of previous studies. To explain this result, we would need a deeper knowledge of the characteristics of the services provided to the farm. Indeed, the collected data only concern whether the farmer uses consultancy services for irrigation, but no information was provided on the type of service offered, whether it concerns only the irrigation structures or aspects related to water quality and use, or whether it helps with emergency issues or is a more continuous and planned service.

Lastly, the signs of the coefficients related to concerns of market risks or health and pollution dangers are consistent with the relationships underlined in the literature [25,63]. When farmers are concerned about the quality of products, workers' health, or environmental issues, the propensity to use wastewater decreases by 76%, 90%, and 87%, respectively. This highlights how such negative perceptions constitute significant barriers to adoption.

5. Discussion and Conclusions

The propensity of farmers to adopt new practices and/or new resources appears to be closely conditioned by several factors, whose combination is decisive for innovative choices and behaviours [63].

The results from the logit model reveal two main factors that affect farmers' willingness to use reclaimed wastewater for irrigation.

The first factor pertains to human and social capital. An awareness of the applicability of innovations and an understanding of their characteristics influence farmers' propensity to adopt new practices. This awareness depends on the ability to utilise information and is related to accumulated prior knowledge and absorptive capacity [67]. Human capital characteristics play a relevant role in this ability. Our results indicate that farmers with higher levels of education are more likely to utilise alternative water resources. This finding aligns with previous studies in different contexts, which suggest that more educated farmers are more able to perceive the advantages of specific innovations and can evaluate their convenience from multiple perspectives [20,68,69]. Additionally, an accurate knowledge of the legislation on wastewater reuse and its potential field of application positively influences farmers' propensity. These factors play a significant and connected role. A higher level of education creates the conditions for farmers to feel the need to constantly update and inform themselves, positively influencing their attitudes towards proposed innovations [28,58]. Similarly, the adoption of innovation is a function of the information flow from external sources and social networks. In line with previous studies [28,45], our work reinforces the importance of participating in networks, such as Producers' Organisations, which can facilitate the transfer of information and knowledge and enhance the adoption of new practices. Participation in the Producers' Organisation is a primary factor for improving the willingness to adopt the use of reclaimed wastewater for irrigation. Specifically, Producers' Organisations and local farming communities play a vital role in promoting the sharing of experiences, disseminating best practices, and can encourage the development of specific skills related to wastewater use. These networks serve as valuable channels for accessing up-to-date information on national and European regulations, quality standards for reclaimed water, and regional policies.

Our study did not find any significant effect of current advisory services and technical support on the likelihood of using wastewater. This result contrasts with the previous literature, which indicates that support services are effective channels for information transfer and sharing [49,50] and encourage the adoption of innovative and/or unfamiliar practices and products [47,70]. Indeed, the role of technical support merits further examination to better understand the consultancy system's actual functions, the types of services it provides, and the intensity of interactions. Strengthening technical advisory services is essential for helping farmers adopt new irrigation practices in a safe and informed manner. Consultancy may reduce the uncertainties and concerns that may deter future users of this resource.

A second key factor in adopting innovative practices is the risk that farmers associate with implementing new methods. Depending on the specific characteristics of the innovation, the risks can span multiple areas (market, health, and the environment) [21]. When farmers do not fully understand how new practices impact these areas, their decisions are often based on their beliefs. Consequently, risk perceptions can act as significant barriers to using alternative water resources. Our findings indicate that concerns related to product quality, workers' health, and groundwater contamination negatively affect the willingness to use wastewater. These findings are consistent with previous studies [4,61,63].

Human and social capital, along with risk perception, are closely linked, as risk perception depends on access to information and innovation-specific knowledge [55,56,71]. A greater understanding of the benefits of new practices typically reduces the perceived risk and increases trust in the new [54,58,72].

Consistent with the findings of Rizzo et al. (2023) [26], the adoption of innovative agricultural practices is driven by education and training. Indeed, this factor serves as the starting point for changes in production practices and management, allowing farmers to gain in-depth knowledge of new practices and their effects. Simultaneously, this increases confidence in the innovation and significantly reduces the perception of associated risks [9]. Moreover, technical support can be important and indispensable in reducing the uncertainty associated with new practices, enhancing expertise, and ensuring their proper implementation.

Therefore, this study emphasises the need for an integrated approach. It should combine information and technical training interventions to raise farmers' awareness of the impacts and potential uses of alternative water sources and to help them overcome their perceived barriers. The adoption of wastewater reuse practices demands more efficient information channels that provide an accurate and current knowledge of the local context, national and European regulations, quality standards for reusing purified water, and the policy measures in effect at the regional level. Further research is needed to explore how targeted training programmes and communication strategies can minimise the barriers linked to risk perception, thereby aiding farmers' adoption of innovative practices. However, the significant role of Producers' Organisations resulting from our work already gives a clear indication. Collaborating with these organisations and pointing to them as primary channels for transferring knowledge and information to farmers can be an effective strategy for favouring the adoption of reclaimed wastewater irrigation.

In conclusion, this paper offers a comprehensive overview of the factors influencing the adoption of innovative irrigation practices in the agricultural setting of Basilicata. Although this study focuses on a limited geographical area, it offers some valuable insights into aspects that need to be strengthened to ensure the effective and safe use of reclaimed wastewater, thereby promoting the sustainable use of water resources. Some main limitations of the work can be underlined. First, it does not address the issue of the tariff system and its effects on farmers' propensity to use different water resources. Secondly, the analysis was focused on the propensity to introduce wastewater irrigation, regardless of necessity issues. Indeed, the factors affecting the likelihood of using unconventional waters could be different if the farmer has to use reclaimed wastewater due to drought and a lack of fresh water or because of the expected effects. Besides an experience with water shortages, some important variables that typically affect the acceptance of reclaimed wastewater reuse are not included in this work. Trust in institutions, perceived social pressure, and environmental attitudes merit further investigation and require additional research.

Lastly, the farmers' participation in the survey was voluntary; therefore, the sample was not representative or probabilistic. This represents a limitation of the research, as the findings can be related to auto-selection biases and cannot be generalised to all irrigated farms in the study area. Nevertheless, the results provide valuable insights for the local context and highlight key factors that merit further investigation.

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