

Review

# Risk-Yuck Factor Nexus in Reclaimed Wastewater for Irrigation: Comparing Farmers' Attitudes and Public Perception

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**Abstract:** The successes and failures of water reuse schemes are shaped by complex interrelationships between technological, economic, and socio-political factors. However, it has long been recognized that the main challenges to more effective water management are largely social rather than technical. This article reviews the recent literature (2007–2017) to analyze driving factors associated with farmers' concerns and public perception of reclaimed wastewater for irrigation. The aim of the paper is to synthesize how both environmental and health risks and the yuck factor could be addressed in order to promote mutual understanding between farmers and the public. Results show: (1) how farmers and the public perceive environmental and health risks in a similar way, (2) how the yuck factor is more noticeable for the public than farmers, and (3) how constructed wetlands, reclaimed water exchange consortiums, product certification, and direct site visits to water reuse infrastructure could be promoted in order to foster understanding between farmers and the public. The article concludes by providing key research questions for managers and public authorities relating to how to focus on the study of technical and social issues related to water reuse.

**Keywords:** water reuse; risks; yuck factor; farmers; public; perception

## 1. Introduction

Pressures from climate change [1], drought and water resource competition [2,3], and urban growth [4] have put a significant strain on freshwater supplies. Consequently, more and frequent consideration of using alternative water sources have been promoted as a strategic option to increase water supplies and protect river systems. The World Health Organization has considered driving forces for global wastewater reuse, such as water scarcity and stress, food security issues for increasing populations, and environmental pollution from improper wastewater disposal. Agriculture is one of the most vulnerable activities to water scarcity, as it accounts for 70% of global freshwater withdrawals and more than 90% of consumption [5]. Alternative solutions focused on water supply have been promoted in order to address this gap. Some examples are the control and reuse of runoff water [6], desalination of seawater [7], cloud seeding [8], and wastewater reuse [9]. Water reuse was applied to address not only urban and industrial purposes but also agricultural ones [10]. Although reclaimed wastewater for irrigation supports farmers' livelihoods, detailed information regarding the volume of wastewater generated, treated, and used at national and regional scales is unavailable, limited, or outdated [11]. A report by Hamilton et al. [12] tried to deepen on reclaimed water use for irrigation at a global scale, obtaining as a result a value around 20 Mha of land irrigated with reclaimed wastewater

globally. A decade later, Thebo et al. [13], through a GIS-based analysis, was able to estimate that about 6 Mha of land is irrigated using reclaimed wastewater, and about 30 Mha of land is irrigated with diluted or untreated wastewater. This roughly corresponds to 10% of the world irrigation surface area, and to 277 km<sup>3</sup> of wastewater over the 864 km<sup>3</sup> (treated or not) disposed annually [14].

The need for increasing reuse of wastewater in agriculture is not only circumscribed by arid climate and limited to developing countries. Moreover, it is considered a primary objective also for developed countries in which freshwater is still not considered a limiting resource, e.g., USA and EU [15]. Ordinarily, many regions at a world level are exploring the use of alternative water resources in response to emerging water scarcity challenges [16,17], current and future water shortages [18,19], and growing pressures on global water resources [20,21]. As half of the global water bodies are seriously contaminated, wastewater treatment and reuse promote environmental security by alleviating the pollution of freshwater resources, and providing water supply for irrigation [22]. Additional advantages of wastewater reuse could include: (1) a reliable source of nutrients (nitrogen, phosphorus and potassium), and the provision of organic matter to be used in maintaining soil fertility (*fertigation*) and productivity [23,24]; (2) a sustainable water supply source using less energy and costs than other options (e.g., importing water, and desalinated water) [25]; (3) a source able to avoid the resulting impacts of new water supply equipment (e.g., dams) [26]; and (4) a reduction of pollutants discharged to river systems and the environment [27,28]. Conversely, lack of widespread public support and technical implementation are some of the main barriers to be addressed by reclaimed wastewater promoters. Moreover, a major barrier to effluent reuse is the potential and perceived risk to human health and the environment [29]. For agricultural use, quality standards of reclaimed wastewater depend on the type of treatment (primary to tertiary) used [30,31]. According to Tsagarakis et al. [32], primary treatment can be applied for irrigation (forested land and parks in a controlled way). Secondary treatment is appropriate for trees (olive tree, vineyards, etc.), and tertiary treatment is appropriate for all types of cultivations consumed by human beings. However, sources of reusable water may contain a wide array of hazards including microbial, chemical, physical, and radiological agents [33]. Different benchmarks for improving wastewater treatment plants (WWTPs) have been applied over the years, including regional and national regulations to assess basic parameters, such as total suspended solids, (bio)chemical oxygen demand, nitrate, phosphorus, and fecal coliforms or *Escherichia coli* [34]. Nevertheless, emerging contaminants and regulated compounds detection at very low concentrations needs advances in analytical techniques able to report adverse effects [35].

Although technical aspects of wastewater reuse have often been considered a priority [36], social concerns, such as farmers' predisposition to use, and public' attitudes to consume food from reclaimed wastewater, call for more attention [37,38]. Notions of risk are social constructions deeply embedded in historical, social and cultural context, which are perceived differently by individuals, communities, decision-makers, and water managers [39,40]. The starting point for any risk analysis is the setting of a tolerable level of risk able to ensure the lowest order of magnitude of pathogen reductions for producers (WWTPs managers and farmers), while protecting the consumer (public) health [41]. Results obtained from risk analysis can motivate resistance or rejection (yuck factor) attitudes from both farmers and the public as producers and consumers of food. The yuck factor can be described as the feeling of dread and disgust that is associated with consuming or buying agricultural products produced with reclaimed wastewater. The yuck factor has also been defined as a 'psychological repugnance', 'disgust', or 'profound discomfort' [42]. Furthermore, authors like Ormerod and Scott [43] argue that the yuck factor is based on social and cultural perceptions of risk. According to this, opinion influences intention to accept, and intention influences behavior. While previous research has investigated farmers' attitudes towards alternative water sources or compared farmers' perception of reclaimed wastewater with environmental risks, little research has explored public perception. Even less common are studies that compare the attitudes and preferences of farmers with those of the public, deepening on social and cultural issues. This paper aims to synthesize current knowledge about driving factors affecting water reuse in agriculture by considering

both technical and social approaches. The specific objectives are: (1) to identify the main risks perceived by both farmers and the public according to the literature (2007–2017); (2) to deepen on the yuck factor expressed by both farmers and the public in order to summarize the motivations of the first to use and limitations of the second to buy food produced with reclaimed wastewater; and (3) to highlight strategies and recommendations able to promote a better comprehension of risk–yuck factor nexus.

## 2. Data and Methods

To address our three specific objectives, we applied a systematic approach to screening available literature on identified and perceived risks and the yuck factor of wastewater reuse. Data collection has been obtained from the screening approach able to combine a pondered sample with a comprehensive analysis of the literature [44]. Consequently, data analysis is twofold: an inductive–deductive coding approach for reviewing the literature [45] mixed with qualitative content analysis able to identify significant insights about perception and attitudes [46].

### 2.1. Data Collection and Search Terms

The review process has been applied to eight different databases, four of them in English language (Web of Science, Scopus, ProQuest and Directory of Open Access Journals), and another four in Spanish language (Latindex, Dialnet, Scielo, Consejo Superior de Investigaciones Científicas—CSIC database). These databases were selected due to their availability as the most current, powerful, comprehensive and widely used search engines for peer-reviewed literature [47]. We are aware that other forms of knowledge, based on reports, technical issues or guidelines (so-called grey literature), are relevant for addressing this issue, and consequently, they are considered for discussion.

The iterative procedure was conducted by the first author of this paper within a time frame of 12 months (from February 2017 to January 2018). The search was conducted every month (12 times in total) in order to add new results to the first search. To have an orientation of how many references were published since the last search done (January 2018), an update of the literature screening was conducted in November 2018. Consequently, 13 additional references were returned when applying the search terms. Although these references were not included in the analysis, some of them have been considered in introduction and discussion sections. The process started with a matrix of predefined technical and social parameters from existing knowledge on wastewater reuse. The matrix was further polished in order to be applied in each English language database (and later transcribed to Spanish language). In each English language database, the search process has benefited from the use of web interfaces applied to the title of the research paper, including search string operators such as OR operator (for technical terms, such as innovations, mechanisms, and parameters) and AND operator (for social terms, such as attitudes, beliefs, and perception). In order to identify relevant literature, we combined different search terms from technical and social parameters. The specific search keywords used were as follows (\* represents a search engine wild card):

- Technical terms: recycle\*, recla\*, alternative, non-conventional water resources, water reuse, wastewater, greywater, desal\*, sea water, treat\*, and environment\*
- Social terms: percept\*, attitude(s), belief(s), acceptance, resist\*, disgust, support\*, oppos\*, yuck factor, agreement, impact, benefit(s), participat\*, public, farmer(s), irrigator(s), and stakeholder

### 2.2. Screening, Extraction, and Multifocal Approach

The papers returned by the different databases were positively considered for content analysis based on the inclusion criterion at three successive levels: title, abstract, and full text. On each level, the compliance of the content analysis to each or more than one criterion was examined (Table 1). Papers clearly focused on social attitudes and environmental issues, and those including transversal

analysis from studies such as geography, agronomy, environmental sciences, economics, and sociology have been prioritized.

**Table 1.** Admission/exclusion criteria used in the search terms process.

Criterion	Include	Exclude
Peer-reviewing	Peer-reviewed	Everything else
Year	2007 ≤ Y ≤ 2017	Everything else
Geo-location	Global, focused on water stressed countries/regions	Everything else *
Text language	English, and Spanish*	Everything else
Final water use	Irrigation, agriculture	Urban, industrial, environment, and landscape
Method	Qualitative, mixed	Only quantitative (technical)
Highlighted topics	Perception, yuck factor, risks, benefits, impacts, and regulation	Only agronomic values, chemical parameters, and modelling

Source: Adapted from Flávio et al. [48] and Pearce et al. [49]. Note: \* Spanish references have been considered for the whole analysis after observing how most of the literature published in English have been focused on Spanish case studies and social learning processes.

### 2.3. Selection Process

The initial database search retrieved 1725 documents (Table 2). For the purpose of this study, only records from peer-reviewed periodicals (article and state-of-the-art papers) were included in the systematic review. Therefore, books and book chapters, proceedings papers, PhD thesis, research projects report, or industry and government documents were excluded from the systematic review but were used for the thematic review that helped to identify key terms. After screening for peer-reviewed papers, the number of appropriate articles was reduced to 1265 papers (73.3% of the initial amount). From there, a research category selection has been applied to each database. In Web of Science, the selected research categories were *water resources, environmental sciences and studies, engineering environmental, chemical and civil, agriculture multidisciplinary, agriculture engineering, economics, ecology and agronomy*. In Scopus, we selected similar categories: *agricultural and biological sciences, environmental sciences, social science, engineering, economics, econometrics, and finance*. Those subjects selected from ProQuest database were *agriculture, irrigation, water reuse, wastewater treatment, and water management*, and those subjects included in DOAJ database analysis were *water supply, hydraulic engineering, environmental sciences, agriculture, and chemistry*. In databases including Spanish references, subject and thematic categories have been selected: *Agriculture, Social Sciences, and Multidisciplinary* subjects. The research category selection applied to each database allowed us to prioritize 875 papers (82.9% of the papers from Web of Science and Scopus). The title analysis reviewing led to the exclusion of 463 papers for different reasons: (a) papers were not related to agricultural nor irrigation systems (e.g., off-topic papers), and (b) papers clearly focused on technical aspects and data (e.g., simulation optimization models, chemical methods, and health targets). In addition, a cross-match of the title analysis results from each database was done to remove duplicates. A total of 350 papers moved to the abstract level of analysis, of which 144 papers (n = 144) were selected for full-text analysis after excluding those papers unable to include a minimum reference to social issues (e.g., papers clearly focused on wastewater infrastructure, technical innovation, and wastewater costs). Some limitations of this method must be recognized. On the one hand, obtained results are restricted by the keyword combinations used. On the other hand, interesting papers published after the analyzed period were only included in the discussion section. Finally, using the most representative databases has limited the inclusion of secondary relevant publications, some of them very interesting from the point of view of regional case studies but hardly comparable.

**Table 2.** Papers selected from database search analysis.

Database	Initial Search	Criterion 1: Only Technical Terms	Criterion 2: Social Terms	Title Analysis	Duplicated Papers	Abstract Analysis	Full-Text Analysis
Web of Science	664	506	298	208	-	187	83
Scopus	416	362	251	149	107	42	23
DOAJ	284	158	114	56	14	42	7
ProQuest	118	91	64	32	11	21	5
Latindex	97	72	72	26	-	26	10
Dialnet	88	46	46	16	6	10	7
Scielo	42	19	19	15	2	13	6
CSIC	16	11	11	9	-	9	3
Total	1725	1265	875	511	140	350	144

Note: Criterion 1 (only technical terms) is applied as an exclusion parameter, while Criterion 2 (social terms) is applied as an inclusion parameter.

#### 2.4. Data Analysis

A code book of main parameters used for the content analysis has been defined. The coding process has been focused on 5 main themes composed of 17 sub-themes (data columns) (Table 3), including qualitative (author's affiliation, name of case studies, tools and methods used for the analysis) and quantitative data (number of authors, year of publication) filled-in for each of the 144 references ( $n = 144$ ). Both data have been realized with Excel (Microsoft). Furthermore, qualitative information was classified and grouped in order to highlight main discourses and social-learning processes included in each reference.

**Table 3.** Code book including main themes and sub-themes used for the content analysis.

Theme	Sub-Theme	Codes
General info	Reference ID, Database, Source, Year of publication	4
Authorship	Author's name, Author's discipline, Number of authors	3
Case study	Case study name, Country, Number of case studies, Compared/Isolated	4
Analysis	Method(s) applied, Tool(s) used	2
Content	Title, Keywords, Abstract, Main results and conclusions	4

Note: Source (journal, book, chapter book, PhD thesis, and conference proceedings); Author's discipline (field research includes both social sciences, geography, economy, sociology, management, and politics; and natural sciences, e.g., environment, engineering, hydrology, agronomy, hydrology, biology, and chemistry); country (including regional and local names); methods (qualitative: sociological study techniques; quantitative: focused on technical concerns); mixed: gathering both quantitative and qualitative data, comparisons of technical data, and different ways of modelling driving social interventions); tools (e.g., cost-benefit analysis, water monitoring, questionnaire, interview, and literature review).

### 3. Results from Literature Screening

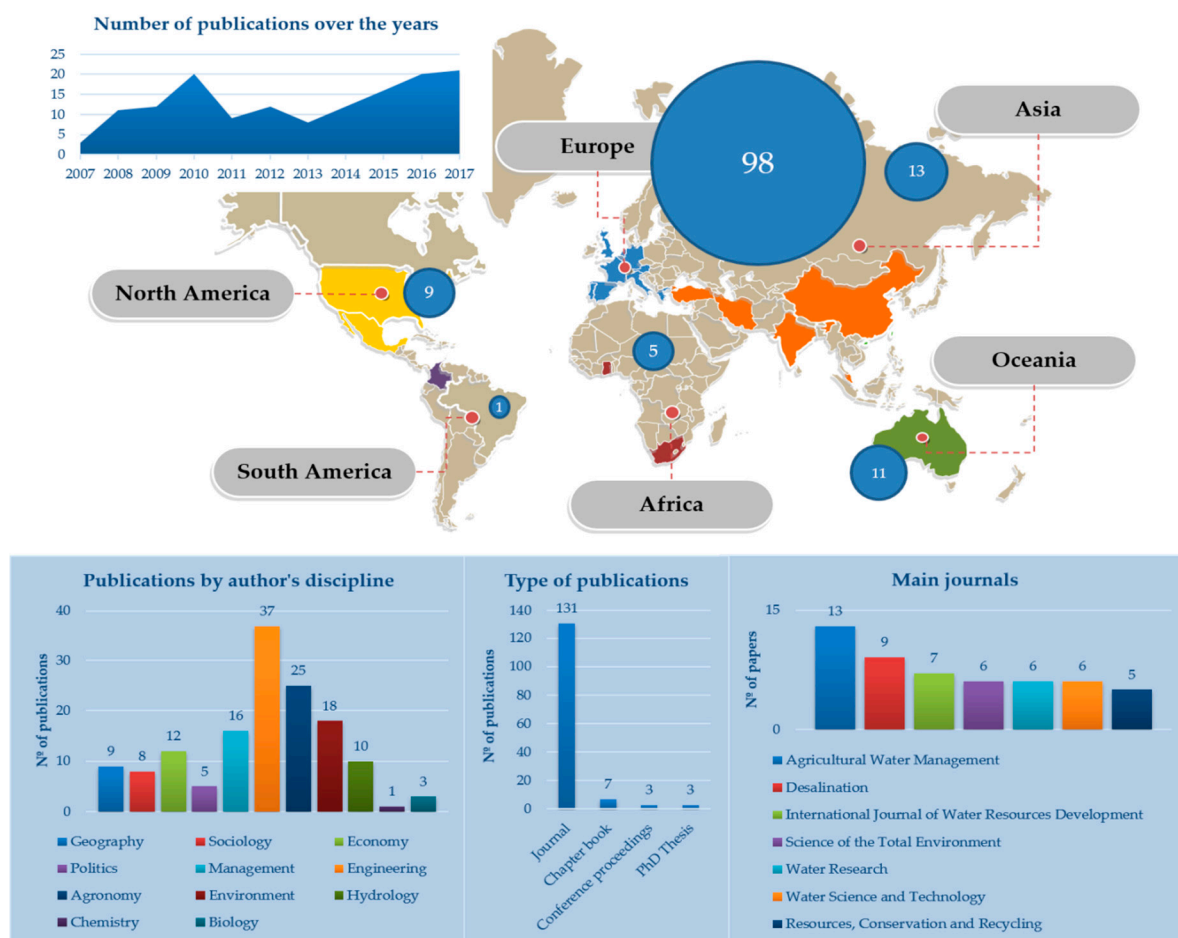
This systematic process for screening literature on the topic of wastewater reuse for agricultural purposes aims to provide an overview of what kind of research studies focused on wastewater risks and the yuck factor currently existing. In addition, questions about how research is framed from different disciplines, in which geographical and temporal context in this research is promoted, and what type of methods and tools are used to deepen on main research topics will be also addressed.

#### 3.1. Publications by Year, Typology, Discipline, and Geographical Context

In consonance with our sample, more than half of the references ( $n = 77$ , 53.5%) were published in the last 5 years (2013–2017), although in 2010 there was an increment of 60% compared to references published in the previous two years. References were mostly retrieved as journal papers ( $n = 131$ , 90.9%), and to a lesser extent chapter books ( $n = 7$ , 4.9%), and PhD thesis and conference proceedings each ( $n = 3$ , 2.1%) (Figure 1). Journal papers were not reduced to a unique school of thought, and they covered a large spectrum of 63 different journals from an extensive field of disciplines, including and combining social and natural sciences. Seven journals collected about 40% of the papers ( $n = 52$ ),

being the journal *Agricultural Water Management* the most cited ( $n = 13$ ). Other journals almost cited were *Desalination* ( $n = 9$ , 6.9%) and *International Journal of Water Resources Development* ( $n = 7$ , 5.3%). Papers from Engineering ( $n = 37$ ), Agronomy ( $n = 25$ ), and Environmental Sciences ( $n = 18$ ) account for more than 55% of the total. However, several research papers include transdisciplinary research profiles able to evaluate stakeholder views, financing and policy implications for reuse of wastewater [50] or to analyze the integrated use of conventional and non-conventional water resources in adapting to drought in a traditional irrigation system [51].

As for the geographical context, by far the most case studies and literature review papers were conducted in Europe ( $n = 98$ , 68.1%), followed by Asia ( $n = 13$ , 9.0%), Oceania ( $n = 11$ , 7.6%), North America ( $n = 9$ , 6.3%), Africa ( $n = 5$ , 3.5%), and South America ( $n = 1$ , 0.7%). It should be noted that 84.7% ( $n = 83$ ) of the papers conducted in Europe are developed in Southern European countries. For example, in Spain ( $n = 63$ , 43.8%), in which studies have been focused on cost–benefit analysis of water reuse projects [52] or deepened on how to put in balance different water sources such as water transfers, desalination, and wastewater reuse [53]. Other studies have been conducted in Greece ( $n = 11$ , 7.6%), in which studies tried to deepen on farmers’ experience, concerns, and perspectives in using reclaimed wastewater [54]. In addition, 7 studies were conducted in different geographical contexts, for example, by comparing public perceptions about desalinated and recycled water in Australia and UK [55], by deepening on food, energy, recycled water, and health nexus in USA and India [56], or by reviewing the current knowledge and future perspectives of benefits and impacts of wastewater reuse in Mexico and France [57].



**Figure 1.** Geographic analysis of selected publications by typology, year of publication, source and author’s discipline. Adapted from Sattler et al. [58]. Note: Template courtesy of [www.yourfreetemplates.com](http://www.yourfreetemplates.com).

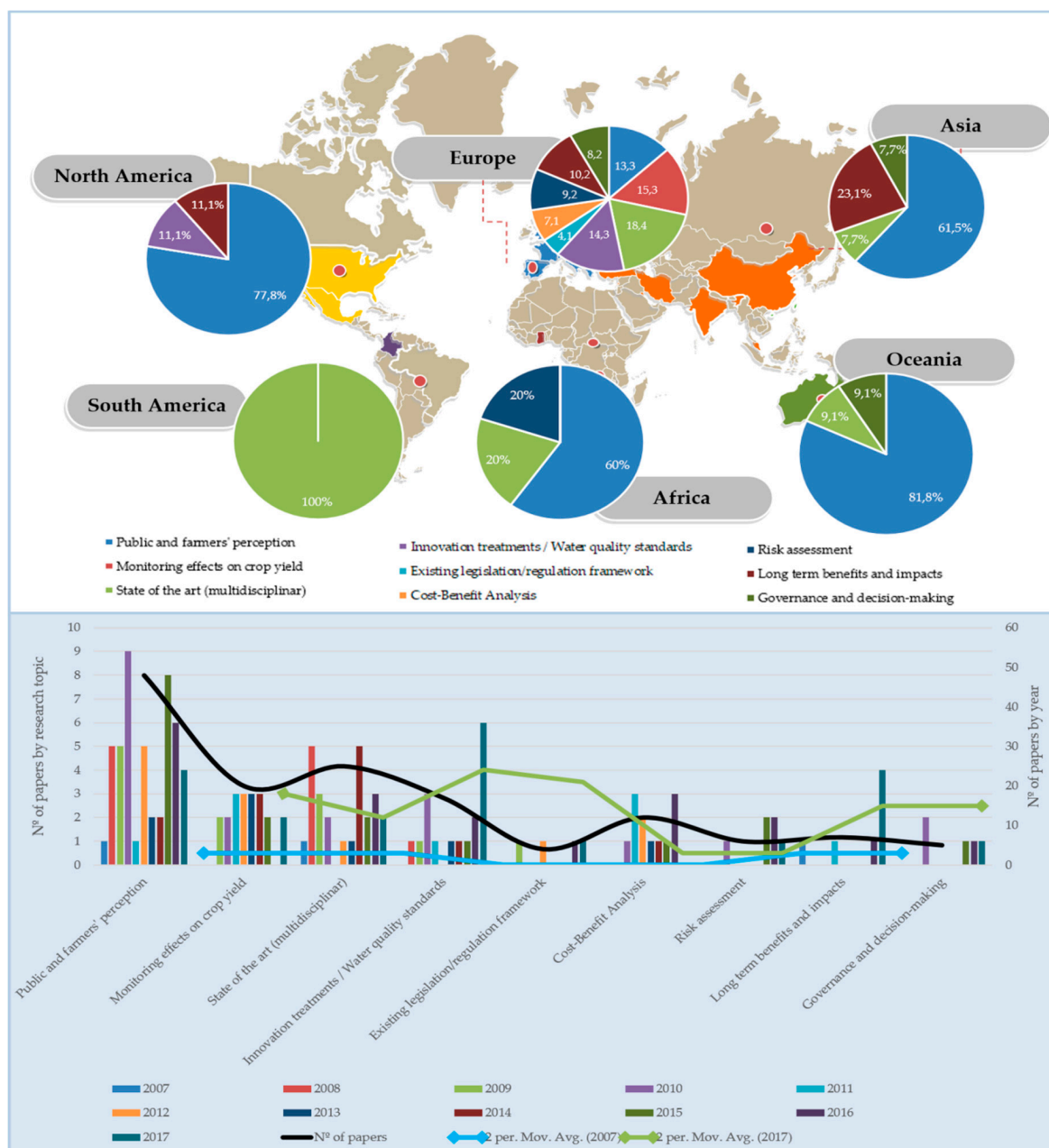
### 3.2. Publication by Research Topics, Case Studies, Methods, and Tools

Nine research topics have been identified to include the overall 144 studies: from issues that are more technical (monitoring effects on crop yield, innovation treatments and water quality standards, cost–benefit analysis, risk assessment, long-term benefits and impacts) to aspects that are more social (public and farmers' preferences, existing legislation and regulation framework, governance and decision-making processes, and state of the art). Public and farmers' preferences is the research topic most cited at a global scale ( $n = 48$ , 33.3%), followed by state-of-the-art papers ( $n = 25$ , 17.4%), and monitoring effects on crop yield ( $n = 20$ , 13.9%). When cross-referencing the main research topics against the geographical context, this reveals that public and farmers' perception is the research topic with more references in all global regions, with about 60% of the references in Asia and Africa and about 80% in North America and Oceania. Exceptions are the region of South America, in which the unique selected reference is a state-of-the-art paper focused on limitations and benefits of wastewater reuse in the agriculture state [59], and the European context, in which the perception topic is ranked fourth ( $n = 13$ ) (Figure 2).

Distribution of reviewed papers per year allows us to analyze how each research topic has evolved over time. Although 4 of the 9 research topics have generated a continuous interest throughout the period analyzed (state of the art, public and farmers' perception, monitoring effects on crop yield, and innovation treatments/water quality standards), some peculiarities can be observed if we take into account annual behavior. For example, while in 2007 public and farmers' perception [60] and long-term benefits and impacts [61] were the interest of the research, a year after, in 2008, the research interest was also focused on public and farmers' perception [62] but state-of-the-art papers [63] were promoted. In 2009, attention was expanded to include topics such as monitoring effects on yield crop [64], innovation treatments [65] and legislation [66], while in 2010 not only cost–benefit analysis and risk assessments [67], but also governance and decision-making debates [68] were conducted. During 2011 and 2012, research interest was focused on cost–benefit analysis [69] and monitoring effects on yield crop [70]. It should be noted how in 2013 and 2014 any paper focused on topics such as legislation and regulation, risk assessment, long-term benefits and impacts, and governance and decision-making. Conversely, these topics have been considered in the last three years of the period (2015–2017), including detailed analysis about effects of saline-reclaimed waters and deficit irrigation assessed by remote sensing [71]. Wastewater reuse potential for irrigated agriculture [72], the use of constructed wetlands for the treatment and reuse of urban wastewater for irrigation [73], and how governance regimes shape the implementation of water reuse schemes [74] have also been considered.

A wide range of methods from qualitative, quantitative and mixed qualitative–quantitative nature has been identified from the literature review (Table 4). Almost half of the studies ( $n = 70$ , 48.6%) employed qualitative methods, while the same proportion of studies used quantitative methods, and the rest of the studies applied mixed methods ( $n = 17$ , 11.8%). Qualitative and quantitative methods are applied according to different aims. Qualitative analysis aims to understand, explore and collect data in order to deepen on a single case study or a regional casuistic. Conversely, quantitative methods are used to provide numerical data and indicators based on a larger number of case studies and experimental plots, which also can be analyzed using statistical and modelling techniques in order to reveal patterns and extrapolate the obtained results [75]. In the 70 studies in which only qualitative methods have been applied, literature review ( $n = 44$ , 62.8%) [76], and semi-structured interviews [77] ( $n = 17$ , 24.3%) are the main techniques used for the analysis, followed by other qualitative methods such as focus groups ( $n = 4$ , 5.7%) [78], discourse analysis [79] and protocols [80] (each one with  $n = 2$ , 2.8%), and Strengths, Weaknesses, Opportunities, and Threats analysis (SWOT) [81] ( $n = 1$ , 1.4%). The use of quantitative analysis techniques has included crops monitoring and experimental plot analysis [82], questionnaires and surveys [83], and risk assessment [84], while mixed methods have been focused on decision support systems [85], life cycle assessment [86], cost–benefit analysis [87], and different indicators and tests [88]. Moreover, it has to be noted that most references combine different methods for triangulation of qualitative and quantitative data [89].

For example, when addressing competences for the use of water by using interviews and state-of-the-art techniques [90], and when planning strategies for promoting reclaimed wastewater in irrigation systems by combining interviews and experimental plot analysis [91].



**Figure 2.** Geographic analysis of selected publications by typology, and year of publication. Note: Template courtesy of [www.yourfreetemplates.com](http://www.yourfreetemplates.com).

**Table 4.** Methods and techniques used for the analysis.

Method Type	Techniques
Qualitative methods (sociological study techniques)	Semi-structured interviews, focus groups, discourse analysis, literature review, SWOT analysis, and protocols
Quantitative methods (technical concerns)	Physical-chemical-microbiological analysis, crops monitoring and experimental field, questionnaires, and risk assessment
Mixed methods (qualitative and quantitative values)	Decision support systems, cost-benefit analysis, life cycle assessment

Note: Mixed methods are not the combination of qualitative and quantitative methods but the use of qualitative and quantitative parameters for its calculation.



## 4. Results from Content Analysis

### 4.1. Environmental and Health Risks

The monitoring effects of treated wastewater have been thoroughly studied, although being not always focused on experimental field conditions. However, environmental and health impacts of using wastewater have been clearly identified in our study as one of the main challenges to be addressed, especially in the case of nutrients such as nitrogen and phosphorus, and occasionally potassium, zinc, boron, and sulphur [92]. Literature also cited other pollutants contained in reclaimed wastewater, such as metals, metalloids, residual drugs, organic compounds, or endocrine disruptor compounds [93]. Moreover, the regular use of reclaimed wastewater can modify the minerals, macro- and micronutrients for plant growth, soil pH, soil buffer capacity, and cation exchange capacity, as reported by Bañón et al. [94] or De Miguel [95]. Most of these impacts are perceived by both farmers and the public, as concluded by Buyukkamaci and Alkan [96] in their study about reclaimed wastewater acceptance potential, or by Gu et al. [97] in their analysis of reclaimed wastewater acceptability. However, it is not usual to ask farmers and the public together about perception of environmental and health risks related to reclaimed wastewater for irrigation. In fact, most of the studies were exclusively focused on farmers' perception of environmental risks and in the opposite site public' perception of health risks. On the one hand, we can identify studies like those carried out by Fatta-Kassinos et al. [98], in which drivers of perceived environmental risks of reclaimed wastewater and the possible accumulation of heavy toxic metals in soil and in the various plant parts are directly analyzed. The obtained results of this type of research consider that although farmers are aware of the fertilizing capacity of using reclaimed wastewater for irrigation, they are concerned due to the long-term reuse of reclaimed wastewater and sludge. Another example of studies clearly focused on farmers' attitudes is the study conducted by Mahesh et al. [99], in which although farmers using reclaimed wastewater are aware of, and benefited from, the nutrient content of the water, they are willing to pay for ensuring the best quality of water in order to reduce the stigma attached to reclaimed wastewater-irrigated vegetables. This result is in line with the study of Sheidaei et al. [100], in which farmers expressed their concern about the loss of soil productivity due to the regular use of reclaimed wastewater for irrigation, and the need to ensure reclaimed wastewater quality standards before using it in food production.

On the other hand, studies focused on how health risks are perceived by the public highlighting a spectrum of attitudes from acceptance to resistance when asking for the compliance of food security standards of using reclaimed wastewater for food production [101]. In fact, both food security and food safety are two of the major public concerns when asking for reclaimed wastewater for irrigation. Various studies have demonstrated that bacteria and enteric viruses are present at high levels in reclaimed wastewater [102]. Moreover, these studies proved how viruses are commonly resistant to conventional wastewater treatment processes and disinfection, and they can be spread in the environment by reclaimed wastewater effluents [103]. Furthermore, they are present in domestic wastewater and could be transmitted to the environment because of their low removal in conventional WWTPs and their long-time survival in the environment [104]. Some studies have been focused on asking about these specific health risks in order to know if they are perceived by both farmers and the public. According to a recent study of Saldías et al. [105] conducted in India, when the public are directly asked, about 75% of the respondents claimed that they were aware of the health risks associated with the use of reclaimed wastewater because water quality is not guaranteed. Moreover, about 78% of farmers indicated that they would produce other crops if the quality of water was better (e.g., vegetables for a higher income). However, although farmers had years of experience in using reclaimed wastewater for food production, some studies highlighted how the lack of information about health risks could affect the decision-making capacity of the farmer [106]. Authors like Keraita et al. [107] and Adewumi et al. [108] consider that this lack of awareness could be explained by the fact that: (1) farmers are not consumers of their own food products, and (2)

farmers' unknown the risks perceived by the consumers. Faced with this situation, authors like Paranychianakisa et al. [109] and Deniz et al. [110] express the need for promoting uniform water quality standards taking into account its final use (agriculture), and according to geographical criteria (starting point conditions of water systems) as factors to mitigate human and environmental risks in food production.

#### 4.2. Yuck Factor

Farmers are ultimately the end users of reclaimed wastewater and their decision to use it can promote or break any water reuse project or policy [111]. According to Mojid et al. [112], farmers are often not free to decide if they use or not reclaimed wastewater for food production. Moreover, they pointed out how unlike the public insists on highlighting health risks farmers tend to focus their decision (acceptance or rejection) for using reclaimed wastewater in terms of water quality standards. However, in some occasions, the attitude of the farmer is contradictory: although farmers can publicly express their rejection to use reclaimed wastewater for irrigation based on specific and tested environmental and health risks, farmers tend to reduce their reclaimed wastewater quality standards (food security) when their production capacity is not ensured (food sovereignty) [113]. It is also relevant to observe that farmers tend to support water reuse as a concept, but that support decreases as the degree of reclaimed wastewater use increases [114]. In line with this idea, although farmers tend to recognize reclaimed wastewater functions (such as increasing soil fertility), they are aware of the invisibility of some environmental effects resulting from the regular use of reclaimed wastewater [115]. According to the literature, the main key factors capable of conditioning the perception of reclaimed wastewater include: (1) the quality standards and regulation criteria [116], (2) the capacity of farmers to manage the agricultural hazards from irrigation with reclaimed wastewater [117], (3) societal concerns surrounding reclaimed wastewater for irrigation [118,119], and (4) recognition of the benefits of wastewater reuse in terms of livelihood provision and economic gains [120]. An interesting question referenced by the literature is the relevance of the terminology when asking for the use of reclaimed wastewater. For example, while treated wastewater implies that the effluent described has been transformed from its previous (polluted) state, recycled wastewater suggests a return towards an even earlier, purer source material [121]. The use of terminology also affects the farmers' willingness to pay for using wastewater: in some occasions, farmers accept to pay for reclaimed wastewater if this is described as 'recycled water' rather than as 'treated wastewater' [122]. In line with this, as the cost of reclaimed wastewater is an important factor in encouraging farmers for using wastewater, and in order to gain acceptance of wastewater reuse, most water reuse projects involve a direct or indirect subsidy, that is, suppliers tend to offer reclaimed wastewater at concession prices, especially in Europe [123].

Although previous studies have been focused on farmers' perception, most of the literature tends to deepen on how the public perceives wastewater [124]. Although the generalization of perceptive studies has not resulted in a generalization of the applied methodologies (each study tends to apply specific questions, different concepts, and combined analysis techniques), public acceptance regarding reclaimed wastewater for irrigation ranges from as low as 40–50% to as high as 70–90% [125]. The lowest percentages could respond to different reasons: (1) many citizens can perceive health risks or suspect about appearance, color and odor of reclaimed wastewater [126]; (2) communities could suspect that wastewater reuse was being promoted in secret and that their environmental and health concerns were being ignored [127]; or (3) water reuse organizations failed to adequately promote the benefits of their operations [128]. Studies conducted by Leong [129,130] suggest that public acceptance of reclaimed wastewater for food production is the result of the combination of multiple factors, including attitude and emotion, subjective norms (influence of people around you), knowledge or information about the water scheme, perceived risks, trust in water control authority, specific reclaimed wastewater use, water cost, and water scarcity scenarios. Another common assumption collected by Rozin et al. [131] focused on how to overcome intuitive contagion-based thinking involved in public reactions to reclaimed wastewater. According to the authors, one solution is to promote specific

wastewater regulation combined with educational activities, because the more wastewater reuse becomes a norm, the less problematic it will be. Part of this educational and familiarity task could be provided from the media. For example, in a case study conducted by Al-Mashaqbeh et al. [132] in the Jordan Valley, more than 70% of respondents expressed their willingness to learn more about water treatment and reuse. In line with these results, another study conducted by Russell and Lux [133] concluded that there were no compelling arguments or evidences that negative reactions to reclaimed wastewater cannot change by promoting opportunities to learn about associated technical and social issues.

## 5. Discussion

Both successes and failures of water reuse schemes around the world are shaped by complex interrelationships between technological, economic, and socio-political factors. Although successful implementation of innovation and new technologies (basically focused on ensuring reclaimed wastewater quality standards) have been promoted in the last couple of decades, this engineering performance has not necessarily been associated with the analysis of how environmental and health risks are perceived by end users, or how the yuck factor affects decision-making processes at a farm level [134]. Our results highlight that effective wastewater promotion and management are largely sociological rather than technical. Farmers' acceptance seems to decline with increased contact with reclaimed wastewater, whereas the public acceptance seems to increase when they are duly informed of and the extent to which they are familiar with potential benefits and risks as food consumers [135]. This statement is somewhat benefited from an overall process of technological 'legitimation', in which attention has been focused on the improvement of reclaimed wastewater treatments [136]. However, some weaknesses have been identified when farmers have to validate this technical progress: fragmentation in policy and regulation measures, limited long-term strategic planning, lack of demonstration when developing wastewater projects, and inadequate community participation [137]. In line with our findings, a recent study conducted by Saliba et al. [138] reinforces the idea that acceptance of wastewater cannot be achieved simply by technological innovation able to reduce environmental and health risks (as assessed by some experts). Furthermore, recent studies have illustrated that the inclusion of reclaimed wastewater as part of the water cycle is a more significant driver of public and farmers' acceptance than insisting in justifying the need for wastewater reuse as a solution to water scarcity scenarios or food security issues [139].

In order to normalize wastewater, use for food production by reducing both environmental and health risks, some strategies could be promoted. These strategies aim to promote an integrated management of farmers' concerns for water scarcity and water quality standards, and public' rejection to consume food from reclaimed wastewater. Two of them could be applied taking into account both social and technical dimensions. The first proposal calls for the promotion of constructed wetlands (CWs) as part of the hydrosocial cycle, with the aim to recognize, reflect, and represent water's broader social dimensions [140,141]. CWs are cost-effective treatments able to remove a broad range of contaminants (chemicals such as organic substances, metals and metalloids; and biological organisms, such as bacteria, viruses, and parasites) from municipal and domestic wastewater [142,143]. Although at a technical level WWTPs are effective systems to remove pollutants, they commonly require large capital investments as well as operation and maintenance costs [144]. Additionally, compared to conventional WWTPs, CWs have a lower visual impact and are particularly interesting to treat wastewater from small and rural communities because they can operate with low energy consumption and do not need highly qualified operators [145]. New strategies to move from traditional WWTPs to innovative CWs promoted in some regions from marketing strategies. For example, the government of Singapore (through the Public Utilities Board) launched in 2000 a wastewater recycling demonstration project, in which a portion of the treated effluent from the Bedok Sewage Treatment Plant was diverted to the water purification plant (with CWs similar functions), called NEWater Factory. The use of language is not free: the aim of the promoters was to ensure that the project was well accepted by

the public (providing a visitor center as an education hub to promote water sustainability), and the concept “new” left in a second place the origin (waste) of water. In a more recent study, Dou et al. [146] check the applicability of CWs as an efficient alternative to conventional irrigation methods, with some contrasted Mediterranean examples in Clermont-Ferrand (France), Milan (Italy), and Amman (Jordan).

The second proposal calls for the establishment of Reclaimed Water Exchange Consortiums (RWECs). Reclaimed wastewater for irrigation enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water resource [147]. The Marina Baja Water Consortium, created in 1977 in Alicante (Spain), is an example of reclaimed wastewater exchange between agricultural and urban-tourist water supplies [148]. The aim of the consortium is to guarantee the integrated management of water resources in the region and to maintain water infrastructure (reservoirs, aquifers and wastewater treatment plants) to assist agricultural and urban-tourist water supplies through the exchange of conventional (surface and underground water) and non-conventional water resources (reclaimed water). Furthermore, in drought situations, rainwater is used for urban and tourist water supply, while treated water is used for irrigation. This water exchange promotes cost savings when being compared with the cost of pumping groundwater or diverting freshwater from a river or water-delivery canal, and this also reduces water scarcity by ensuring a regular water provision throughout the year [149]. On the other hand, the additional availability of freshwater can lead to cost savings in ground and surface water extraction or water transfer [150]. Beyond the economic aspect, and although being not absent of punctual conflicts between irrigators and municipalities regarding reclaimed wastewater quality standards, this strategy allows closing the water gap of hydrosocial regions by ensuring water availability and water quality parameters by promoting integrated water management [151,152].

Both proposals are focused on combining technical knowledge (from engineers and managers' expertise) with social learning (from end users and key stakeholders' involvement), and they are also in line with Hartley's [153] postulates about factors contributing to the degree of public and farmers' acceptance of water reuse. The findings, still valid today despite some nuances, suggest that acceptance is higher when: (1) degree of human contact is minimal; (2) protection of public health is clear; (3) protection of the environment is a clear benefit of the reuse; (4) promotion of water conservation is a clear benefit of the reuse; (5) cost of treatment and distribution technologies and systems is reasonable; (6) perception of wastewater as the source of reclaimed water is minimal; (7) awareness of water supply problems in the community is high; (8) the role of reclaimed water in overall water supply scheme is clear; (9) perception of the quality of reclaimed water is high; and (10) confidence in local management of public utilities and technologies is high. CWs and RWECs are able to spread the benefits of reclaimed wastewater for irrigation and to make them closer to farmers and the public at individual and community levels [154]. Moreover, direct site visits to CWs and RWECs could have a significant impact on farmers and the public acceptance of reclaimed wastewater, because studies have shown that although individuals accept experts' opinions on reclaimed wastewater quality, they tend to rely more on their personal impressions and tested benefits [155]. However, this could be not enough. A recent study conducted by Shafiquzzaman et al. [156] focused on consumers' perception of water reuse products shows how it is necessary to develop a Consumer Perception Index (CPI) for assessing reclaimed wastewater reuse potential. The starting point to develop this index is the conception of consumer perception. According to the authors, consumer perception can be described in terms of: (i) a psychological factor which influences their purchase behavior, and (ii) a process by which individuals interpret the information received from the environment about the product. The calculation of the CPI could be useful as the first step to define a reclaimed wastewater product certification able to raise farmers' confidence and public' acceptance. Furthermore, communication should focus not only on the solution (reclaimed wastewater reuse), but also on the underlying problem (water scarcity, water consumption, and water pollution). Some initiatives have been conducted, for example, by promoting more active public engagement methods, such as site visits

to water recycling facilities and water tasting events in which people could be exposed to different water types and food products [157].

## 6. Conclusions

In-depth analysis of the literature highlights how the best way to increase farmers and the public acceptance of reclaimed wastewater reuse for irrigation is by addressing environmental and health risks and the yuck factor together. Both technical issues (risks) and social questions (perception) should be considered as the two sides of the same coin that have to be analyzed together. However, after several decades focused on improving technical questions, effective reclaimed wastewater promotion and management has become a largely sociological rather than technical question. Our analysis shows how farmers' predisposition to use reclaimed wastewater for irrigation tends to decline after years of use due to the tested effects on soil and food productivity, whereas the public acceptance tends to increase when they are duly informed of and the extent to which they are familiar with potential benefits and limited risks as food consumers. The challenge is to identify farmers and public expertise, doubts, fears, and cultural values associated to reclaimed wastewater use in order to systematically address concerns through a framework of educational, policy, and management strategies. Different strategies should be considered, and two of them have been considered in this study (CWs and RWECs), with the aim to promote an integrated management of farmers' concerns for water scarcity and water quality standards, and public' rejection to consume food from reclaimed wastewater. The success of both depends on the ability to promote new forms of interaction between farmers and the public from creative methodologies. These methodologies should be able to overcome stereotypes, prejudices, and even false beliefs about reclaimed wastewater reuse without minimizing existing risks and technical limitations. A methodological proceeding crosses disciplinary boundaries of water resources management and policy, extending it to the social sciences with the aim to deepen on how cultural values are able to affect decision-making processes and attitude change. To address this gap, it is essential that engineers and social scientists work together. Engineers can provide the best, safest, and efficient solutions to ensure water quality standards, whereas social scientists can facilitate better understanding of the reasons that explain rejection or acceptance from farmers and the public perception to reclaimed wastewater for irrigation. Moreover, managers can take profit of this coupled technical-social approach to promote holistic water management between urban and agricultural water use.

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