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*Review*

# Exploring Factors Shaping Farmer Behavior in Wastewater Utilization for Agricultural Practices: A Rapid Review

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**Abstract:** In recent years, circular economy strategies have gained attention in agriculture, particularly regarding the utilization of wastewater as an alternative water source. This study employs a rapid review methodology to examine farmers' attitudes toward wastewater use in agriculture. By analyzing studies in literature published from 2000 to 2023, this review identifies the key factors influencing farmers' adoption of wastewater irrigation. These findings are valuable for policymakers seeking to develop targeted policies that support and encourage the adoption of wastewater irrigation, thereby contributing to sustainable water resource management.

**Keywords:** wastewater; alternative irrigation; farmers' behavior; sustainable water management



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## 1. Introduction

Agriculture is highly susceptible to water scarcity, as it generates 70% of the world's freshwater withdrawals and over 90% of the globe's total water consumption [1]. Water scarcity is a critical global challenge, exerting profound impacts on various regions worldwide [2]. The problem of water scarcity is exacerbated by factors such as population growth, changing dietary preferences, and climate change. Population growth drives the escalating demand for crop production and the associated need for irrigation water [3]. Additionally, changes in global dietary preferences, especially towards diets richer in animal protein—which requires significant amounts of water to produce—further strain global water resources [4,5]. Climate change compounds these issues by affecting water availability, leading to more frequent and severe droughts in many areas [6,7].

Coping with water scarcity involves both demand-side and supply-side strategies. On one hand, water conservation and efficient water use practices play a pivotal role. Implementing technologies such as drip irrigation, adopting precision agriculture, and promoting water-efficient crops are strategies for managing water demand [8]. Additionally, public awareness campaigns and education programs can instill water-saving habits among consumers [9]. On the other hand, increasing water availability involves harnessing alternative water sources and optimizing existing ones. Indeed, investing in new infrastructure to augment water supplies is becoming increasingly unsustainable from both economic and environmental perspectives [10]. The costs associated with developing and maintaining large-scale infrastructure projects such as dams and reservoirs are often exorbitant [11], and these projects can have detrimental ecological impacts, disrupting local ecosystems and biodiversity [12].

Against this backdrop, attention is shifting towards innovative and more environmentally friendly practices—based on a circular economy perspective—to obtain alternative water sources. In particular, wastewater treatment and reuse is gaining prominence as a strategy to alleviate water scarcity and upcycle byproducts, providing a sustainable solution that addresses both economic and environmental concerns while supporting agricultural needs [13]. In the literature, the term 'wastewater' is applied to refer to various stages of polluted water. Broadly, wastewater can be categorized into untreated and treated wastewater. Untreated wastewater is defined as water discharged without undergoing any form of treatment. The properties of treated wastewater differ based on the treatment method used, which can range from primary to advanced tertiary treatments [14]. Wastewater treatment can be divided into primary treatment, secondary treatment, and tertiary treatment. Primary treatment typically entails a reduction in organic load and pathogens of approximately 30–40%. Secondary treatment typically achieves a reduction in organic load of 95%, while tertiary treatment achieves a near 99% reduction in organic load. Both secondary and tertiary treatments involve disinfection processes [15]. Based on the type of treatment, various utilization options are determined for wastewater. Primary treatment is fit for forest and park irrigation with stringent safety protocols. Secondary treatment suits tree crops like olives and vineyards, provided there is no direct crop contact. Tertiary treatment is optimal for all human-consumed crops [16]. Lastly, the advanced treated wastewater is used for indirect drinking and for the recharging of surface and groundwater bodies. Only secondary and tertiary treatment processes are deemed suitable for irrigation purposes. Specifically, secondary treated water is recommended for non-food crop irrigation, being used in gardens, ornamental plants, and parks. Conversely, tertiary treated water is preferable for irrigating food crops [5]. In this paper, 'wastewater' is used to specifically denote treated wastewater unless otherwise stated. Any reference to untreated wastewater will be explicitly labeled as such to avoid confusion.

The adoption of wastewater for irrigation provides several advantages. Compared to other alternative water sources (e.g., desalination), wastewater needs less energy, thus resulting in lower production costs [17]. Being rich in inorganic and organic compounds, wastewater also represents a source of nutrients, enhancing soil productivity [5]. As this practice allows us to divert the discharge of wastewaters towards water bodies, it also mitigates eutrophication [18]. Wastewater might thus be a pivotal innovation for arid and semi-arid countries facing water scarcity and could be used in practice to support the circular economy transition in the global agricultural sector [19].

From a policy perspective, upcycling wastewater serves various strategic purposes. The European Green Deal emphasizes the importance of circular economy principles, including the sustainable use of resources such as water. This is particularly supported by the Circular Economy Action Plan, which prioritizes the efficient use of water and nutrients in agriculture. The Lisbon Strategy underlines the need for environmentally sustainable development, aligning with the broader normative shift towards integrating wastewater reuse into agricultural practices. Furthermore, the use of wastewater plays a crucial role in complying with the Water Framework Directive (WFD-Directive 2000/60/EC) (i.e., to reach "the good ecological status" of European water bodies) and meeting the Sustainable Development Goals (SDGs) established in Johannesburg [20].

Despite substantial endeavors in the EU, currently, the reuse of wastewater is limited, accounting for only a small fraction (approximately 2.4%) of total treated water [21]. Various barriers, stemming from intricate interconnections between technological, economic, and socio-political factors, continue to impede the widespread adoption of water reuse. Even though technological and organizational aspects are of paramount importance [22], several authors stress the role of farmers' behavior as barrier to reusing wastewaters in agriculture [23–27]. As perceptions, attitudes, and opinions influence individuals' intentions, which, in turn, influence their behavior [28–32], farmers' positive or negative views related to wastewater may influence the implementation of this new practice (Even ifDespite the fact that, in this research paper, we focus on socio-behavioral aspects as antecedents of farmers' decisions, the literature provides different theories. To illustrate, farmers' decisions can be explained through the rational choice theory [33], the theory of planned behavior (TPB) [34], the diffusion of innovations theory [35], and the social learning theory [36,37]).

Albeit some studies aknowledge the importance of integrating stakeholder's socio-behavioral factors to build water policies [38], literature is mostly focused on the technical dimensions involved in the use of wastewater (e.g., treatment technologies [39], benefits and drawbacks [40] application in agriculture [41–43]). In the application of wastewater for agricultural purposes, several techniques are utilized, such as surface irrigation, sprinkler irrigation, drip irrigation, and subsurface drip irrigation. Each, all of these methods which offers a unique approach to distributing treated wastewater to crops, boasting specific benefits and factors to consider. For instance, surface and sprinkler irrigation can irrigate extensive areas but involve direct contact with plant foliage and fruits, potentially raising health concerns. Conversely, drip and subsurface irrigation target the root zone directly, minimizing health risks to consumers and fostering healthier plant growth. Therefore, there is limited research focusing on understanding the perspectives, attitudes, and social dynamics that influence farmers' willingness to adopt this alternative water source [15] or the factors that drive its acceptance [25]. Therefore, this research article summarizes the current knowledge about factors influencing farmer's behavior towards the use of wastewater for irrigation. More specifically, it provides an overview of current insights on this topic through a rapid review of the scientific literature produced in the period of 2000–2023. By synthesizing and examining relevant studies in the literature, this review seeks to capture a snapshot of the evolving attitudes, perceptions, and behavioral aspects related to farmers' adoption of wastewater. Understanding these aspects is crucial for formulating informed policies, designing effective interventions, and promoting sustainable practices concerning wastewater use in the agricultural sector. Through this review, we aspire to contribute valuable insights that can inform future research directions and facilitate the development of strategies aimed at fostering the widespread and sustainable adoption of wastewater in agriculture.

## 2. Materials and Methods

### 2.1. Review Approach

A rapid review approach was chosen for this article due to its advantages and suitability for the research objectives. Rapid reviews are beneficial when there is a need to synthesize existing evidence quickly, making them ideal for time-sensitive topics or projects [44]. Given the need to provide a comprehensive overview of studies produced in a wide timeframe, a rapid review enables the synthesis of key findings without the extended timeline required for traditional systematic reviews, which follow a more rigorous protocol [45]. Nevertheless, the rapid review methodology is still designed to identify patterns, trends, and gaps in the existing literature [46].

A structured query was formulated, employing the following eighteen search terms combined through Boolean operators: "Wastewater AND irrigation AND farmer AND [behavior OR attitude OR perception OR perspective OR opinion OR orientation OR position OR standpoint OR response OR willingness OR preference OR belief OR acceptance OR driver OR understanding]". The selection of keywords for the query was carefully conducted to ensure semantic alignment with the domain of behavior. This thorough approach ensures that the chosen words, in terms of both their number and relevance, accurately represent the phenomenon being studied.

The research was conducted using Scopus, which is recognized as a major multidisciplinary database including peer-reviewed research papers. Keywords were selected within the fields "article title, abstract, and keywords". The review was restricted to English-language, peer-reviewed empirical articles, reviews, and book chapters published during the last twenty-three years (2000–2023). The rationale for selecting the year 2000 as the starting point of our timeframe stems from its relevance in European legislation on wastewater. In 2000, the European Commission introduced the Water Framework Directive 2000/60/EC, which established a unified normative framework for the management and protection of European water bodies. This legislative milestone addressed the previously fragmented approach to water protection and incorporated preceding legislation, including the Urban Treated Wastewater Act of 1991. Studies dated 2024 but already available online by the end of 2023 were taken into consideration.

*2.2. Selection Process and Eligibility Criteria*

The inclusion/exclusion criteria adopted in the study are shown in Table 1. The initial screening was based on criteria 1, 2, and 3. Starting with 156 records, in this phase, non-English publications, publications that were not articles, reviews, or book chapters, and publications outside the reference timeframe were removed. The process continued in Excel for the subsequent phases of selection, when titles and abstracts were analyzed, and 87 records were excluded. The selected records were then read in full, and another round of selection was conducted following a more in-depth analysis. After assessing the full texts of the remaining 48 studies, we excluded 5 more, resulting in 43 studies meeting our criteria. In the latter two stages, only the final inclusion/exclusion criterion was applied: "Overly technical work with no reference to socio-behavioral aspects of farmers". Specifically, only studies investigating socio-behavioral factors influencing the use of wastewater in agriculturewere considered. Therefore, articles with a technical focus (e.g., geology articles employing the term "behavior" to analyze metal or nutrients behavior in soil) or focusing on subjects other than farmers (e.g., consumers) were excluded. The selection process is illustrated in Figure 1.

**Table 1.** Inclusion and exclusion criteria.

| Criterion | Inclusion | Exclusion |
|---|---|---|
| n.1 Language | English | All languages other than English |
| n.2 Year of publication | 2000–2023 | Before 2000 |
| n.3 Source type | Articles, Reviews, Book chapters | All others |
| n.4 Study focus | Study focusing on farmers socio-behavioral factors influencing the use of wastewater in agriculture | Overly technical work with no reference to the socio-behavioral aspects of farmers |

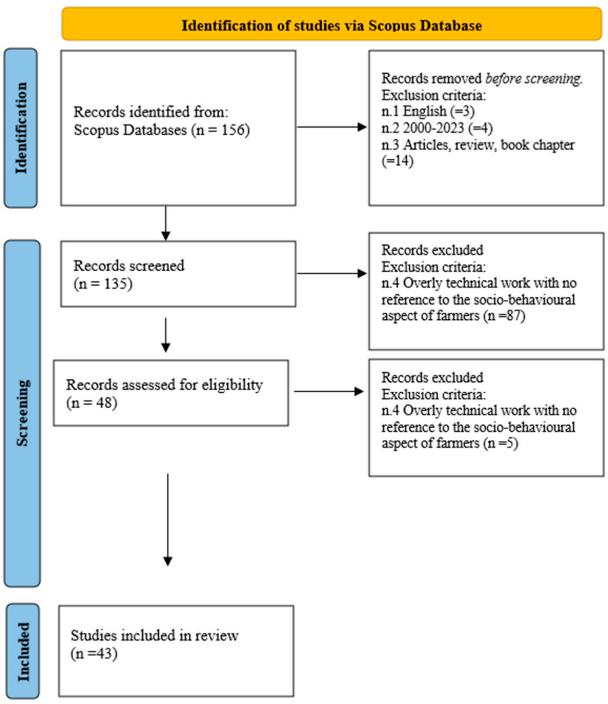


**Figure 1.** Flowchart of the selection process.

For each record, the type of socio-behavioral factors investigated is reported in Table 2. The table summarizing socio-behavioral factors presents the main categories derived from the analysis of the studies included in the review, reflecting the outcomes of the search criteria employed in our study. This information was crucial for analyzing the content of the articles selected, and used to identify seven categories related to the drivers of the adoption of wastewater in agriculture.

**Table 2.** Analyzed articles (n = 43).

| Author | Title | Study Area | Socio-Behavioral Factors |
|---|---|---|---|
| Adams et al., 2023 | Urban agriculture and farmers' willingness to pay for treated wastewater: Insights from vegetable producers in the greater Accra metropolis of Ghana | Ghana | Driving factors of WTP (experience) |
| Al-Najar et al., 2019 | The effect of education level on accepting the reuse of treated effluent in irrigation | Palestine | Education |
| Alsa'di, A. et al., 2023 | Utilization of treated municipal effluent for irrigating agricultural land in Palestine: The driving factors and existing practices | Palestine | Disgust, worries about the quality, health concern |
| Antwi-Agyei et al., 2016 | Risk perceptions of wastewater use for urban agriculture in Accra, Ghana | Ghana | Health risk perception, awareness |
| Arimiyaw et al., 2020 | On-farm urban vegetable farming practices and health risk perceptions of farmers in Kumasi | Ghana | Health risk perception |
| Bakopoulou et al., 2020 | Investigation of farmers' willingness to pay for using recycled water for irrigation in Thessaly region, Greece | Greece | Driving factors of WTP (attitude toward climate change) |
| Ballesteros et al., 2022 | Using reclaimed water to cope with water scarcity: an alternative for agricultural irrigation in Spain | Spain | Health risk perception, yuck factor, perception of public institutions |
| Birol et al., 2008 | Evaluating farmers' preferences for wastewater: Quantity and quality aspects | Cyprus | Driving factors of WTP (attitude and perception toward product obtained from wastewater) |
| Carr et al., 2011 | Water reuse for irrigation in Jordan: Perceptions of water quality among farmers | Jordan | Perception of wastewater quality |
| Dare et al., 2018 | Farmer perceptions regarding irrigation with treated wastewater in the West Bank, Tunisia, and Qatar | Tunisia, Qatar, Palestine | Farmers perception about health, environment, perception of public institutions role, religious beliefs |
| Deh-Haghi et al., 2020 | Farmers' acceptance and willingness to pay for using treated wastewater in crop irrigation: A survey in western Iran | Iran | Driving factors of WTP (risk perception and education) |
| Faour et al., 2023 | Growers' irrigation practices, knowledge, trust, and attitudes toward wastewater reuse in Lebanon, Jordan, and Tunisia through a food safety lens | Lebanon, Jordan, Tunisia | Knowledge of the practice, attitude, trust in institutions |
| Friedrichsen et al.,2021 | Yuck! Plural Valuation of Constructed Wetland Maintenance for Decentralized Wastewater Treatment in Rural India | India | Social and cultural aspect, yuck factor |

**Table 2.** *Cont.*

| Author | Title | Study Area | Socio-Behavioral Factors |
| --- | --- | --- | --- |
| Genius et al., 2012 | Assessing preferences for wastewater treatment in a rural area using choice experiments | Greece | Driving factors of WTP (education) |
| Haldar et al., 2021 | Institutional challenges and stakeholder perception towards planned water reuse in peri-urban agriculture of the Bengal delta | Bangladesh | Awareness, environmental perception, willingness, psychological aversion |
| Hamdan et al., 2022 | Willingness of farmers to use treated wastewater for irrigation in the West Bank, Palestine | Palestine | Perception, attitudes, role of regulations, religious beliefs |
| Houessiononet al., 2017. | Economic valuation of ecosystem services from small-scale agricultural management interventions in Burkina Faso: A discrete choice experiment approach | Burkina Faso | Driving factors of WTP (preference toward wastewater) |
| Jiménez et al., 2011 | Agricultural water reuse in Nicaragua: Extent, actual practices, perception and perspectives | Nicaragua | Perception of public institutions |
| Keraita et al., 2008 | Perceptions of farmers on health risks and risk reduction measures in wastewater-irrigated urban vegetable farming in Ghana | Ghana | Health and environment risk perception |
| Khanpae et al., 2020 | Farmers' attitude towards using treated wastewater for irrigation: The question of sustainability | Iran | Attitudes, environmental and health perception |
| Mahjoub et al., 2022 | Use of groundwater and reclaimed water for agricultural irrigation: Farmers' practices and attitudes and related environmental and health risks | Tunisia | Environmental awareness, acceptance, perceived regulations |
| Majoub et al., 2018 | Public Acceptance of Wastewater Use in Agriculture: Tunisian Experience | Tunisia | Environmental awareness, social acceptance |
| Maleksaeidi et al., 2018 | Vegetable farmers' knowledge, attitude and drivers regarding untreated wastewater irrigation in developing countries: A case study in Iran | Iran | Knowledge, health and environmental concerns |
| Mayilla et al., 2017 | Perceptions of using low-quality irrigation water in vegetable production in Morogoro, Tanzania | Tanzania | Perception of water quality |
| Menegaki et al., 2009 | What's in a name: Framing treated wastewater as recycled water increases willingness to use and willingness to pay | Greece | Driving Factors of WTP (disgust, regulations awareness) |
| Michetti et al., 2019 | Interpreting farmers' perceptions of risks and benefits concerning wastewater reuse for irrigation: A case study in Emilia-Romagna (Italy) | Italy | Environmental risk perception, knowledge |
| Mojid et al., 2010 | Farmers' perceptions and knowledge in using wastewater for irrigation at twelve peri-urban areas and two sugar mill areas in Bangladesh | Bangladesh | Health perceptions, knowledge |

**Table 2.** *Cont.*

| Author | Title | Study Area | Socio-Behavioral Factors |
|---|---|---|---|
| Owusu V., 2015 | Safer Irrigation Technologies under Uncertainty: Evidence from Ghana | Ghana | Health concerns |
| Owusu et al., 2012 | Perception on untreated wastewater irrigation for vegetable production in Ghana | Tunisia | Health risk perception |
| Petousi et al., 2015 | Farmers' Experience, Concerns and Perspectives in Using Reclaimed Water for Irrigation in a Semi-Arid Region of Crete, Greece | Greece | Perception of institutions, experience |
| Qureshi et al., 2022 | Challenges and prospects of using treated wastewater to manage water scarcity crises in the Gulf Cooperation Council countries | Arab Emirates | Attitude towards climate change |
| Rekha et al., 2010 | Farmers' perception of treated paper mill effluent irrigation | India | Education, risk orientation |
| Ricart and Rico, 2019 | Assessing technical and social driving factors of water reuse in agriculture: a review on risks, regulation and the yuck factor | Global | Environmental risk perception, health risk perception, perception of public institutions |
| Ricart et al.,2019 | Risk-yuck factor nexus in reclaimed wastewater for irrigation: comparing farmers attitude and public perception | Global | Environmental risk perception, health risk perception, perception of public institutions |
| Ricart and Rico-Amorós et al., 2021 | Constructed wetlands to face water scarcity and water pollution risks: learning from farmers' perception in Alicante, Spain | Spain | Environmental risk perception, health risk perception, perception of public institutions |
| Saldías et al., 2017 | Understanding farmers' preferences for wastewater reuse frameworks in agricultural irrigation: lessons from a choice experiment in the Western Cape, South Africa | India | Driver factors of WTP (regulations awareness, environment perception) |
| Saldias et al., 2016 | Stakeholders' attitude towards the reuse of treated wastewater for irrigation in Mediterranean agriculture | South Africa | Acceptance, trust in institutions |
| Saliba et al., 2018 | Stakeholders' attitude towards the reuse of treated wastewater for irrigation in Mediterranean agriculture | Italy | Social acceptance, institutional awareness |
| Sheidaeia et al., 2016 | Farmers' attitude towards wastewater use in Fars Province, Iran | Iran | Health risk perception, environmental risk perception, institutions |
| Sohail et al., 2021 | Farmers' awareness about impacts of reusing wastewater, risk perception and adaptation to climate change in Faisalabad district, Pakistan | Pakistan | Climate change risk perception |
| Suri et al., 2019 | U.S. farmers' opinions on the use of nontraditional water sources for agricultural activities | USA | Health risk perception, knowledge |
| van Opstal et al., 2012 | A participatory modelling approach to define farm-scale effects of reclaimed wastewater irrigation in the Lockyer Valley, Australia | Australia | Institutional involvement, he |
| Woldetsadik et al., 2018 | Farmers' perceptions on irrigation water contamination, health risks and risk management measures in prominent wastewater-irrigated vegetable farming sites of Addis Ababa, Ethiopia | Ethiopia | Perception of health risk, religious beliefs |

Note: WTP: Willingness To Pay.

## 3. Results

### *3.1. Descriptive Statistics of Selected Studies*

In this section, descriptive statistics related to the final output of records are shown. In recent years, the literature exploring farmers' attitudes, perceptions, and behavior toward using wastewater in agriculture has grown (Figure 2). More precisely, if one considers quartiles of the reference timeframe (6 years each), in the period of 2000–2005, no studies were published on this topic; then, the research identified 9 studies in the second period (2006–2011), 10 studies in the third (2012–2017), and 24 studies in the fourth (2018–2023). Therefore, around 56% of the papers selected were published in the last six years.

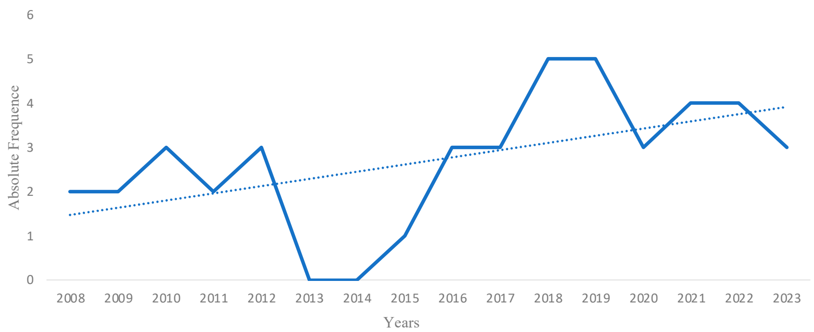


**Figure 2.** Trend in number of publications.

Figure 3 reveals that there is significant heterogeneity in terms of subject areas among the investigated articles, with Environmental Science (34%), Social Sciences (13.2%), and Agricultural and Biological Sciences (12.3%) being the most represented fields. This finding highlights the need to address the topic of wastewater use by considering both technical (agronomic and environmental) and social (social science) points of view. The other subject areas are as follows: Engineering (7.5%), Earth and Planetary Sciences (5.7%), Biochemistry, Genetics and Molecular Biology (4.7%), Energy (3.8%), Business Management and accounting (2.8%), Chemical Engineering (2.8%), Economics Econometrics and Finance (2.8%), and Other (10.4%). These results demonstrate that the topic is highly multidisciplinary and heterogeneous.

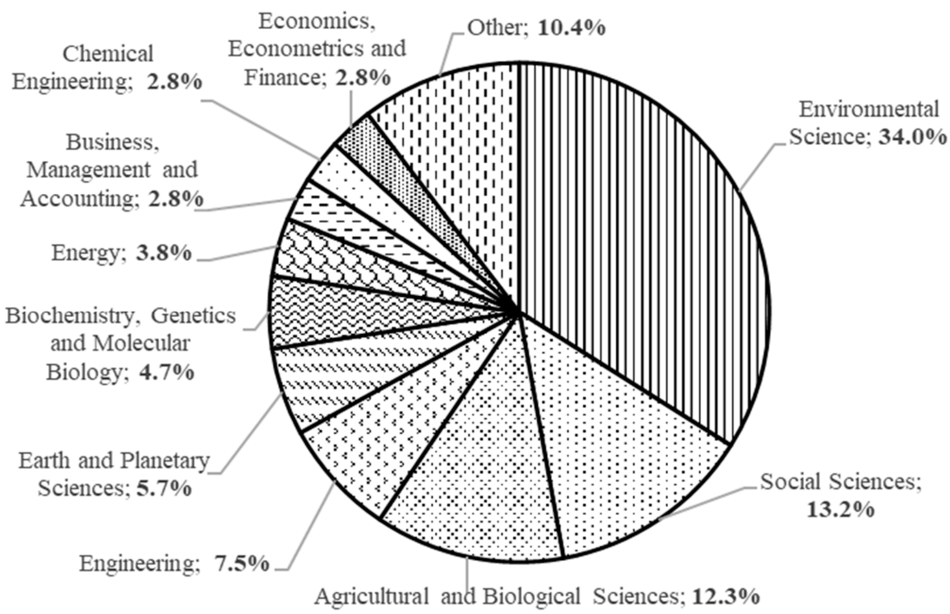


**Figure 3.** Articles by subject area.

Figure 4 shows the main research areas of the selected articles based on a different criterion, namely the affiliation institution of the first author. Following this criterion, several topics are covered, with the highest percentage of articles being published by authors specifically involved in carrying out water-related studies, followed by Agricultural Economics and Economics.

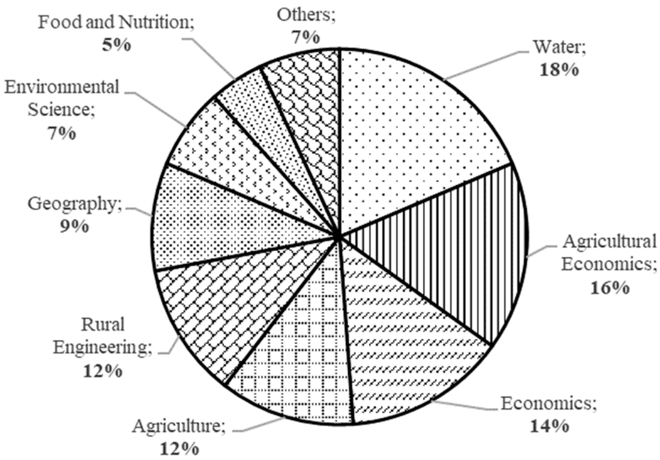


**Figure 4.** Affiliation institution of the first author.

Examining the data based on geography (Figure 5), the most extensively studied countries are Ghana (5 studies), Tunisia (5), Greece (4), Iran (4), Palestine (4), India (3), Bangladesh (2), Italy (2), Jordan (2), Qatar (2), and Spain (2). Each article may belong to multiple countries; therefore, the sum of the records within parentheses does not correspond to 43. Furthermore, Australia, Bahrein, Burkina Faso, Cyprus, Ethiopia, Kuwait, Lebanon, Nicaragua, Oman, Pakistan, Saudi Arabia, South Africa, Tanzania, United Arab Emirates, and USA are investigated in one case study. Out of the analyzed papers, 35 investigate farmers' behavior in developing countries, while 15 articles focus on developed countries. Several studies investigate Asian (24, mainly examining the southern part) and African countries (14). The studies investigating European farmers (9) are concentrated in Mediterranean countries such as Greece (4), Italy (2), Spain (2), and Cyprus (1). Finally, only 3 papers look at the Americas (2) and Oceania (1). Comparing the distribution of the studies with global annual mean temperatures [47] also highlights that research on this topic prevails in warm geographical regions.

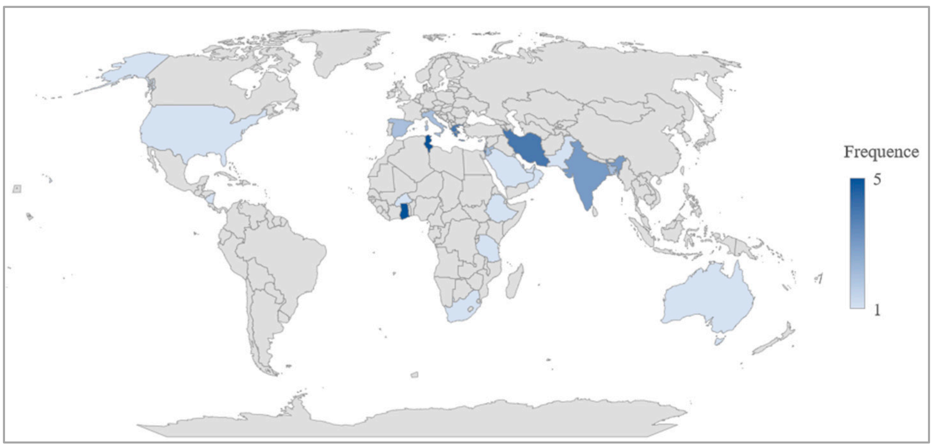


**Figure 5.** Geographical distribution of selected studies.

*3.2. Determinants of Farmers' Adoption of Wastewater*

Based on the socio-behavioral factors detected for each article (Table 2), we identified seven distinct thematic clusters (Figure 6):

- Environmental risks (n = 10);
- Health risks (n = 11);
- Farmers' perceptions of public institutions (n = 8);
- Knowledge of the practice (n = 5);
- Religious beliefs (n = 4);
- Climate change (n = 6);
- Willingness to pay (WTP) (n = 9).

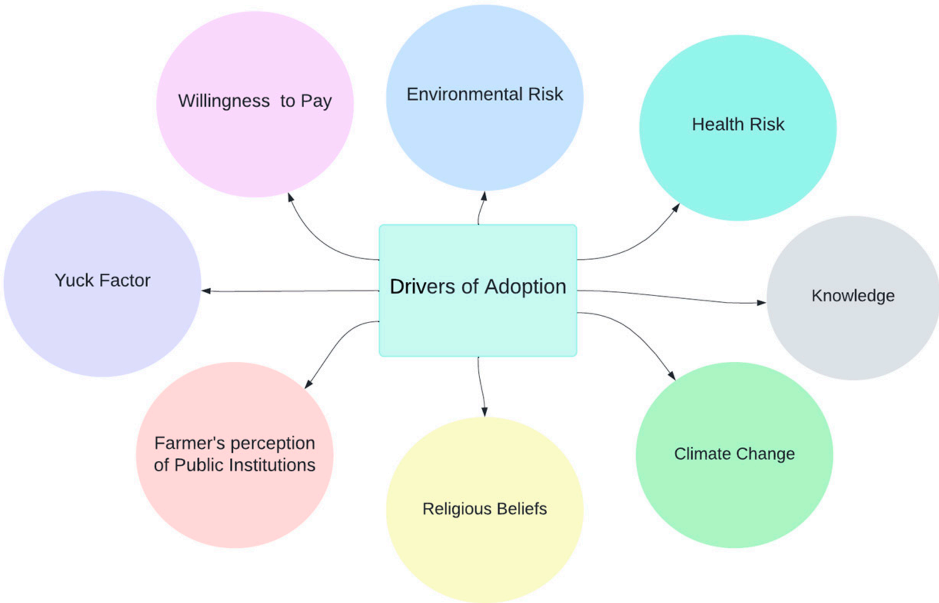


**Figure 6.** Drivers of adoption.

Each article may belong to multiple clusters; therefore, the sum of the records within parentheses does not correspond to 43. The clusters focus on the analysis of antecedents of intention as drivers of wastewater adoption. WTP is not a direct antecedent, but it was included in the analysis as it is a result of antecedents' interplay. Therefore, it is worth specifying that we focused solely on the drivers of WTP and the characteristics that explain its variability.

3.2.1. Environmental Risks

Although arid regions stand to gain significant benefits from wastewater in agriculture, its utilization poses potential risks to farmers and the environment. The environmental risks encompass the degradation of aquatic ecosystems and the pollution of soils and groundwater [48]. In this paragraph, we present findings pertaining to the environmental dimension, highlighting how these aspects are perceived by farmers. The potential risks associated with wastewater depend on the elements contained therein. On the one hand, wastewater is rich in nutrients (phosphorus, nitrogen, potassium), which can be advantageous for soil fertility and contribute to a reduction in the use of fertilizers. On the other hand, other contaminants, such as metals and metalloids, have been identified, which may instead contribute to the degradation of soil and aquatic environments [15].

Dare and Mothar [49] highlight a generally positive attitude among Tunisian farmers toward wastewater enhancing agricultural productivity and reducing the need for fertilizers. This is also confirmed by Khanpae et al. [27], Sheidaei et al. [50], and Tayyab Sohail et al. [51], as, in their studies, farmers perceived that the improvement in fertility of their farmland is attributed to irrigation with wastewater. In addition to its nutrient content, farmers have recognized another positive effect of wastewater—its ability to mitigate the adverse impacts of climate change. Indeed, the need for water and the reliability of alternative sources for irrigation lead farmers to view wastewater positively as a means of coping with water scarcity [26,27,51–53].

By contrast, the negative aspects perceived by farmers concern the presence of pollutants and their impact on soil and aquifers [15]. Many scholars have conducted surveys revealing that farmers believe using wastewater pollutes the environment, especially in the case of groundwater [1,48,50,53,54]. However, the main negative environmental side-effect associated with the use of wastewater relates to the presence of salt. The latter strongly affects electrical conductivity, which leads to alterations in land porosity, threatening soil health. Long-term exposure to salt could translate into fish extermination due to salt intrusion from the sea and the general alteration of aquatic habitats [23,50]. Finally, soil quality degradation negatively influences crop productivity.

#### 3.2.2. Health Risks

Wastewater contains a diverse range of enteric pathogens, encompassing viruses, bacteria, protozoa, and helminths. The presence of these contaminants poses significant health risks for individuals engaged in activities related to wastewater-irrigated fields or those consuming foods irrigated with wastewater. The potential health concerns are particularly pronounced when consuming raw or uncooked items such as salad crops and certain vegetables [26].

Some studies conducted in low-income countries highlight that farmers have experienced skin infections, blistering skin, itchy skin, skin rashes, and injuries to the hands and legs [16,17,40]. These articles focused on untreated wastewater including other pathogens in addition to solid waste derived from road-side garbage during runoff from rainfall. According to Khanpae et al. [27], skin infection is perceived as a health risk, mainly because wastewater users often do not apply protective procedures for irrigation, such as wearing gloves, goggles, and a water-resistant suit. Sheidea et al. [50] argue that there is a low perceived health risk of becoming infected from viruses, bacteria, and protozoa because most farmers do not have a deep knowledge about the health risks of wastewater. According to Carr et al. [37], the perception of health risks by farmers could be biased (declared as more positive than it is) due to the concern that the price of water will be raised or that treated water will not be provided if a negative perception is documented. In line with this, Antwi-Agiei et al. [55] assert that to sustain their livelihoods and maintain access to wastewater, farmers often downplay the health risks associated with using wastewater for vegetable cultivation. Farmers are aware of the precarious nature of wastewater usage due to its illegal status and social disapproval. Consequently, they minimize health concerns, hoping that this will enable them to continue using it. Some may even argue that their chosen source of irrigation water presents no risk, contributing to the underreporting of associated health concerns [23].

#### 3.2.3. Farmers' Perception of Public Institution

Articles falling into this category recognize that the way farmers perceive water authorities not only affects the adoption of wastewater but also shapes their overall attitude towards it. In general, regarding treated wastewater, the authority's role is to guarantee resource distribution while upholding water quality standards in accordance with current regulations. However, services are not always ensured, and users' standards may not be met. For example, Haldar et al. [53] show that the enforcement of rules and regulations related to wastewater discharge in the area of the Bengal Delta is only partially implemented and that governmental bodies exhibit limited levels of stakeholder engagement, which is crucial for achieving effective environmental governance. In addition, Ballesteros- Olza [56] highlight the lack of institutional coordination and confusing normative setting in Spain, hampering the implementation of water reuse projects. The results of both of these studies demonstrate that political support for water reuse would enhance the bureaucratic process and encourage the use of treated water.

Further issues include the reliability of the practice and access to wastewater. Jimenez et al. [57] show that farmers in Nicaragua felt that the government should take action, including providing education on safety, in order to spread the practice, guarantee access to the resource, and increase income and the area of irrigated land. In this case, water authorities seem to be almost absent, with just a small percentage of farmers that had formally requested a permit to use wastewater receiving a reply. Moreover, Sheidaei et al. [50] surveyed Iranian farmers on their awareness of the laws and regulations related to the safe reuse of wastewater in agriculture. Only half of the respondents acknowledged having a positive understanding of these regulations.

These conditions translate into a distrust in institutions by farmers. In the study by Faour et al. [58], only 40% of the farmers sampled trusted local authorities' control of wastewater quality. In this study, the level of trust was found to be lower for Tunisian and Lebanese farmers compared to Jordanians. Additionally, Menegaki et al. [59] explored the reasons for Greek farmers' reluctance to use wastewater, emphasizing "trust in institutions" as the second most significant factor after "disgust". This result is also confirmed in Petousi et al.'s study [60], which found a clear correlation between the level of trust in the local authority managing the scheme and farmers' attitudes towards wastewater. In some cases, this aspect is so significant that low levels of trust lead farmers to prefer a privately managed scheme to publicly managed ones [48].

#### 3.2.4. Knowledge of the Practice

Some studies recognize the importance of knowledge and information for fostering acceptance towards using wastewater. For example, Hamdan et al. [61] found that farmers more familiar with the regulations on this alternative source and its potential consequences on health and the environment had a more positive attitude towards its use. Aligned with this, Sheidaei et al. [50] and Khanpae et al. [27] note that farmers with a higher level of understanding regarding the impact of wastewater on crop yields and production costs were more likely to prioritize the use of wastewater for irrigation. Furthermore, Deh-Haghi et al. [1] analyze the determinants of the willingness to use and the WTP towards wastewater for irrigation. The authors show that within the realm of knowledge and attitudinal variables, the strongest influences on the willingness to use were health risk perception and education. Conversely, when considering the willingness to pay, the most substantial impacts stemmed from education and information. Finally, Michetti et al. [25] found that greater information and knowledge enhance openness to adopting wastewater innovation by increasing acceptance levels.

#### 3.2.5. Religious Beliefs

Religious beliefs play a crucial role in Arab countries, influencing thoughts, beliefs, and attitudes, even those regarding irrigation practices. Aside from its ordinary applications, water also holds religious significance. According to the Qur'an, water is acknowledged as a means of achieving ritual purification. To engage in specific worship activities, particularly ritual prayers (*salah*), individuals are required to be in a state of ritual purity [62]. The use of water is regulated by the Quran, which specifies the type of water that should be used based on its intended purpose, whether mundane or religious.

Considering the significance that water holds in the Islamic faith, Dare and Mothar [49], Hamdan et al. [61] and Woldestadik et al. [62], include among the potential determinants of wastewater adoption the variable of "religious beliefs". The underlying hypothesis is that religious beliefs are a deterrent to the adoption of wastewater. Except for Woldestadik et al. [63], who analyzed a sample of Ethiopian farmers where the presence of Muslims was accompanied by a significant number of Christians, Dare and Mothar [49] and Hamdan et al. [61] focused on Tunisia, Qatar, and Palestine, countries with a clear Islamic majority. However, in no case was this variable found to be significant.

### 3.2.6. Yuck Factor

The yuck factor can be described as the unsettling and repulsive feeling connected to the consumption or purchase of agricultural products that are produced using wastewater. In general terms, the yuck factor is a form of 'psychological repugnance', 'disgust', or 'profound discomfort.' According to the review of Ricart and Rico [26] and Ricart et al. [15], the yuck factor is related to the 'affect heuristic', asserting that people's readiness to embrace a specific hazard is influenced by an emotional reaction (affect) preceding the cognitive assessment of information. In contrast to these explanations that center on psychological aversion, scholars such as Ormerod and Scott [64] contend that the yuck factor stems from social and cultural perceptions of risk. In this context, Menegaki et al. [59] investigated the reasons for unwillingness to use wastewater among a sample of 188 Greek farmers, highlighting that disgust is the most frequent cause, accounting for 33% of reasons. In line with this, Alsa'di et al. [65] show that disgust and worries about quality are the main barriers Palestinian farmers encounter (68.2% over a sample of 44 farmers), while Mojid et al. [24] found in Bangladesh that the yuck factor was mostly prevalent when farmers had alternatives to wastewater and when they were not very aware of any beneficial aspects of using wastewater.

### 3.2.7. Farmers' Attitudes towards Climate Change

The recognition of wastewater as a valuable resource with the potential to mitigate farmers vulnerability to climate change is growing. The articles belonging to this category investigate how farmers perceive climate change. For instance, in the study by Haldar et al. [53], 75% of respondents considered water reuse a good solution for combating climate change increasingly affecting coastal areas in Bangladesh. In line with this, Ricart and Amoròs [66] show that the use of wastewater is perceived as a less risky measure and more reliable option in terms of addressing climate change impacts. However, the respondents in this study reported climate change adaptation barriers, highlighting the lack of government support in promoting adaptation measures and the lack of cooperation between stakeholders and farmers (good governance). Moreover, Khanpae et al. [27], Maleksaiedi et al. [54], and Owusu et al. [67] argue that climate change makes water less accessible, and this condition makes farmers more eager to use wastewater. Also, Deh-Hagh et al. [1] show a generally positive attitude toward wastewater, justifying it with farmers' awareness of water scarcity.

### 3.2.8. Willingness to Pay (WTP)

The articles analyzed in this study investigated farmers' willingness to pay for using wastewater for irrigation. Since countries do not share the same currency, WTP ranges are reported for each study area (Table 3). Therefore, we converted each currency into euros based on the Purchasing Power Parities (PPPs) to allow for comparisons. This method allowed us to eliminate the difference between price levels among countries [68].

**Table 3.** WTP ranges for each study area investigated.

| Study Area | WTP Range | Currency | EUR/PPP Adjusted |
|---|---|---|---|
| Iran | 1,200,000–1,800,000 | Rials/ha | 29.40–37.70 |
| Bangladesh | 22–40 | USD/per cropping season | 0.18–0.33 |
| Palestine (West Bank) | 0–0.58 | USD/$m^3$ | 0.14 |
| Tunisia | 0–0.30 | USD/h | 0.089 |
| South Africa | 2.76–3.07 | ZAR/$m^3$ | 0.15–0.17 |
| Greece | Up to 0.10 | EUR/$m^3$ | Up to 0.10 |
| Cyprus | 0.025–0.37 | CYP-$m^3$ | 0.012–0.041 |

The reported WTP ranges exhibit significant variability. This heterogeneity is attributed to the differences in wastewater management, availability, and quality, which fluctuate considerably from state to state. This condition led the authors to address WTP considering different aspects related to wastewater. For instance, in Iran and Bangladesh, Deh-Haghi et al. [1] and Haldar et al. [53] investigated farmers' WTP concerning the quality of wastewater. In both areas, the availability of freshwater fails to meet the demand for irrigation purposes. Therefore, wastewater already represents a real alternative source, and farmers already pay for it. However, the treatment process does not guarantee high-quality standards. In these cases, WTP reflects the value that farmers attribute to a treatment process that yields an improvement in the quality of treated wastewater. In line with this, Genius et al. [69] focused on water quality, and farmers were found to be willing to pay an additional 22% on their water bill to reduce the unpleasant odor of the water.

On the contrary, in Greece, Petousi et al. [58] and Bakoupolou et al. [70] analyzed the WTP of treated wastewater use regardless of its quality. Indeed, in Greece, wastewater is still free. Both studies demonstrate that farmers are willing to pay for this source of water but wish to pay less than the current price of freshwater.

Birol et al. [71] addressed the WTP from an environmental perspective, revealing that farmers are willing to pay for the replenishment of aquifers. The greater the wastewater quality and the quantity of wastewater used for replenishment, the greater the WTP.

Dare et al. [49] analyzed the WTP for water of farmers in Tunisia and the West Bank (Palestine). According to this study, farmers in the West Bank believe that there are no conditions under which a water service should be paid for. In Tunisia, farmers already pay a price set by water authorities for wastewater. However, due to the bad management of the service, they are not satisfied with this price. Also, Saldias et al. [59] demonstrate that the type of management and the reliability of the service matter.

## 4. Discussion

Through using a rapid review methodology, this study aimed to delve into the socio-behavioral factors influencing farmers' use of wastewater for irrigation in agriculture. Our findings indicate that despite the considerable potential of wastewater to serve as an alternative resource capable of alleviating the pressures of impending water scarcity and reducing water and ecosystem pollution, its widespread adoption requires attention on users' socio-psychological factors.

The trend regarding the number of publications on this topic is increasing, with 56% of the analyzed records being published in the last 6 years. Since climate change is increasingly perceived as a global threat to agriculture, a growing number of scholars are focusing on using wastewater as a viable solution for coping with water scarcity [72–74]. The necessity for research in this field is also due to evolving legislation, as international political agendas prioritize wastewater to address pressing water scarcity issues and ensure sustainable agricultural practices. In this context, it is worth mentioning the European Green Deal, which, through the Circular Economy Action Plan, emphasizes the need for improving water use efficiency in agriculture. Additionally, the Water Framework Directive pursues similar objectives, focusing on the safeguarding of European water bodies from both qualitative and quantitative points of view.

The quantitative concerns are primarily associated with arid regions, where water scarcity is more intense. For this reason, wastewater has gained a high degree of importance [56–58] in these areas. Most documents included in this review focus on study areas situated in regions of the world characterized by average annual temperatures ranging from 13 to 29 degrees Celsius, commonly referred to as arid and semi-arid areas.

As for the socio-behavioral factors driving farmers' adoption of wastewater, one of the most pressing issues is the perception of risks. When individuals evaluate the likelihood of negative occurrences resulting from hazardous activities and technologies, they express their risk perceptions through subjective judgments that translate into attitudes, perception, and beliefs [75]. In line with this, our results deal with risk perceptions related to the environment, health, and climate change. Findings indicate idiosyncratic viewpoints among farmers. Some authors highlight a positive attitude towards the utilization of wastewater. This positivity stems from the presence of nutrients, which have a beneficial impact on crop production and reduce the need for fertilizers [27,49–51]. Other authors, however, highlight that the presence of contaminants and pathogens in the water translates into concerns for farmers who fear for the health of aquatic ecosystems and soil. This heterogeneity of perceptions was not found regarding health risks where the perception is universally negative but varies in intensity depending on the farmer's knowledge of the practice. This is confirmed by recent studies in the literature underlining various factors that influence farmers' risk perceptions, culminating in a collection of widely acknowledged aspects such as environmental attitudes, practices, knowledge, information, experience, and culture [29,31,76].

The results show that the yuck factor, depending on the cultural perception of risk, is identified by farmers as a relevant barrier in wastewater use [24,57]. Another dimension associated with cultural influences on beliefs and perceptions pertains to the role of religion. In Arab countries, where religion significantly shapes individuals' daily lives, the utilization of wastewater has been a subject of intense debate. Indeed, findings indicate that religious beliefs do not hold statistical significance in influencing wastewater usage. This is supported by the Organization of Eminent Scholars in Saudi Arabia, who have permitted the utilization of wastewater for all purposes, encompassing both religious and secular domains [61]. However, as only a few studies have analyzed this domain, further investigation would be needed to exclude religious beliefs from determinants of wastewater adoption. Further results concern the perceptions of institutions. The delay in implementing regulations and standards regarding wastewater is associated with low levels of stakeholder engagement, which are crucial for effective environmental governance. Additionally, a lack of institutional coordination is commonly highlighted to hamper the implementation of reuse projects [38,43,62]. Accordingly, Khalid et al. [77] recognized the need to adequately adhere to laws and regulations on wastewater use in the agricultural sector, especially in developing countries. Moreover, Saliba et al. [78] argue that enhancing communication and conducting awareness campaigns based on stakeholders' perspectives are essential for informing the public about the different facets of wastewater reuse. The wide range of factors impacting the determination of intention is confirmed by the findings concerning WTP. WTP, considered as an expression of intention, shows significant heterogeneity across countries. This relates to country-specific socio-cultural aspects, reflecting the different attitudes toward wastewater in agriculture.

## 5. Conclusions

Wastewater use has the potential to help farmers cope with water scarcity, mitigating the increasingly negative effects of climate change in agriculture and representing a valid option for the sustainable and circular reuse of natural resources. Our findings provide an overview of the antecedents (beliefs, attitudes, perceptions) of farmers' behavior towards the adoption of wastewater for irrigation. More specifically, the antecedents are categorized into seven thematic areas: (i) environmental risks, (ii) health risks, (iii) perceptions of public institutions, (iv) knowledge of the practice, (v) religious beliefs, (vi) yuck factor, (vii) attitudes towards climate change, and (vii) willingness to pay. The heterogeneous socio-behavioral factors and their role in influencing farmers' acceptance and adoption of wastewater echo the call for policymakers to incorporate considerations of behavioral antecedents into the formulation of agricultural policies. One key recommendation stemming from our analysis is to prioritize education campaigns aimed at promoting the use of wastewater in agriculture. By increasing awareness through the dissemination of information about this valuable resource, policymakers can encourage more sustainable and efficient agricultural practices while also addressing public concerns and beliefs.

In summary, our study emphasizes the importance of considering the socio-behavioral aspects of farmers' decisions. By acknowledging the diverse aspects of human behavior and integrating insights from behavioral science, policymakers can improve the effectiveness, relevance, and sustainability of agricultural policies in addressing future challenges.

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