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Intervention strategies for the safe use of semi-treated wastewater by Iranian farmers: An approach for safe food production in the circular economy

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ABSTRACT

The safe use of wastewater in irrigation practices in developing countries, and especially regions with water shortages, is an issue of concern for policymakers and society at large as the unsafe use of treated or semi-treated wastewater can pose potential risks to the environment, the safety of agricultural products and ultimately food safety. The implementation of supplementary parameters surrounding irrigation conditions with treated or semi-treated wastewater at the farm level depends on the behaviours of farmers, with psychological factors coming into play. Furthermore, accurate intervention strategies can guide farmers towards the safe usage of wastewater for irrigation. In this study, we have used survey data from Mashhad County in Iran to test the components of the theory of planned behaviour, including the effects of two intervention strategies, namely government enforcement and cooperative involvement, on farmers' safety behaviours when it comes to using semi-treated wastewater for irrigation practices. Structural equation modelling was employed for the analysis. The results show that the three key components of the theory of planned behaviour, that is attitude, subjective norms, and perceived behavioural control, have a significant impact on the intentions of farmers to engage in the safe use of semi-treated wastewater for irrigation. Additionally, cooperative involvement is more effective for the farmers than government enforcement. This suggests that there should be an increase in the official support available for agricultural cooperatives that operate as wastewater collectives.

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KEYWORD Agri-product safety; municipal wastewater treatment; theory of planned behaviour; irrigation; cooperatives

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1. Introduction

One of the most important actions for dealing with water scarcity and protecting the environment is the treatment of municipal wastewater and its reuse, especially in the agricultural sector (Scheierling et al., 2011, Wichelns and Drechsel, 2011). According to the 2017 UN World Water Development Report, approximately more than 80% of wastewater (and about more than 95% in some developing countries) is released into the environment without treatment (UN-Water, 2017). Reusing reclaimed water, especially for irrigation purposes, is a contribution to the circular economy (Lahlou et al., 2021) and as water scarcity increases in many parts of the world, economists have long advocated for employing reclaimed wastewater in irrigation practices (Dinar, 2024). Water scarcity and the reuse of reclaimed water is such an important matter that the EU has even issued a guideline for it (EU Commission, 2022). Back to the definition, treated wastewater is wastewater that has been processed through a wastewater treatment plant (WWTP) up to certain standards and its pollutants or health hazard components are reduced. If these standards are not acquired, the wastewater is considered at best as partially treated (also named semi-treated) wastewater (Jiménez et al., 2009). Despite benefits that are assigned to the use of wastewater in agriculture such as year-round availability and fertiliser cost-saving (Reznik et al., 2019), the unsafe use of wastewater for irrigation can pose potential risks to the environment, the safety of agricultural products and ultimately food safety (Rong-guang et al., 2008). Potential risks arise because almost two-thirds of municipal wastewater is often used without any treatment (Trinh et al., 2013, Khanpae et al., 2020). Different types of wastewater and their applications can be illustrated as (UNW-DPC, 2013): 1) direct use of untreated wastewater from the sewerage system for irrigation on the farm, 2) direct use of treated wastewater occurs after wastewater has undergone a treatment before irrigation, 3) the downstream farmers' indirect use of treated or untreated urban wastewater when water from a river mixed with treated or untreated urban wastewater, 4) planned use of wastewater which means the conscious and controlled use of wastewater either raw (i.e. untreated) or diluted (i.e. treated). Most of the indirect use of wastewater for irrigation occurs without planning. Untreated, partially treated, or mixed wastewater is used for agricultural purposes around the world. This is mainly because many cities, especially in developing countries such as Iran, cannot afford the cost of wastewater treatment (Sheidaei et al., 2016, Khanpae et al., 2020). According to the WHO guideline (WHO, 2006), the main components of wastewater that can affect soil and crops are nutrients, salts and ionic elements, metals, pathogens, toxic organic compounds, organic matter, suspended solids, acid and bases (Rahman et al., 2018a). Nutrients consisting of components such as nitrogen, phosphorus and potassium are fertilizers for crops but

higher concentrations could be in excess of crop needs and risk to the environment (Rahman et al., 2018a, UNW-DPC, 2013, Qadir and Scott, 2009). Higher concentrations of salts and ionic elements such as sodium, boron or chloride which are available in wastewater increase the electric conductivity (EC) and are harmful to both crops and humans. Furthermore, higher concentrations of metals such as cadmium, chromium, nickel, zinc, lead, and arsenic in wastewater are toxic for humans and harmful to plants (Rahman et al., 2018a, UNW-DPC, 2013, Qadir and Scott, 2009). Additionally, pathogens like bacteria (such as *Salmonella Typhi* or *Vibrio cholerae*), viruses (such as Hepatitis A), and worms (such as *Ascaris lumbricoides*) which are available in wastewater can cause diseases like typhus, cholera, hepatitis epidemic or ingesting of worm eggs (Rahman et al., 2018b). Therefore, wastewater use for irrigation imposes different health risks to farmers, food chain workers and consumers due to possible microbial and chemical contamination (UN-Water, 2017). The level of these risks depends on the treatment level, type of irrigation and local conditions (Rahman et al., 2018b). As a result, some supplementary actions should be taken for the safe use of treated or semi-treated municipal wastewater, especially in developing countries (Esfandiari et al., 2022). Nevertheless, these supplementary actions are lacking in many countries and they need social acceptance and there should be no misconception or resistance against them by farmers. For instance, Rodriguez et al. (2020) have reported the farmers' opposition to the use of treated wastewater instead of untreated wastewater in Latin America as they believed the wastewater nutrients have been removed through treatment in WWTPs. Therefore, farmers are at the midpoint of the safe application of wastewater for irrigation that should not be neglected by policymakers. In another case, in a recently published report by the Iranian Parliament, the investigatory parliamentary commission has announced its concern on the application of untreated/semi-treated or treated wastewater in irrigation practices in more than 48,000 ha of agricultural fields all over the country. The investigatory report shows that contaminated effluent is used for irrigation of cereals, fruits and vegetables without employing any compliances in many parts of the country, especially around the capital city of Tehran which endangers the health of many consumers of food products. The reported information from the Food and Medical Organisation to the parliamentary enquiry shows dangerous levels of toxic particles in different fruits and vegetables. Interestingly, the parliamentary report does not provide any suggestion that targets the farmers' behaviour for the safe use of unconventional water for irrigation. In its proposal, the report focuses on different administrative actions, orders or plans for the government such as building new small or large WWTPs, separating trash and sewage from their origin or imposing further compliances on the application of pesticides or herbicides which are probably very costly to be implemented and out of the capacity of the Iranian government. Even the report confesses

that despite having legal punishment for using unauthorised wastewater, as long as water scarcity is available, the ban of farmers from using wastewater for irrigation is not possible (Islamic Consultative Assembly,¹ 2023).

In this regard, the safe use of treated or semi-treated municipal wastewater depends on several aspects, such as crop management, irrigation methods, irrigation interval from harvest time, and post-harvest methods, which can be effective in reducing crop contamination (Janeiro et al., 2020). In connection with product management, the World Health Organization (WHO) has proposed different plant groups such as raw, cooked, or processed plants and industrial plants according to the microbial contamination of treated or semi-treated wastewater (WHO, 2006, Esfandiari et al., 2022). Therefore, selecting the best cultivation pattern in proportion to the quality of treated or semi-treated wastewater can play an important role in reducing crop and food pollution (Vali, 2016, Janeiro et al., 2020). Choosing the right irrigation method is another parameter that can reduce the contamination of products irrigated with treated wastewater (Keraita et al., 2007a; Esfandiari et al., 2022, Drechsel et al., 2022). For instance, localized irrigation (e.g. surface and subsurface trickle irrigation) causes less pollution than flooding and sprinkler irrigation (Moradinejad, 2019), as the irrigation water is applied at the root area, thus reducing the direct contact between products and the recycled water (Drechsel et al., 2008; Keraita et al., 2007a). Additionally, research has shown that stopping irrigation with effluent before harvest reduces pollution. Therefore, for each day that irrigation doesn't happen, the amount of pollution decreases significantly (Keraita et al., 2007b; Drechsel et al., 2008, Drechsel et al., 2022).

The implementation of the mentioned supplementary parameters in irrigation conditions with treated or semi-treated wastewater at the farm level depends on the behaviour of farmers. If farmers use the treated or semi-treated municipal wastewater safely, the risk of contamination can be greatly reduced. However, the behaviour of farmers depends on economic, social and psychological factors. Psychological factors are the most important dimension of farmers' decisions and can make farmers more responsible for their behaviour (Savari and Gharechaei, 2020). Therefore, it is necessary to understand the factors that affect farmers' behaviour surrounding safe handling of wastewater utilisation that can help improve crop health and food safety. Most studies on the use of municipal wastewater in agriculture focus on its acceptance by farmers and farmers' attitudes towards using treated wastewater for irrigation. However, there is limited information on the psychological factors that influence the practices of farmers surrounding safe behaviour when using treated or semi-treated wastewater.

¹The Islamic Consultative Assembly or Majlis is the official name of the Iran's parliament.

Another issue of concern is the intervention strategies to guide farmers' safe behaviour. Intervention strategies can be divided into educational strategies (Gil et al., 2015, De Leeuw et al., 2015), information strategies (Gil et al., 2015, Wang et al., 2021) and structural strategies (Wang and Lin, 2020). Educational and information strategies are designed to change people's motivations, perceptions, knowledge, and common norms (Abrahamse et al., 2005, Steg and Vlek, 2009, Wang et al., 2021). Social organisations such as cooperatives play a vital role in educating and sharing specific information among farmers (Holland, 2018). Structural strategies are designed to change the conditions under which behavioural choices are made. Such strategies include changes in the availability, costs, and actual benefits of the alternative behaviours. Enforcing the law and imposing certain types of penalties on those who violate them is one way to change costs and benefits of alternative behaviours, which provides a viable structural strategy (Steg and Vlek, 2009, Abrahamse et al., 2005, Wang et al., 2021). The sustainability of these policy instruments requires action and implementation by local governments. The effectiveness of these strategies depends on farmers' perceived impact of government enforcement and cooperative involvement (Dawkins et al., 2019, Wang et al., 2021).

Theories in the field of environmental psychology are suitable for assessing people's behaviour (Bamberg, 2013, Onwezen et al., 2013). The theory of planned behaviour (TPB) is one of the most useful socio-psychological theories for predicting pro-environmental behaviours (Faisal et al., 2020). This theory has been applied to a wide range of behaviours, such as agricultural wastewater treatment (Wang et al., 2021), environmental protection (Hameed et al., 2019) and adoption of on-farm silos (Vaz et al., 2020). Furthermore, the application of the TPB and other behavioural models to find the socio-psychological factors affecting the adoption of sustainable agricultural innovations has increased our knowledge of adoption practices (Rosário et al. 2022).

Based on a careful review of the existing literature, we noticed that a comprehensive study that 1) determines the psychological factors affecting farmers' behaviours in the safe use of wastewater in irrigation practices and 2) evaluates the effectiveness of the intervention strategies (considering the social acceptance of the intervention policy) in the context of the developing countries, is lacking. Therefore, by focusing on semi-treated wastewater, we intend to contribute to the existing literature by providing empirical evidence on farmers' behaviours in the safe use of semi-treated wastewater in Iran. As a result, this research has three main objectives related to the farmers' behaviour in using semi-treated wastewater. First, the circumstances that farmers have accepted to exchange their irrigation water quota from freshwater resources for semi-treated wastewater are analysed and illustrated. Second, as the TPB has successfully explained

various types of environmental behaviours (Wang and Lin, 2020), this study utilises it to identify the psychological factors affecting farmers' behaviours in the safe use of wastewater. Subsequently, this study evaluates and compares the effects of two intervention strategies, namely cooperative involvement and government enforcement, on the safe behaviour of farmers using semi-treated wastewater in Iran. Therefore, farmers' behaviours were analysed by testing the TPB via employing structural equation modelling (SEM).

In this way, primarily, in the case of the classical TPB model, the present study identifies the relation between farmers' behaviour in the safe use of semi-treated wastewater, behavioural intentions, and the three main components of TPB, namely attitudes (ATT), subjective norms (SN), and perceived behaviour control (PBC). Second, the present study proposes and tests an extended TPB model to examine intervention strategies. Finally, using the extended TPB model, the present study compares intervention strategies for policy-making towards safe food production considering the utilisation of semi-treated wastewater. The field research for this study was carried out in the Northeast of Iran in the Mashhad County, an area facing a severe water shortage, thus causing farmers to use semi-treated wastewater for irrigation. This is despite the fact that there are limitations for using recycled water (e.g. cultivation patterns, irrigation methods, and harvest time). Cooperative involvement and government enforcement were considered as the two intervention strategies that could be applied in this case. Based on the results, cooperative involvement and government enforcement are both effective intervention strategies leading to the safe use of wastewater, although cooperative involvement displays more of an effect on this. In the next section, the conceptual framework and research hypotheses are presented and the methodology is described in the third section. The results and discussion are provided in sections four and five, and finally, the conclusion is summarised.

2. Conceptual framework and research hypothesis

In this section, we look to the available literature on the application of the TPB to explain the farmers' behaviour and develop a conceptual framework and research hypothesis. Furthermore, the conceptual framework is extended by considering the intervention strategies. Therefore, firstly, the conceptual framework of the classical TPB model is defined to identify farmers' behaviour surrounding the safe use of semi-treated wastewater. In this context, different hypotheses are developed to test the intentions and the three main components of TPB are considered: attitudes (ATT), subjective norms (SN), and perceived behaviour control (PBC). Secondly, the TPB model is extended to examine intervention strategies.

2.1. Theory of planned behaviour (TPB)

The TPB is a cognitive social theory that explains the voluntary behaviour of individuals (Ajzen, 1985, 1991). In this theory, behaviour is the central factor that's determined by an individual's intentions, while intentions, in turn, are predicted by attitude, subjective norms (SN), and perceived behavioural control (PBC) (Ajzen, 1991). Attitude is the degree to which a person evaluates the desired behaviour positively or negatively (Wauters et al., 2010), or refers to a person's favourable or unfavourable assessment of behaviour (Abrahamse et al., 2009). In the TPB, attitude cannot directly determine behaviour, but indirectly determines it through behavioural intentions (Bamberg & Möser, 2007). Another variable of this theory is the SN or perceived social pressure to face or not to face a behaviour (Wauters et al., 2010). In other words, SN refers to perceived social pressure to perform or not perform a behaviour and it focuses on an individual's perception of the extent to which others approve or disapprove of a specific behaviour (Abrahamse et al., 2009). The third variable in this theory is the PBC, which indicates an individual's perceived ability to successfully perform a specific behaviour (Wauters et al., 2010). In fact, the PBC is the ease or difficulty of perceiving behaviour by an individual (Abrahamse et al., 2009). Given the above conceptual framework of TBP and its components of attitudes, SN and PBC, the five hypotheses related to the classical TPB model that are considered by this study are as follows:

H1: Farmers' attitudes towards the safe use of semi-treated wastewater have a positive and significant effect on their intention to use semi-treated wastewater safely.

H2: Farmers' SN towards the safe use of semi-treated wastewater have a positive and significant effect on their intention to use semi-treated wastewater safely.

H3: Farmers' PBC towards the safe use of semi-treated wastewater has a positive and significant effect on their intention to use semi-treated wastewater safely.

H4: Farmers' PBC towards the safe use of semi-treated wastewater has a positive and significant effect on their behaviour (BEH)² for the safe use of semi-treated wastewater.

²In order to test the level of behaviour, we define it with the abbreviation BEH later on in analysis part.

H5: Farmers' intentions to use wastewater safely have a positive and significant effect on their behaviour (BEH) surrounding the safe use of wastewater.

2.2. Extension of the TPB model

Numerous studies have shown that the TPB can be extended according to the topic and the target audience. Thus, the addition of new variables to the model increases the predictive power of the model (Whitmarsh and O'Neill, 2010; Fielding et al., 2008). The current study examines the impact of the two intervention strategies as additional variables in the TPB model, that is cooperative involvement and government enforcement, on the behaviour of farmers for the safe use of semi-treated wastewater. Cooperative involvement is considered a strategy that increases farmers' information and provides the necessary services to farmers, while government enforcement represents a strategy of determining regulations and monitoring the safe use of semi-treated wastewater by farmers.

2.2.1. Agricultural cooperatives

Agricultural cooperatives are formed by a voluntary combination of labour and capital, and farmers are their main body, which are democratically managed and service oriented (Li et al., 2021). Agricultural cooperatives can affect farmers' safe production behaviour in several ways (Ji et al., 2019). The first goal of cooperatives is to provide agricultural inputs with low cost and high safety, which has an important effect on the safe behaviour of farmers (Li et al., 2021). Second, the creation of cooperatives, which behave as producers' organizations, are one of the possible ways to increase the bargaining power of scattered primary agricultural producers, as cooperatives make bulk purchases of agricultural commodities, give technical assistance and advice to their members, and sell collectively to processing industries (Samoggia et al., 2022). Third, cooperatives can influence safe production by facilitating access to educational resources and technical training for farmers (Wang, 2009, cited in Chen et al., 2018, 2348; Moustier et al., 2010; Lee et al., 2019). Cooperatives can also directly, through inspection, and indirectly, through social control (such as motivation, punishment, and reward) influence the implementation of the necessary standards for safe production by farmers (Zhou et al., 2019). Therefore, cooperatives can have an important role in improving the quality and safety of agricultural products (Li et al., 2021).

Researchers have studied the role of cooperatives on farmers' behaviour in safe production from different perspectives. In their study, Al Zadjali et al. (2013) showed that cooperatives affect the environmental awareness of their members, so that the cooperative members recognise the risks associated

with the use of pesticides compared with the non-members. They also found that cooperatives are an effective medium for disseminating knowledge and awareness of pesticide use laws and regulations. The results of a study by Zhong et al. (2016) as cited in Li et al. (2021) showed that trust between members of agricultural cooperatives could help to improve product quality and safety. Chen et al. (2018) found that cooperatives ensure safe production by providing production services to farmers. Shahroudi et al. (2008) found that farmers' membership in cooperatives affects farmers' attitudes towards water resource management.

As mentioned earlier, this study argues that cooperatives educating and increasing farmers' knowledge makes them aware of the benefits and desirability of the safe use of semi-treated wastewater at the farm and leads the farmers to have a positive attitude towards safe behaviour. In addition, perceived social pressure and SN concerns that are raised by cooperatives influence farmers to act in a safe manner. On the other hand, this study suggests that cooperatives facilitate farmers' access to production resources, and this is a reason for increasing the motivation and more responsible actions of farmers in relation to the safe use of semi-treated wastewater. Finally, by supporting farmers, cooperatives help them to control their personal behaviour for safe production. Considering the role of cooperatives and the TPB model, the three following hypotheses related to the effectiveness of cooperative involvement are defined as follows:

H6: Cooperative involvement has a positive and significant effect on farmers' attitudes surrounding the safe use of semi-treated wastewater.

H7: Cooperative involvement has a positive and significant effect on farmers' SN regarding the safe use of semi-treated wastewater.

H8: Cooperative involvement has a positive and significant effect on farmers' PBC in relation to the safe use of semi-treated wastewater.

2.2.2. Government

The safety of agricultural products is affected by a number of external factors, such as government enforcement and involvement (Li et al., 2021). The government's influence on farmers' safe production behaviour is mainly reflected in various aspects, among which regulatory-based policy instruments are the most common (Zhang et al., 2018). Various studies provide evidence showing the role of governments in promoting the safe production of agricultural and food commodities. Sapbamrer et al. (2023) conducted research on the use of pesticides in Thailand and found that government regulatory policies and regulations play a crucial role in reducing pesticide usage and mitigating risks in a sustainable manner. Wang et al. (2015) also

showed that the government can affect the safe use of pesticides among farmers by implementing policies such as penalties, subsidies, and setting standards. Zhang et al. (2018) argued that the stricter the regulatory rules of a government on chemical inputs, the greater the willingness of farmers to use them safely. The above evidence shows the essential role of government in shaping the norms related to farmers' behaviours regarding safe production practices. Thus, the present study suggests that when farmers realise that the government is enforcing regulations regarding the safe use of wastewater, their motivation to avoid penalties increases, which, in turn, raises more social pressure on farmers to use wastewater safely (Wang and Lin, 2020). Moreover, according to the above study, it can be argued that government enforcement makes it possible to impose some penalties in the face of legal violations, which in turn emphasises the real costs and benefits of safe behaviour, as farmers usually behave in a way that makes the use of wastewater as cheap as possible. Thus, when farmers understand the effective enforcement measures put in place by a government, they realise that the cost of the safe use of wastewater is not high compared to a potential cost of punishment, which in turn leads to a perceived ease of implementing the safe use of wastewater (Wang and Lin, 2020). Therefore, the present study tests the following hypotheses:

H9: Government enforcement has a positive and significant effect on farmers' SN surrounding the safe use of semi-treated wastewater.

H10: Government enforcement has a positive and significant effect on farmers' PBC in relation to the safe use of semi-treated wastewater.

According to all previous arguments, the hypothetical relations and the theoretical framework of this research are presented in Figure 1. As can be seen, hypotheses 1 to 5 are based on the original TPB model. In addition, the present study examines the effect of two intervention strategies surrounding the safe use of semi-treated wastewater among farmers by considering these two intervention factors in the TPB model. Therefore, hypotheses 6 to 10 are based on the extended TPB.

3. Methods

3.1. *Constructs and their measuring items*

Following the conceptual model that's presented in Figure 1, the empirical methodology has been adapted to investigate the psychological and interventional factors affecting the behaviours linked to the safe use of semi-treated wastewater by farmers. Table 1 reports the measurement items of the

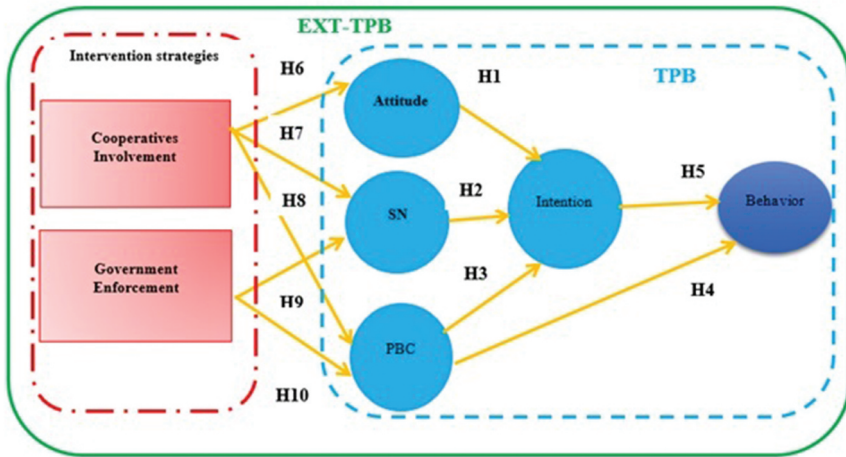


Figure 1. Conceptual model of the TPB and the extended TPB used in the study. Source: own elaboration.

seven study constructs³ and their sources. The scale for responding to each item is a 5-point Likert scale that was comprised of “strongly disagree”, “disagree”, “no idea”, “agree” and “strongly agree” that was included in the questionnaires. Based on the knowledge that was acquired from the literature review, the components for the different constructs of the study were designed. In relation to the agricultural cooperatives, the present study designed three items based on past studies and field observations in the study area. Furthermore, based on the experimental results and the research of Wang and Lin (2020), this study determined four measurement items for government enforcement. Farmers’ behaviour regarding the safe use of semi-treated wastewater was the key dependent variable that defined how farmers face the imposed restrictions of semi-treated wastewater utilisation in the agricultural sector. In order to reduce risks for acquiring the necessary food safety level, restrictions that encourage the safe utilisation of semi-treated wastewater in the field are determined as follows:

- (i) Cultivation patterns commensurate with the quality of semi-treated wastewater.
- (ii) Using the appropriate irrigation method and observing the distance between the last irrigation and harvest.

³In management studies and social science research, measuring variables is crucial, and each study involves several constructs, also known as latent variables. These constructs are abstract concepts that cannot be directly observed or measured. Therefore, they are defined conceptually to help readers understand the meaning and concept of the structure. To indirectly measure these constructs, researchers use observable indicators or manifest variables that are associated with the construct (Habibi & Kolahi, 2022).

Table 1. Constructs and their measurement items.

Constructs and their abbreviations	Measurement items	Source
Behaviour (BEH)	<ul style="list-style-type: none"> • I use the cultivation pattern according to the quality of semi-treated wastewater (BEH1). • I use the proper irrigation method (drip) to reduce pollution (BEH2). 	Esfandiari et al. (2022); Janeiro et al. (2020)
Intention (INT)	<ul style="list-style-type: none"> • I tend to safely use semi-treated wastewater in the future (INT1). • If there is a plan for the safe use of semi-treated wastewater, I would like to participate (INT2). • I want to use better facilities to safely use the semi-treated wastewater on my farm (INT3). 	Rezaei et al. (2018); Savari and Gharechaei (2020); Wang and Lin (2020)
Attitudes (ATT)	<ul style="list-style-type: none"> • I think investing in the safe use of semi-treated wastewater is worthwhile (ATT1). • I think I have to meet all the necessary standards for safe production with semi-treated wastewater (ATT2). • I use semi-treated wastewater safely even if my production costs increase (ATT3). 	Wang and Lin (2020); Rezaei et al. (2018)
Perceived Behavioural Control (PBC)	<ul style="list-style-type: none"> • I think I can use the semi-treated wastewater safely (PBC1). • I have enough knowledge and information about the safe use of semi-treated wastewater (PBC2). • I have enough resources about the safe use of semi-treated wastewater (PBC3). • I have enough skills about the safe use of semi-treated wastewater (PBC4). 	Savari and Gharechaei (2020); Wang and Lin (2020); Rezaei et al. (2018).
Subjective Norms (SN)	<ul style="list-style-type: none"> • People who are very important to me want me to use the semi-treated wastewater safely on the farm (SN1). • My friends and relatives believe that the semi-treated wastewater on the farm should be used safely (SN2). • My neighbours believe that the semi-treated wastewater on the farm should be used safely (SN3). 	Rezaei et al. (2018); Savari and Gharechaei (2020); Wang and Lin (2020)
Cooperative Involvement (CI)	<ul style="list-style-type: none"> • Cooperatives increase my awareness and knowledge of the safe use of semi-treated wastewater with access to information resources (CI1). • The services and support provided by the cooperative encourage me to use semi-treated wastewater safely (CI2). • Cooperatives conduct appropriate training courses on the safe use of semi-treated wastewater (CI3). 	Li et al. (2021); Lee et al. (2019); Zhou et al., (2019); Al Zadjali et al. (2013); Zhang et al. (2018).

(Continued)

Table 1. (Continued).

Constructs and their abbreviations	Measurement items	Source
Government Enforcement (GE)	<ul style="list-style-type: none">• The government is working hard to determine whether users of semi-treated wastewater are violating the regulations (GE1).• The government has the necessary conditions (manpower and budget) to determine whether the effluent is used safely or not (GE2).• The government can definitely identify the farmers who use the semi-treated wastewater unsafely (GE3).• I use semi-treated wastewater safely due to government punishment (GE4).	Wang and Lin (2020); Tosun (2012)

For this purpose, restrictions on the use of semi-treated wastewater were listed in the questionnaires and farmers were asked to report on the level of the safe use of semi-treated wastewater on their farms according to the restrictions. To determine the level of the safe use of semi-treated wastewater, a 5-point Likert scale was used in the questionnaire, which ranges from “I am significantly weak” (=I) to “I do remarkably well” (=V).

3.2. Study area and intervention strategies

The study area is the Kashafrud catchment area located in north-eastern Iran in the province of Khorasan Razavi in Mashhad County (Figure 2).

Reference to the latest available statistics from the regional agricultural office in 2021) (AOKR, 2022), with 56,536 hectares of agricultural land (46, 771 hectares of irrigated cultivated area and 9,765 hectares of rain-fed cultivated area), Mashhad County has an extraordinary potential for exploiting water and soil resources by having a total area of 9168 km². In terms of agriculture, it has been identified as an important County in Khorasan Razavi Province. The water supply of this region is from underground and surface sources and despite having 995 deep wells, 102 semi-deep wells (KRRWC, 2023), 351 springs, 326 qanats⁴ and three dams (AOKR, 2022), it is facing problems of water shortages. In 2021, the total irrigated cultivated area was reduced by more than 8000 ha from 55193 ha in 2014 (MPOKR, 2020).

⁴A “qanat”, also known as a “kariz”, is an ancient underground water supply system that uses a gently sloping subterranean aqueduct to transport water from an aquifer or water well to the surface for irrigation and drinking purposes. This technique was developed in present-day Iran around 3,000 BC and subsequently spread to other parts of the world (Maghrebi et al. 2023).



Figure 2. Geographical location of the study area in Mashhad County, Iran. Source: own elaboration.

With a population of 3.619 million in 2022, Mashhad City is the official centre of Mashhad County and is a large-scale provider of wastewater that's a potential and practical source for irrigation water. Mashhad is a commercial, industrial and touristic metropolitan city which has faced an increasing water deficit for many years. This urban water shortage was the reason for demanding freshwater quotas for agriculture in the region. The city has offered 1.2 times more semi-treated wastewater to farmers as compensation for their freshwater quotas from two nearby dam reservoirs. Since 2006, 21 million m³ of irrigation water has been given up by farmers for 25 million m³ semi-treated wastewater based on a fixed contract between water rights-holding farmers and the Regional Water Company (Danso et al., 2018). However, due to the lack of advanced WWTPs in this city, recycled water does not have the necessary quality standards for unlimited use as a WWTPs are not available for advanced dilution of wastewater. In this regard, some farmers may informally use semi-treated municipal wastewater to irrigate crops such as tomato, Persian melon (cultivars of *Cucumis melo*), sugar beet, medicinal herbs, fodder corn, barley and wheat, although the quality of semi-treated wastewater is not safe enough to be used indefinitely. In summary, the farmers have different benefits in this exchange deal: a) having a reliable and continuous supply of semi-treated wastewater compared to volatile freshwater resources especially during the drought period at the higher quantity level, b) acquiring higher nutrient content embedded in semi-treated wastewater, c) exemption from paying for pumping and transferring water costs.

Considering the unsafe use of semi-treated wastewater, government offices such as the Khorasan Razavi Regional Water Company, Khorasan Razavi's Department of Environment, and the Khorasan Razavi Agriculture Organization have issued restrictions (such as cultivation patterns according to the effluent quality, irrigation method used, and the time between the last irrigation and the crop harvest) on the use of semi-treated urban wastewater.

In addition, due to the social pressures related to the unsafe use of semi-treated wastewater, farmers have started to create collective actions for the safe use of semi-treated wastewater. In order to support collective action, the government has considered these collectives as a branch of agricultural cooperatives. These cooperatives provide necessary services and training to farmers for the safe use of semi-treated wastewater. On the other hand, the government has defined rules and regulations for the safe use of semi-treated wastewater on farms and for monitoring the performance of farmers. Therefore, fines are defined for farmers who do not use semi-treated wastewater safely. However, such restrictions increase the costs of production and farmers cannot cultivate their desired crops. In particular, some farmers may not want to comply with these regulations. Therefore, it is very important for the policymakers and society at large to know:

- The effectiveness of the above intervention policies.
- Whether they have been able to have a significant effect on the farmers' behaviours linked to the safe utilization of semi-treated municipal wastewater.
- The magnitude of the policy interventions.

3.3. Statistical population and sampling methods

The object of research in this study is a sample of farmers who are members of agricultural cooperatives and use semi-treated municipal wastewater in Mashhad County. In this study, a simple random sampling method was used. Based on the Krejcie and Morgan's (1970) table, the sample size was determined to consist of 215 farmers (Savari and Gharechaei, 2020). This sample size was also confirmed by Cochran's (1977) correlation approach. The survey was conducted in Persian. Face-to-face interviews were administrated with farmers in the sample after they provided informed consent orally and volunteered to participate in the survey. The data collection took place between April 2021 until July 2021. The demographic characteristics of farmers can be seen in Table 2. In terms of age, 25.6% of farmers were under 30 years old, 55.3% were between 30 and 50 years old and 19.0% were over 50 years old. In terms of education, 23.3% of farmers were illiterate, 48.4% had elementary education, 24.6% had high school education and a limited percentage had college education (3.7%).

3.4. Empirical model

In order to analyse the data, structural equation modelling (SEM) with Smart PLS and excel software was used. SEM is a powerful set of multivariate analysis techniques that determines the relationships between variables

Table 2. Demographic characteristics of the farmers using semi-treated municipal wastewater.

Variable	Category	Frequency	Percentage
Age	Lower than 30	55	25.58
	From 30 to 50	119	55.35
	More than 50	41	19.07
	Sum	215	100
Education	Illiterate	50	23.26
	Elementary	104	48.37
	High school	53	24.65
	College Education	8	3.72
	Sum	215	100

Source: study results.

using measurement models and structural models. The measurement model examines the relationships between latent variables and observed variables. While the structural model evaluates the relationships between latent variables that allow the testing of statistical hypotheses (Byrne, 2010, Kline, 2023), observed variables are directly observed and measured. In contrast, latent variables are not directly observed or measured, rather, they are measured indirectly through the observed variables. SEM allows the measurement error to be reduced by testing several variables related to the latent variable and presenting a graphical image using confirmatory factor analysis (CFA) (Hatcher & O'Rourke, 2013, Kline, 2023). Another feature of SEM is that it considers the potential measurement error in all variables. Furthermore, structural modelling allows the appropriate specification of the model to be found for the sample covariance variance matrix (Kline, 2023, Petljak et al. 2017).

4. Results

4.1. Measurement model

Before estimating the structural model, the measurement model was employed (Gerbing & Anderson, 1992). In the measurement model, the relationship between the latent hypothetical variables and the set of observed variables was investigated using confirmatory factor analysis (CFA) and the fit of the extended TPB model was confirmed. Table 3 shows that the standardised factor loadings (λ) of the observed variables were statistically significant according to the t-values. Therefore, the observed variables are selected correctly to measure the latent variables. Based on the results of Table 4, the data strength was confirmed according to the convergent validity and reliability of the latent variables of the model. As it can be seen, the values of composite reliability are between 0.835 and 0.903, which are more than the threshold of 0.7 recommended by Gefen et al. (2000). In addition, the values of the average variance

Table 3. Fit indicators of the extended TPB model (factor loads).

Variable	Measuring item	λ	t-value
Cooperative Involvement (CI)	CI1	0.884	55.851
	CI2	0.868	46.193
	CI3	0.728	19.208
Government Enforcement (GE)	GE1	0.806	26.763
	GE2	0.782	26.684
	GE3	0.818	34.776
	GE4	0.781	26.995
Attitudes (ATT)	ATT1	0.860	39.233
	ATT2	0.801	21.031
	ATT3	0.782	24.038
Subjective Norms (SN)	SN1	0.852	41.459
	SN2	0.765	22.196
	SN3	0.759	20.275
Perceived Behavioural Control (PBC)	PBC1	0.782	27.082
	PBC2	0.643	11.802
	PBC3	0.848	44.707
	PBC4	0.842	35.126
Intention (INT)	INT1	0.770	17.612
	INT2	0.847	50.624
	INT3	0.836	35.519
Behaviour (BEH)	BEH1	0.909	73.734
	BEH2	0.906	55.107

Source: study results.

Table 4. Fit indicators of the model extended TPB (reliability and validity tests).

Variable	Measuring item	Cronbach's α	Convergent validity	
			Composite Reliability	AVE
Cooperative Involvement (CI)	CI1	0.769	0.868	0.689
	CI2			
	CI3			
Government Enforcement (GE)	GE1	0.810	0.874	0.635
	GE2			
	GE3			
	GE4			
Attitudes (ATT)	ATT1	0.747	0.856	0.664
	ATT2			
	ATT3			
Subjective Norms (SN)	SN1	0.706	0.835	0.629
	SN2			
	SN3			
Perceived Behavioural Control (PBC)	PBC1	0.791	0.863	0.613
	PBC2			
	PBC3			
	PBC4			
Intention (INT)	INT1	0.754	0.859	0.670
	INT2			
	INT3			
Behaviour (BEH)	BEH1	0.786	0.903	0.824
	BEH2			

Source: study results.

extracted (AVE) for all constructs are greater than 0.613 and in accordance with the range recommended by Hair et al. (2012). The values of Cronbach alpha are between 0.706 and 0.810, confirming the proposed value (above 0.5) of Paul et al. (2016). Table 5 shows that the estimated AVEs for latent variables ($0.783 < \text{AVE} < 0.908$) are greater than their correlation ($0.513 < r < 0.777$), which confirms the diagnostic validity of the study structure based on the Fornell and Larcker (1981) criteria.

4.2. Structural model

After estimating the measurement model, at this stage, the relationships between the latent variables were measured to test the hypotheses through structural equations. Table 6 and Figure 3 show the path coefficients with p-values. According to the obtained coefficients, it is observed that there is a significant and positive structural relationship between the three variables of attitude ($\beta = 0.371$, $p^5 < 0.01$), PBC ($\beta = 0.417$, $p < 0.01$) and SN ($\beta = 0.131$, $p < 0.10$) with farmers' intentions to use semi-treated

Table 5. Discriminant validity (inter-correlations) of constructs with square roots of the AVE.

Latent variable	1	2	3	4	5	6	7
1. Cooperative Involvement (CI)	0.830						
2. Government Enforcement (GE)	0.697	0.797					
3. Attitudes (ATT)	0.494	0.479	0.815				
4. Subjective Norms (SN)	0.550	0.513	0.762	0.793			
5. Perceived Behavioural Control (PBC)	0.777	0.742	0.486	0.564	0.783		
6. Intention (INT)	0.653	0.630	0.672	0.649	0.671	0.818	
7. Behaviour (BEH)	0.626	0.558	0.684	0.681	0.612	0.720	0.908

Source: study results.

Table 6. Results of the structural model.

Hypotheses	Hypotheses Paths	Path c=Coefficients	P-value	Significance
H1	ATT → INT	0.371	0.000	Supported
H2	SN → INT	0.131	0.085	Supported
H3	PBC → INT	0.417	0.000	Supported
H4	PBC → BEH	0.235	0.002	Supported
H5	INT → BEH	0.562	0.000	supported
H6	CI → ATT	0.494	0.000	Supported
H7	CI → SN	0.375	0.000	Supported
H9	CI → PBC	0.505	0.000	Supported
H10	GE → SN	0.251	0.007	Supported
H11	GE → PBC	0.389	0.000	Supported

Source: study results.

⁵p refers to p-value in this section.

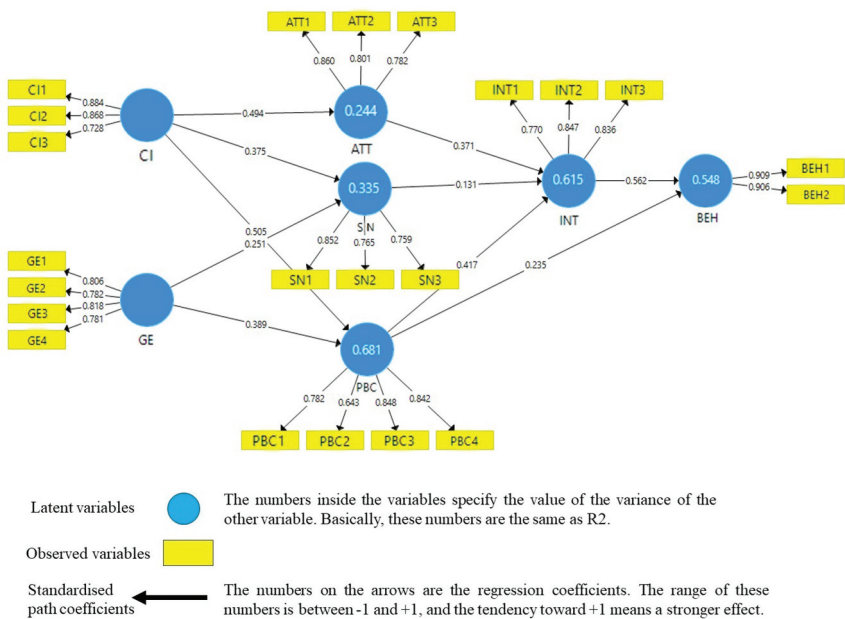


Figure 3. Extended TPB structural model with standardised path coefficients. Source: study results.

wastewater safely. According to Table 6, the effect of farmers' intentions on their behaviour surrounding the safe use of semi-treated wastewater is equal to 0.562. In other words, the variable of farmers' intentions to use semi-treated wastewater safely has a positive and significant effect on their behaviour regarding the safe use of semi-treated wastewater. The relationship between PBC and safe semi-treated wastewater use behaviour was significant with a coefficient of 0.235 at the significance level of 0.05. The results of the variables of intervention factors also indicate that government enforcement and agricultural cooperative involvement has a positive and significant effect on farmers' SN and PBC in relation to the safe use of semi-treated wastewater. The coefficients and significance levels can be seen in Table 6. In addition, the cooperative involvement has a positive and significant effect ($\beta = 0.494$, $p < 0.01$) on farmers' attitudes (ATT) surrounding the safe use of semi-treated wastewater.

In order to determine the overall impact of the two intervention factors (CI and GE), a bootstrap test was conducted at a 95% confidence level using 500 bootstrap samples. The results are presented in Table 7, where the total indirect effect of each exogenous factor on the safe use behaviours of semi-treated wastewater is provided after all variables were standardised. Both intervention factors were found to have a significant impact on the safe use behaviour of semi-treated wastewater, with a p-value below 0.01. Notably,

Table 7. Total indirect effects of intervention factors on the safe use behaviour of semi-treated wastewater.

Intervention Factors	Point estimate	Standard deviation	T-Statistic	P-value
Cooperative Involvement (CI)	0.368	0.043	8.568	0.000
Government Enforcement (GE)	0.201	0.038	5.233	0.000

Source: study results.

the total indirect effect of CI (0.368) was found to be greater than the effect of GE (0.201).

5. Discussion

As we have illustrated, the field observations show that freshwater scarcity in Mashhad City has encouraged the regional water authority to invite farmers to replace their freshwater quota with regulated semi-treated wastewater at a higher quota level. Additionally, they are encouraged to apply certain compliances. As we have discussed in the introduction and conceptual framework, the acceptance of compliance by the farmers is an important factor in the safe application of treated or semi-treated wastewater for irrigation. Therefore, the acceptance of compliance is a voluntary behaviour that can be explained by TPB. The three key components of the theory of planned behaviour (TPB), attitude, subjective norms, and perceived behavioural control (PBC), have a significant impact on the intentions of farmers to engage in the safe use of semi-treated wastewater. This suggests that when farmers have more positive attitudes towards the use of semi-treated wastewater, stronger social norms encouraging its use and a greater sense of control over the behaviour, their intentions to use semi-treated wastewater safely increase. The results of many previous studies, such as farmers' intentions and behaviour towards a circular economy for water recycling in paddy fields (Moradnezehadi et al., 2023), farmers' intentions to use fertiliser safely (Savari and Gharechaei, 2020) and farmers' intentions to contribute to food safety at the farm level (Rezaei et al., 2018), confirm these findings. These studies show that farmers' intentions can be influenced by their ATT, SN, and PBC over their behaviour. In addition, the order of magnitude of these effects is PBC, ATT, and SN, respectively, so PBC plays a major role in farmers' intentions to safely use semi-treated wastewater. Our results are consistent with the findings of the previous studies in the fields of people's environmental behaviour (De Leeuw et al., 2015) and the adoption of climate-smart agricultural practices by farmers (Atta-Aidoo et al., 2022), which show that PBC is the starting point to change the intention. The positive effect of PBC on farmers' safe behaviour was also confirmed. This shows that farmers' perceptions of their capacity and degree of control over adoption significantly affect their intentions and actual behaviour (Vaz et al., 2020). Previous studies have confirmed the positive

effect of PBC on water conservation behaviour (Fielding et al., 2012) and environmental protection (Wang and Lin, 2020). However, studies such as (da Silva et al., 2020) claim that PBC is not a significant predictor of smallholder farmers' intention to adopt production practices. Based on the results, farmers' intentions had a significant impact on their behaviour surrounding the safe use of semi-treated wastewater. Since the most direct predictor of behaviour is intention (Rezaei et al., 2018), when farmers intend to use wastewater safely, they perform safe behaviour, which is in accordance with the results of the study by Ahmmadi et al. (2021). Moradnezehadi et al. (2023) also found that farmers who intend to recycle water in paddy fields also do this behaviour.

Cooperative involvement had a direct and significant effect on ATT, SN and PBC of farmers towards the safe use of wastewater and, in turn, became a positive and significant predictor for changes regarding the behaviour of safe wastewater usage. As mentioned earlier, ATT includes emotional and cognitive components, so it is argued that cooperatives, by increasing farmers' knowledge, affect their attitudes (ATT) towards the safe use of wastewater. Also, since SN refer to an individual's perception of whether or not to perform a particular behaviour (Ahmmadi et al., 2021, De Bruijn, 2010), it can be said that cooperatives as a social organisation can play an important role in shaping the norms for safe production. In addition, the more control farmers have over their perceived behaviour towards the safe use of semi-treated wastewater, the more they intend to use wastewater safely. Therefore, it can be said that, by providing services, cooperatives have a great impact on the PBC of farmers in relation to the safe use of semi-treated wastewater. In general, it can be said that cooperatives, by educating and increasing farmers' information, increase their awareness about the safe use of wastewater and encourage safer production. These results are consistent with the findings of previous studies, such as Dos Santos et al., (2020) and Ji et al. (2019).

Government enforcement had a significant direct effect on PBC. As farmers realise that regulatory measures (government enforcement) are very effective, they will have more control over the safe use of semi-treated wastewater at the farm level and behave more safely. Therefore, the implementation of regulations for the safe use of wastewater has a strong deterrent effect. In addition, government enforcement had a direct and significant effect on SN (similar to Wang and Lin (2020)).

Since the total indirect effects of cooperative involvement on the behaviour surrounding safe wastewater usage are greater than government enforcement (Table 7), we can say that cooperative involvement has a greater impact on the safe wastewater usage behaviour than government intervention. Therefore, the provision of services, education and information by cooperatives in the field of safe wastewater usage can be more effective

than government enforcement. Therefore, it can also be said that the collective actions of farmers can be more effective than government enforcement for producing food safely and thus improving food safety, especially in developing countries such as Iran where governments do not have the necessary resources, intentions or authority to directly manage and implement regulations. As a result, it seems that the empowerment of agricultural cooperatives is an effective tool for disseminating knowledge and information related to the safe use of wastewater for safe food production, which surpasses government enforcement. The results of studies by Zhang et al. (2018) and Al Zadjali et al. (2013) confirm the same observation in this study. Finally, Wang and Lin (2020) also obtained similar results in their study. They found that both strategies of increasing knowledge (educational strategy) and government regulations (structural strategy) are effective in the wastewater treatment behaviour of swine farmers, but educational strategies are more effective than structural strategies.

Ignoring farmers at the midpoint of using wastewater for irrigation safely and ignoring their attitude, subjective norms, and perceived behavioural control that shape their behaviour can make any policy ineffective by imposing risks to the health of humans and the environment as explained at the beginning of this paper. However, this is mainly the case in developing countries. As Rodriguez et al. (2020) have shown, even the perception of treated or untreated wastewater can be wrong by farmers causing protests against any policy or investment on the safe use of wastewater. The report by the investigatory parliamentary commission of Iran which became publicly accessible in July 2023 shows that farmers and their behaviour are not at the midpoint of policy-making. Despite having enough information about the massive application of different types of wastewater for irrigation, the report has ignored providing any policy that targets farmers, increases their awareness or changes their attitude or behaviour (Islamic Consultative Assembly, 2023). These are two examples of top-down policies that ignore farmers. This study is an attempt to show farmers should be at the core of policy-making and that empowering collectives and cooperatives can be a more effective approach to increase food safety and health compared to the isolated regulations that diverge from reality.

6. Conclusion

In this study, by employing the theory of planned behaviour (TPB), we have used survey data from Mashhad County in north-eastern Iran to test the effectiveness of two intervention strategies: namely cooperative involvement and government enforcement regarding the safe use of semi-treated wastewater in irrigation and safe food production. The

TPB is extended to include the intervention strategies. The results show that involvement in agricultural cooperatives that encourage farmers to use semi-treated wastewater safely in irrigation is more effective when it comes to farmers' safe production behaviour than government enforcement and regulatory measures. Based on the results, some practical policy suggestions can be provided. Firstly, according to the role of cooperatives in providing services, training, and increasing farmers' knowledge of supplementary actions regarding the safe use of semi-treated wastewater for irrigation and further safe production of food items and improving food safety, there should be an increase in official support for agricultural cooperatives, and especially those that are operating as wastewater collectives. Secondly, the regulatory authorities should be empowered to operate more effectively in monitoring the safe use of wastewater in irrigation. Government agencies can conduct inspections of farms to ensure that farmers are following the established regulations and using semi-treated wastewater safely. Inspections can identify and address non-compliance cases. Thirdly, the two intervention strategies should function accordingly and not in conflict with each other. The cooperatives' provision of services, education and information and collective administration of wastewater use should be accompanied by the authorities' regulatory enforcement and possible conflict should be avoided and conflict settlement resolution should be designed for such cases. Additionally, the collective action of farmers in using semi-treated wastewater for irrigation through the agricultural cooperatives can be better regulated and a legal framework can be provided for those cooperatives.

In future studies, the effects of extension offices and digital education on farmers' behaviour can be studied. Another area of further study is the role of other stakeholders and actors in the food supply chain and their responsibility for food safety in the case of semi-treated wastewater utilisation for irrigation and food production by considering guidelines such as WHO 2006 recommended multi-barrier approach (WHO, 2006). Furthermore, the consumer's willingness to pay for food produced by semi-treated wastewater compared to fresh water could be determined. Moreover, the empowerment of wastewater collectives and the deepening of the regulatory framework in monitoring the authorities and their effectiveness can be analysed by considering the institutional economy and regional differences. Additionally, the efficiency of farmers who are part of the wastewater collectives and use semi-treated wastewater for irrigation can be compared to non-users and possible productivity differences and influential factors in their efficiency can be determined. Finally, those potential agricultural regions that already use or may use the semi-treated wastewater should be mapped and available locally, regionally or

nationally and experiences can be gathered and analysed for knowledge sharing and implementation as water scarcity increases.

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