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Wireless sensor network for small-scale farming systems in southwest Iran: Application of Q-methodology to investigate farmers' perceptions

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ABSTRACT

The application of wireless sensor networks (WSNs) has been promoted worldwide as an approach to smart farming, sustainable resource management and improved crop productivity. Despite their promotion, WSNs are not widely adopted in the whole world, especially by small-scale farmers. The adoption of WSN technologies is strongly affected by the perceptions of farmers who are the main users and potential adopters of such technology. Yet, the way WSN technology is perceived has been poorly studied. This study aims at closing this gap by investigating the small-scale farmers' perception regarding the application of WSNs for farming systems in Khuzestan Province, Iran. This research employed Q-methodology, an approach that integrates both qualitative and quantitative data allowing to study individuals' subjective understandings of a specific topic. The Q-sort procedure was performed in the field with twenty-five small-scale cereal farmers (with less than 2 ha of land). Next Q-factor analyses were conducted using the PQMethod software. Results propose to group farmers along with four types of perceptions regarding the application of WSNs, namely support-seekers, resistance-adherents, optimists and adoptive-adherents. These four groups cover 67% of the variance across perceptions. Various perceptions have shown that farmers have different views on WSN applications. Awareness of these perceptions can provide a valuable frame for policy and decision-makers, and allow for addressing the farmers' concerns and for developing appropriate and specific strategies for each group.

1. Introduction

Small-scale and family farming plays an important role in establishing sustainable food systems. At a global level, there are approximately 500 million farms having less than 2 ha (Lowder et al., 2016), which provide more than 80% of the food consumed in a large part of the Global South and make a significant contribution to food security and poverty reduction (Gong et al., 2019). Small-scale farmers are often poor and depend on farming as the main source of food, income and employment (Ogutu and Qaim, 2019). However, these farmers face many difficulties in making farming decisions (Nyadzi et al., 2019). Previous studies (Munyua and Adera, 2009; Naveed and Anwar, 2013; Nyadzi et al., 2019) have shown that small-scale farmers often take wrong decisions and make mistakes due to a lack of accurate and relevant information. These farmers need proper information to plan their activities, choose inputs and apply inputs at the right time and place (Elly and Silayo, 2013). However, they face several challenges in collecting and accessing the required information from appropriate sources (Munyua and Stilwell, 2010).

Wireless sensor networks (WSNs) are one of the main tools in the smart farming technological package that could be used as an alternative source of information in agriculture (Camilli et al., 2007). Through a WSN's base station, the farming information from WSN nodes is gathered and transmitted through the internet, so that the farmland's ecological environment can be monitored remotely via computers, mobile phones, and other devices (Li and Guo, 2014). Therefore, remote decisions such as precision planting, irrigation scheduling, fertilization, pest management and harvesting can be made based on the information and data that have been obtained as such (Lavanya and Srinivasan, 2018). WSNs enable farmers to reduce waste

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and involve more effective use of inputs (seeds, herbicides, fertilisers), more efficient application of tillage machinery, improved crop and field assessments, and the appropriate management decisions at the right time and place (López Riquelme et al., 2009). The more precise decisions based on data collected by WSNs contribute to reducing costs, increasing farm income and reducing negative environmental consequences (Mahmood Jawad et al., 2017).

WSN technologies has recently been implemented in a number of agricultural projects. The focus, however, has been largely on WSN adoption in developed countries (Damas et al., 2001; Morais et al., 2005; Kim and Evans, 2009; Kaloxylos et al., 2012), excluding the recent few applications in developing countries (Ali, 2015; Byamukama et al., 2018; Muangprathub et al., 2019; Rasooli et al., 2020). Despite these applications, WSN adoption is still underdevelopment because most of the projects are either exploratory or in their early stages of development and use. In other words, the full potential of WSNs in farming has not yet been established, especially for developing countries. The main reason for the low WSN adoption rate in developing countries can be attributed to the fact that the WSN technology is more complex and knowledge-demanding compared to conventional agriculture strategies and therefore, can be more difficult for farmers to adopt (Villa-Henriksen et al., 2020). For example, rural farmers in developing countries may be constrained by low levels of literacy and lack of exposure to software interfaces, which likely make the WSN designs inappropriate for them (Pongnumkul et al., 2015).

Some studies show that the implementation of WSNs in developing countries can provide good opportunities for agriculture (Mafuta et al., 2012; Ali, 2015; Byamukama et al., 2018). Dube (2013) investigated how Ethiopian farmers can track their farms using their mobile phones in conjunction with WSN data. He found that a technology based on mobile and wireless networks can monitor field parameters and protect plants that result in sustainable crop production and poverty reduction. El-kader and El-Basioni (2013) provided an overview of WSNs use in Egypt. They mentioned that the use of WSNs in potato farming contributes to improving the production and storing processes allowing for a better control of diseases and harmful fungi. Mafuta et al. (2012) describe the implementation of WSNs in rural areas of developing countries such as Malawi. Ali (2015) has established a real-time WSNs monitoring system in Africa that can send soil moisture information from sensors to the farmers' mobile phones. Based on his report, using such information, farmers will decide on the appropriate fertilizer and be aware of the crop irrigation water levels. Despite the great potentials of WSNs for improving agricultural productivity and the various benefits expected from this technology, WSN adoption is still very limited in the Global South. The uptake is especially low by small-scale farmers (Byamukama et al., 2018).

Iran is one of the developing countries where the majority of farmers are small-scale (Jamshidi et al., 2019). The lack of relevant and sufficient agricultural information by small-scale farmers is one of the main factors constraining efforts to improve agriculture (Alibaygi et al., 2011). These farmers are engaged in traditional farming with limited use of modern technologies (Soltani et al., 2014). Most of them use their own experience and indigenous knowledge to make farming decisions (Bagheri et al., 2011). Arguably, these decisions may not be sufficiently precise and expose farmers to over or underutilization of inputs, which reduces productivity. In addition, the challenges farming systems face such as water scarcity, soil salinity and natural disasters pose many threats to agriculture, including reductions in agricultural productivity, production stability and farmers' incomes (Mirzaei et al., 2019). To overcome the challenges in the agricultural sector, the adoption of digital agricultural technologies has been of great concern to the Iranian government. According to Iran's 6th Five-Year National Development plan (2016–21), governmental agencies should support farmers by promoting the knowledge on, and use of, digital and improved technologies. This should contribute to improving the country's levels of agricultural productivity and allow it to secure food supply. Iranian researchers have conducted some studies on WSN applications and several WSN-based monitoring systems have been developed for crops like sugar beet (Bagherpour et al., 2015), sugarcane (Khorasani Fardavani et al., 2009), potatoes (Mohammad Zamani et al., 2014) and grapes (Karimi et al., 2018). However, the application of WSNs is mostly limited to scholarly studies whereas the adoption of WSNs by farmers has not yet received enough attention. Iranian farmers are not yet familiar with the WSN technology, and the technology has not yet been adopted in arable farming in the country so far.

The farmers' adoption process with respect to agricultural technologies, such as WSNs, is complex and can be affected by many factors (De Steur et al., 2019). Numerous studies have reported that the adoption of agricultural technologies is strongly affected by the perceptions of farmers who are the main users and key agents to adopt the technology (Abdollahzadeh et al., 2015; Barnes et al., 2018; Aldosari et al., 2019). However, the diversity of perceptions is often ignored, hidden or denied. Developing an overview of different perceptions of farmers will increase the awareness about other perceptions (Forouzani et al., 2013). In turn, identifying the farmers' perceptions may unfold their attitude, intention and use behavior. It is therefore essential to understand the farmers' perceptions toward WSN applications for proper management and planning. This has not yet been studied as far as we know. The present study aims at filling this gap by investigating the farmers' perceptions toward the application of WSN technologies for farming systems in Khuzestan Province, which is the major production area of strategic food and export crops (such as cereals) in Iran. By understanding the farmers' perceptions, the results of this study can be used to support the development of more appropriate policies to adopt WSNs in the agricultural sector. Awareness of the farmers' perceptions will increase our understanding of which policies may more likely be socially acceptable and therefore be adopted by farmers.

To perform this study, a Q-method technique was applied. Q-methodology provides a means for analyzing subjectivity, a person's viewpoint, beliefs, opinion, attitude, values, thoughts, and the like (Taheri et al., 2020). In contrast to survey studies that often use quantitative methods such as attitudinal questionnaires to determine perceptions across large groups (Forouzani et al., 2013), a Q-study typically uses small sample sizes with a low response rate from participants. The low response does bias the findings because the main objective is to identify the different perceptions that exist within a certain population, and not to check the proportional distribution of the perceptions within the larger population (Brown, 2019). In recent years Q-methodology has become an increasingly useful and important method for identifying different perspectives in different contexts of agricultural technologies' adoption including organic farming (Zagata, 2010), intensive farming (Levesque et al., 2019) and management practices (Schall et al., 2018). With regard to smart farming and WSN applications in particular, there is no study which used this method to identify the farmers' perceptions. Thus, this study used Q-methodology which, so far, has not been used in the field of WSNs application. The results therefore extend the current body of knowledge on agricultural technologie's adoption by investigating Q-methodology in a new field of agricultural technology (i.e., the WSN technology).

2. Background: Wireless sensor networks and its potential for small-scale farmers

The monitoring of the crop production environment is of crucial interest to any farmer. However, WSN technology is often disregarded, and considered to be a complex technological intervention applicable mainly to large-scale fields (Bauer et al., 2019). What makes the promotion of WSNs difficult is that the advantages of adopting WSNs by small-scale farmers are still unclear. To highlight the potential applications of WSNs for small-scale farmers, Fig. 1 explains under what conditions (context) and for which farmers (small-scale farmers) WSN is appropriate. In many regions, constraining factors for small-scale food production include a lack of resources, land, and water. Moreover,

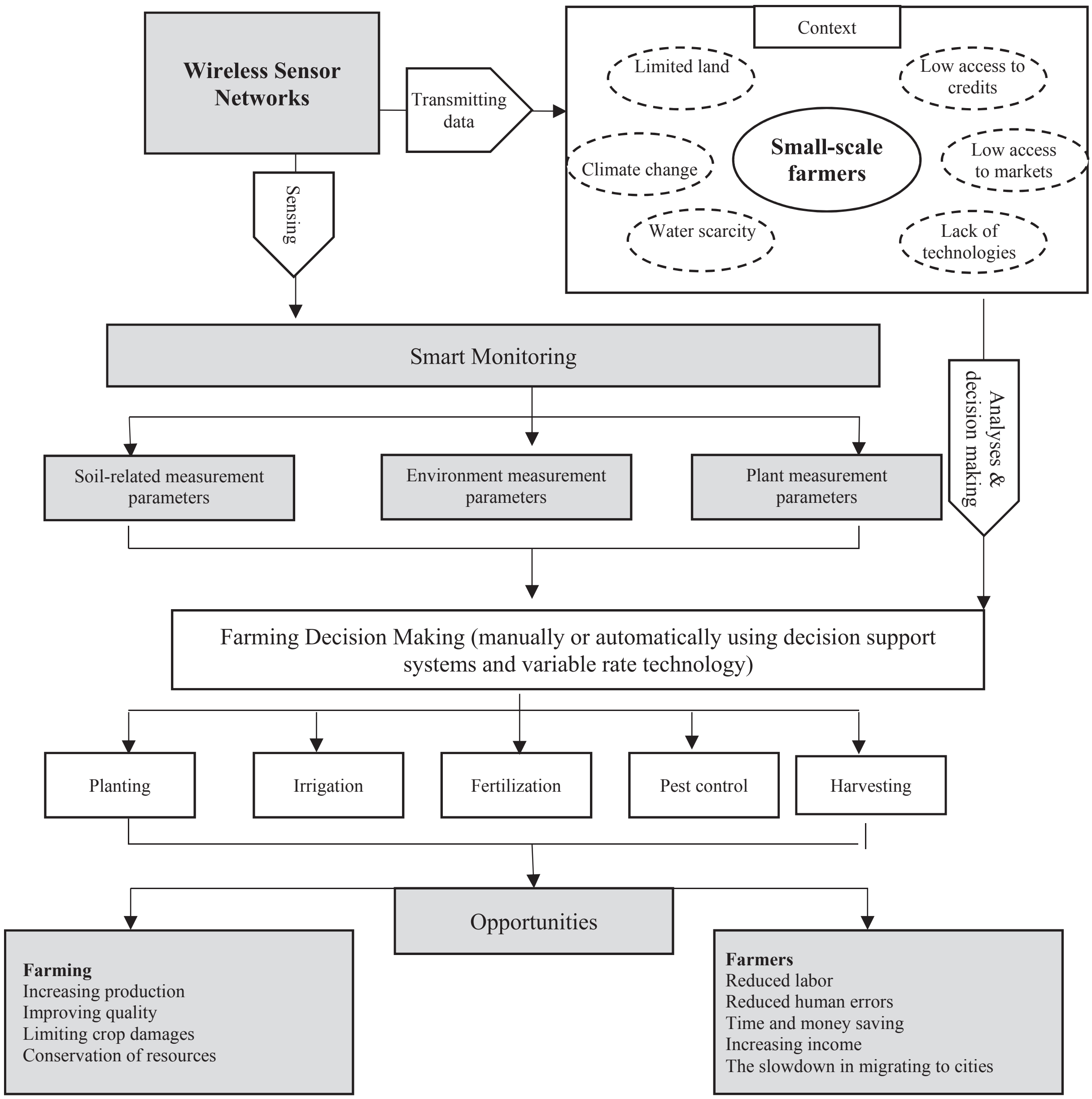

Fig. 1. The application of WSN for small-scale farmers.

natural disasters and climate change pose particular threats (Mirzaei et al., 2019) as do the unfavorable socio-economic situations and low access to the markets, credit, and technologies (Soltani et al., 2014). Smart monitoring by implementing WSNs could therefore be of interest to assist small-scale farmers at different levels of farming decision making (Banđur et al., 2019). WSNs could give continuous access to farming information such as soil, environment and plant measurement parameters, which in turn, result in more cost-effective and timely farm management and production decisions (Muangprathub et al. 2019). This includes different soil-related measurement parameters such as temperature, moisture, dielectric permittivity, rain/ water flow, water level, conductivity and salinity. Environmental sensors such as those measuring humidity, ambient temperature, and wind speed ensure intelligent and improved decision making on planting, irrigation or fertilizer application. The potential applications of the sensors that are attached to plants or trees, include a controlled use of fertilizer, crop quality monitoring, pest control and harvesting (Ojhaa et al., 2015). Field monitoring by the sensors will contribute to reducing costs, increasing farm income and time saving (Mahmood Jawad et al., 2017). As such the use of WSNs could help small-scale farmers by increasing farm yields, reducing production costs, improving safety and quality, limiting crop damages and resource conservation (López Riquelme et al., 2009). The use of WSNs can also reduce the chances of human errors and improve the manageability of cropland production (Rehman, 2015).

3. Methodology

3.1. Study area

This study was conducted in the province Khuzestan that is located in the southwest of Iran (Fig. 2). The region covers an area of 64,236 square kilometers and comprises 3740 villages. Khuzestan province is ranked first among other provinces of Iran in terms of cereal (wheat, barley, rice, and maize) production (representing 33 percent of the total Iranian cereal production and 52 percent of the total Iranian export crops production) (Ahmadi et al., 2018). The adoption of digital and improved agricultural technologies has been of great concern in the province (Hormozi et al., 2012). However, WSNs have scarcely been adopted in farming which is surprising in a province that often is a

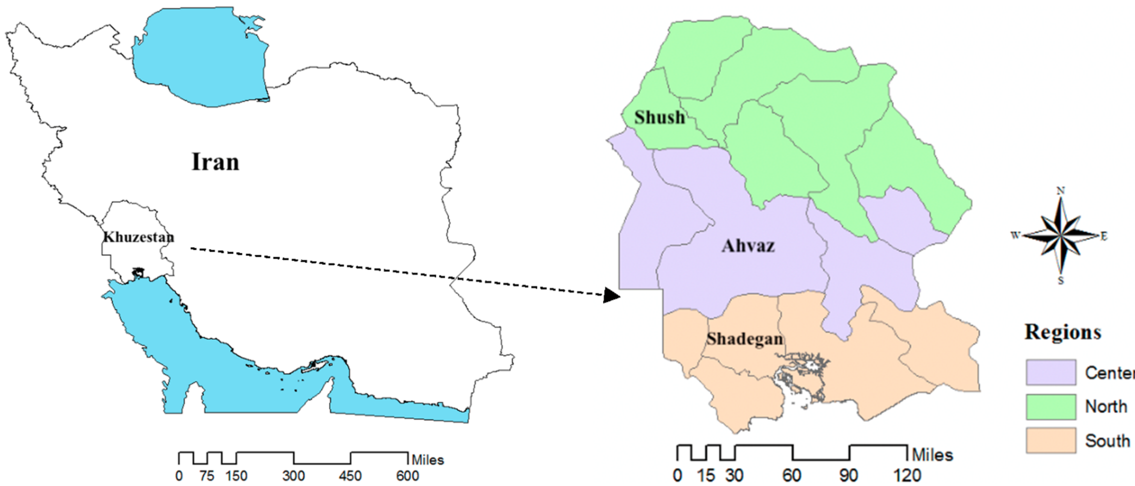

Fig. 2. Location of the study area.

pioneer in the adoption and extension of new technologies. The low rates of adoption of agricultural WSN technologies by farmers make it necessary to explore the ways to promote the adoption process of farmers with regard to this technology. The data was collected in the North, Center and South of the province. Based on the statistics from the Jihad Agricultural Organization of Khuzestan (2019), the counties with the highest hectares of cereal production in every region were chosen for the study: Shush from the North (93935 ha of cereal production), Ahvaz from the Center (51695 ha of cereal production), and Shadegan from the South (19896 ha of cereal production).

3.2. Material and methods

This research did not conduct a survey study but applied the Q-methodology which integrates the qualitative and quantitative processes to study the individuals' subjective understandings of a specific topic (Ramlo, 2019). The Q-methodology was first introduced by the British physicist–psychologist Stephenson in 1953 (Brown, 2019). This method is widely extended across numerous fields including political science, health policy studies, marketing, journalism, education, environmental and agricultural studies (Zagata, 2010; Schall et al., 2018; Levesque et al., 2019; Ramlo, 2019). The Q-methodology is effective to explore the perceptions for obtaining data from a relatively small sample of farmers, and it provides the respondents with a concise way of expressing their perceptions with a minimal researcher interference. The Q-methodology is also very useful for exploring the individuals' perception about a new topic (Taheri et al., 2020). In our case with the new field of agricultural technology (i.e., WSN technology), and the small number of farmers who are already familiar with WSNs, the Q-methodology could be one of the best methods to discover the perceptions of farmers. The Q-methodology as introduced by Van Exel and de Graaf (2005) was implemented in this research by the following five steps: (1) identification of the concourse (Q-population), (2) development of the Q-sample, (3) selection of the respondents (P-set), (4) Q-sorting, and (5) analysis and interpretation. A summary of the five steps of the Q-method process is available in Table 1. All Q- method analyses were performed using the PQMethod software, version 2.35.

Fig. 3 illustrates the eight steps of our approach. The first step includes the participation of farmers, agricultural experts, and the researchers of the study. The two steps shown in dark gray include the participation of agricultural experts, the two steps in light gray indicate that farmers participated and the other three steps shown in white correspond to the work performed by the study researchers.

Note that the sample used in this analysis may be considered limited. Yet, this is not uncommon in studies using the Q-methodology. Most Q-methodological studies use data from around 15 to 60 respondents (Barbosa et al. 2020). In a Q-study by Barbosa et al. (2020), data were collected from 28 rural women to identify their perceptions on the succession of family farms. Moser and Baulcomb (2020) in their Q-study interviewed 31 participants to identify their perspectives on climate change adaptation. In another Q-study by Tuokuu et al. (2019), 15 stakeholders were selected for participation. According to Jensen (2019), a total of 14 individuals participated in a Q-study to identify the groups of beneficiaries with distinct ecosystem service endpoints. In another Q-study by Walder and Kantelhardt (2018), data were collected from 30 farmers to identify different perceptions towards multifunctional agricultural ecosystems and sustainable production have been identified. According to a Q-study by Hermelingmeier and Nicholas (2017), 33 researchers participated to identify their perspectives on the ecosystem services concept. Moreover, the WSN technology we study is new in the study area, which limited the number of knowledgeable people to be interviewed.

3.3. Robustness check

The robustness of our results was evaluated using a discriminant analysis. A discriminant analysis is a method used to classify cases into already identified groups based on a set of original variables which are considered relevant for the study (Zhao, et al., 2020). Once the farmers were grouped by the Q-factor analysis, a Fisher's linear discriminant analysis was conducted to validate the classification obtained by the Q-factor analysis and to confirm each farmer's group membership. SPSS V25 was used to perform the discriminant analysis. The variables to be used in the discriminant analysis were selected was based on their discriminating power. Accordingly, the socio-economic variables (age, education, sex, county) that showed significant differences in the Chi-square tests of association among the groups, and not previously used in the classification process, were used to validate the groups identified by Q-factor analysis.

4. Results

4.1. Factor analysis

Based on the results of the Q-factor analysis, the farmers were divided into four groups representing four factors based on the differences in their perceptions towards the application of WSN, and 67% of the total variance was explained by four factors. Table 2 shows the Q-sort loadings of each factor, the variance explained by each factor, the level of eigenvalue, and the number of defining sorts. Out of the 25 farmers, 24 significantly loaded on the factors while one farmer did not load on any factors (farmer #12). This farmer is not represented by the perceptions that were identified.

Table 1
The different steps of the process of Q-methodology.

Steps	Description and definition	Implemented
Identification of the concourse (Q-population)	A concourse (Q-population) refers to the volume of discussion on a subject (Ramlo, 2019).	● The concourse of statements for this study came from literature, several field observations, semi-structured interviews with 12 individual agricultural specialists, and four focus group discussions with informant farmers (more details on the participants of the interviews and focus group discussions are available in Annex A). ● The statements were grouped according to the components of the Theory of Acceptance and Use of Technology (UTAUT) which is one of the novel models in the field of technology adoption, and its aim is to explain user's intention to use technology (Venkatesh et al., 2003) (Annex B). ● After correcting repetitive and vague statements, ninety statements made up the concourse.
Development of the Q-sample	The second step of performing a Q-study is to select from the concourse a sample (called a Q-sample) representing the universe of discourse (Brown, 2019).	● The ninety statements were adapted to the study sites and during a prioritization process the most representative statements were selected by four colleagues who were not involved in the study but had a good knowledge about the study area. ● The final Q-sample included 38 statements that were then offered to the participants Each Q-sample statement was assigned by a number. The full set of statements are given in Annex C. ● The Q sample statements and their corresponding numbers were printed on individual cards (one statement per card), resulting in a Q-sorting pack of 38 cards. ● The Q-sample was pilot tested.
Selection of the respondents (P-set)	The P-set is a non-random sample of respondents who are likely to have a clear view regarding the topic under consideration (Brown, 1993).	● A Q-study typically uses a diverse range of participants. ● In this study, key informant small-scale cereal farmers with less than 2 ha of land (who may have a divergent understanding about WSN application) were invited to participate. ● With the help of extension agents, 25 key informant cereal farmers were identified and were asked to participate in the Q-sorting.
Q-sorting	Q-sorting is the process where the respondents rank the Q-sample statements according to a rating pattern (Van Exel and de Graaf, 2005).	● The farmers were asked to sort 38 Q-sample statements according to a rating pattern along a continuum from -2 (completely disagree) to $+2$ (completely agree). ● The farmers were interviewed about the statements they placed in the extreme columns, i.e., completely disagree (-2) and completely agree (+2).
Analysis and interpretation	The objective of the analysis and interpretation process is to identify groupings among the Q-sorts and to identify the degree of agreement or disagreement between the respondets (Maki Sy et al., 2018).	● A 25*25correlation matrix of all Q-sorts is calculated. ● A centroid method was undertaken on the matrix of Q-sorts. ● A varimax rotation was used to rotate the factors. ● The Q-sorts defining each extracted factor were flagged. ● The consensus and distinguishing statements were identified. ● The factors were interpreted.

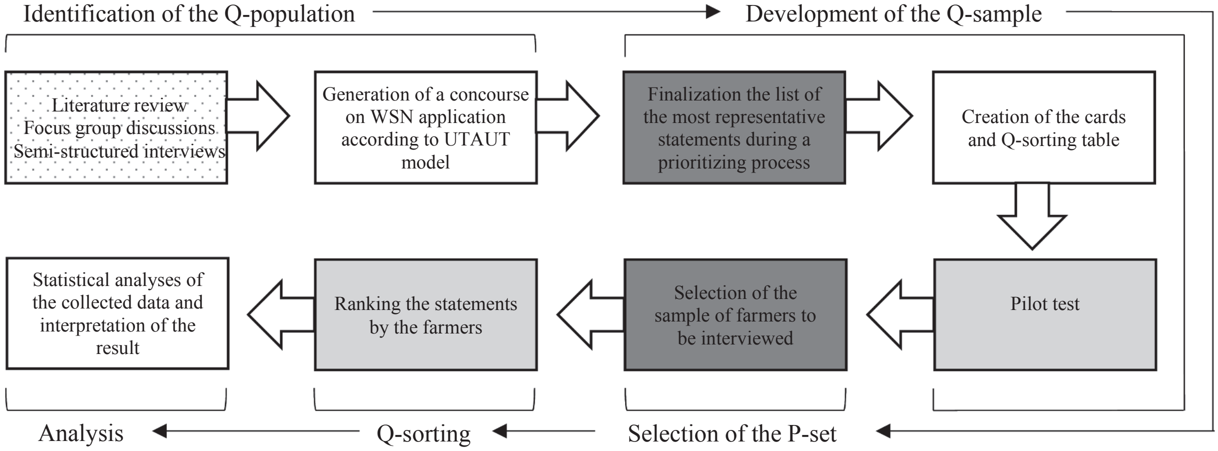

Fig. 3. Overall approach scheme representing the different steps of the study.

A description of the main characteristics of the farmers included in the study is provided in Tables 3. The average age of the farmers was 46 years. Considering the work experience of the farmers, the maximum and minimum work experience was respectively 60 and 2 years which indicates a diverse range of farmers and shows that both young and more experienced farmers were considered in the study. The farmers are smallholders with an average farm size of 1.5 ha. They were mostly male. About 52% of them had less than a high school education, 28% had a high school diploma and 20% studied beyond high school.

4.2. Distinguishing and consensus statements

The Q-sorts of the four identified factors that are representative of different groups of farmers sharing similar perceptions regarding WSN application are shown in Fig. 4. It represents how each statement would be ranked by a farmer loading for 100% on that factor. An example of how to read the grid is explained for the Q-sort of factor 1. Farmers in this factor 1 indicated to "completely agree" with statements 36, 34, 25, 5, 24 and 6. The statements ranked as "completely disagree" by this factor are statements 11, 18, 27, 35, 4 and 28. Annex D gives the ideal Q-sorts for each factor.

Table 2
Factor matrix for all Q-sorts (four factors after rotation).

Q-Sort	Factors			
	Factor 1	Factor 2	Factor 3	Factor 4
1	0.44	0.00	0.15	0.68^{X}
2	0.68^{X}	−0.03	−0.27	0.20
3	0.01	0.84^{X}	−0.05	0.00
4	0.87^{X}	0.01	0.02	0.09
5	0.14	0.87^{X}	−0.04	−0.07
6	0.10	−0.04	0.03	0.89^{X}
7	0.76^{X}	−0.04	0.16	0.18
8	0.67^{X}	0.10	0.09	−0.07
9	0.12	0.15	−0.11	0.52^{X}
10	−0.01	−0.05	0.09	0.95^{X}
11	0.47	0.01	0.11	0.59^{X}
12	0.10	−0.06	0.54	−0.05
13	0.93^{X}	0.08	−0.04	0.20
14	0.91^{X}	0.00	0.04	0.30
15	0.05	0.62^{X}	−0.07	−0.01
16	0.18	−0.11	0.06	0.74^{X}
17	0.05	0.00	0.96^{X}	0.04
18	−0.05	0.89^{X}	−0.02	−0.09
19	0.01	−0.00	0.90^{X}	0.11
20	0.51^{X}	0.12	0.21	0.04
21	0.00	0.76^{X}	0.10	0.11
22	0.03	0.02	0.85^{X}	0.04
23	0.08	−0.01	0.65^{X}	0.07
24	0.16	0.86^{X}	0.13	0.01
25	−0.07	0.86^{X}	0.00	−0.08
Eigenvalue	5.69	4.91	3.22	2.30
Variance explained (%)*	19	19	14	15
Cumulative variance percentage	19	38	52	67
Number of defining sort	7	7	4	6

Note: Factor loadings marked with superscript star were flagged by PQMethod software (p-values: $*p \leq 0.01$).

According to Van Exel and de Graaf (2005), an overview of the consensus and distinguishing statements can be used to highlight the similarities and differences between factors. For a better understanding of the differences and similarities of the perceptions among the farmers, the distinguishing statements among the factors are analysed (Table 4). Factors will be described in the following sections by using these statements.

Consensus statements are those which do not differentiate between any of the factors. Only 3 of the 38 statements are consensus statements (Table 5). Across the four factors, the farmers are somewhat ambivalent or unsure about the fact that WSNs can improve the quality of production on a farm. They believe the government does not support a WSN application and they believe that farmers do not have enough information about WSN applications. It is also worth mentioning that the WSN technology is new to most farmers interviewed and they all felt a risk for the outcomes to be expected. To give an example, one farmer noted: *"to decide to adopt and implement WSNs, farmers need to observe the performance of WSNs in the farm situation. If WSN technology meets the perceived needs of farmers and there are enough incentives to encourage their adoption, they can quickly take up".*

4.3. Farmers' major perceptions

The statements used to describe each factor are either the most extreme ranked statements i.e. "completely agree" or "completely disagree" (Fig. 4), distinguishing statements that statistically differentiate the discourse from other factors at a $P < 0.05$ significance level (Table 4), consensus statements which do not differentiate between any of the factors (Table 5), or the comments made by the farmers during the post sort interviews. For each factor, numbers in parenthesis refer to the number of related statements and its ranking among other statements. For instance, for the description of factor 1, (36: +2) indicates that statement 36 is rated as completely agree in a +2 position.

4.3.1. Factor 1: Support seekers

The most extreme ranked statements for this factor are presented in Table 6. The farmers in this factor strongly emphasized that WSNs are not available and accessible to farmers (27: −2) and the necessary resources to install a WSN system are not available (18: −2); as one farmer said in his post sort interview: *"in terms of software and hardware,*

Table 3
The basic characteristics of farmers by factors.

Characteristic		Factor 1	Factor 2	Factor 3	Factor 4	Total
Mean of personalcharacteristic	Age (years)	50.14	46.00	37.50	47.83	46.12
	Agricultural experience (years)	23.28	20.14	14.25	20.33	20.32
	Farm size (ha)	1.35	1.64	1.62	1.41	1.50
Sex	Male	7	7	3	5	23
	Female	0	0	1	1	2
Education	Illiterate	2	3	0	0	5
	Elementary	1	1	3	2	8
	High school	2	2	1	2	7
	Bachelor	2	1	0	1	4
	Master	0	0	0	1	1
Main crop	Wheat	3	4	2	1	11
	Barley	1	0	0	1	2
	Rice	1	3	2	4	10
	Maize	2	0	0	0	2
County	Shush	2	0	1	5	8
	Ahvaz	3	3	3	1	10
	Shadegan	2	4	4	0	7

WSN components are not available in the domestic market and they are also very costly". The availability and accessibility of the WSN equipment at affordable costs are then main concerns. The farmers in this factor also referred to knowledge and information problems to explain the limited adoption of WSNs. They believed that farmers do not have enough information (28: −2) and skills to implement WSNs on their farms (4: −2). One of them explained that "*people in rural areas are not familiar with new technologies. They are uneducated and traditional and their farming has few innovations"*. They therefore believe that it is necessary to provide information and training in order to increase the adoption of WSNs. One of the farmers stated: "*the WSN must be distributed by the government. Farmers expect the government to provide the farmers with appropriate knowledge of WSNs and facilitate farmers' decisions whether or not and how to adopt WSNs to achieve the best results"*. The governmental support for adopting WSNs was considered critical in generating positive attitudes. The farmers in this factor attributed the limited WSN adoption to a lack of support. Hence, these farmers are considered to be support seekers.

4.3.2. Factor 2: Resistance-adherents

Table 7 displays the most extremely rated statements for the second factor which hosts seven farmers. Farmers who belong to this factor believed that the application of WSNs is knowledge intensive and complex to implement (14: +2). They also believed that learning to apply the WSN system would not be possible for farmers (7: −2). From their perspective, the high initial cost of WSNs is beyond the economic reach of farmers (32: +2) and farmers cannot afford WSNs on their farms (23: −2). This is illustrated by the following statement: "*WSNs*

Factor 1

Completely disagree				Completely agree
-2	-1	0	+1	+2
11	38	32	12	36
18	7	15	26	34
27	22	8	33	25
35	23	29	13	5
4	30	16	2	24
28	10	20	9	6
	21	17	3	
	37	31	19	
		1		
		14		

Factor 2

Completely disagree				Completely agree
-2	-1	0	+1	+2
25	10	32	3	14
21	29	19	30	35
28	20	17	36	37
34	15	16	8	1
7	31	12	5	33
23	6	2	13	11
	22	4	9	
	27	18	24	
		38		
		26		

Factor 3

Completely disagree				Completely agree
-2	-1	0	+1	+2
19	32	33	29	25
21	9	16	22	31
12	8	4	1	38
28	27	34	26	2
13	17	35	37	10
23	18	36	7	20
	14	30	11	
	24	15	6	
		3		
		5		

Factor 4

Completely disagree				Completely agree
-2	-1	0	+1	+2
11	20	17	3	12
24	26	16	32	25
8	6	29	22	36
33	21	31	15	34
28	7	19	2	9
18	14	30	35	10
	4	1	23	
	5	37	13	
		27		
		38		

Fig. 4. Q-sorts of four identified groups sharing similar perceptions regarding WSN application (for the correspondence between the random numbers assigned to the statements see Table 4).

Table 4
Distinguishing statements among identified factors.

No.	Statement	Z-Scores			
		F1	F2	F3	F4
1	It is too difficult to interpret data collected by WSNs.	−0.07	1.49	0.79	−0.02
2	WSN application causes society to move toward sustainable agriculture.	0.82	−0.19*	1.54	0.73
3	WSNs enable farmers to reduce waste.	0.67	1.26	0–0.04	0.84
4	Farmers have enough knowledge and skills to implement WSNs in their farm.	−1.69*	−0.22	0.00	−0.92
5	The implementation of WSNs will lead to intergenerational and intragenerational justice.	1.39	0.72	−0.17*	−1.01*
6	Monitoring by the implementation of WSNs could provide more precise data to assist the farmers in their decision making.	1.21	−0.72	0.56	−0.69
7	Learning to apply the WSNs system would be easy for farmers.	−0.79	−1.74*	0.71*	−0.82
8	WSNs help to improve environmental quality.	0.03	0.72*	−0.75	−1.46
9	I will apply WSNs.	0.72	0.19	−0.75*	1.49*
10	WSNs decrease the production costs.	−0.85	−0.41	1.41	1.40
11	Data security of WSNs is high.	−0.96	1.40	0.67	−1.02
12	The application of WSN is understood as an effective way for utilizing resources.	1.20	0.00*	−1.54*	1.65
13	Installing WSNs as an economic policy tool can play an effective role in controlling the free use of resources in the agricultural sector.	0.82	0.43	−1.58*	0.61
14	I would find the WSN system to be complex for the farmers.	−0.44	1.74*	−0.79	−0.88
15	I will recommend other farmers to try WSNs.	0.10	−0.65	−0.04	0.74
16	Use of WSNs can significantly increase the quality of production.	0.03	0.00	0.00	0.00
17	Use of WSNs can significantly increase the quantity of production.	0.00	0.00	−0.79*	0.10
18	There exist necessary resources to install WSN system.	−1.20	−0.29	−0.79	−1.65
19	The WSN system makes farming activates more enjoyable.	0.56	0.08	−1.12*	−0.01
20	Using WSNs would enable farmers to accomplish farming tasks more quickly.	0.00	−0.61	1.41*	−0.53
21	The governmental support WSN application.	−0.87	−0.87	−1.47	−0.82
22	Cost–benefit and added value of WSNs is clear.	−0.80	−0.72	0.93	0.79
23	Farmers have enough money to afford WSNs in their farm.	−0.84	−1.74	−1.58	0.68*
24	WSNs reduce water losses in farming system.	1.32*	0.16*	−0.83	−1.29
25	WSNs are appropriate for all farm context and size.	1.43	−0.87*	1.58	1.65
26	WSNs prevent or reduce potential human problems.	1.14	−0.39	0.79	−0.58
27	WSNs are available and accessible to farmers.	−1.57	−0.74	−0.79	−0.19
28	Farmers have enough information about WSNs.	−1.69	−1.74	−1.58	−1.65
29	I feel like being under social pressure to use WSNs in my farm.	0.03	−0.49	0.97*	0.00
30	The implementation of WSNs involves a mandatory change in the traditional farming.	−0.85*	1.03*	−0.04	−0.02
31	Agriculture extension establishments and initiatives support WSNs application.	0.00	−0.67	1.58*	0.00
32	WSNs lead to sustainable resource management.	0.23	0.16	−0.69*	0.84
33	The implementation of WSNs is as an effective way for field monitoring.	1.02	1.48	0.04*	−1.49*
34	WSNs could be used as an alternative information source in agriculture.	1.43	−1.74*	0.00*	1.56
35	WSN installation can reduce the amount of product due to lower input consumption.	−1.63*	1.74*	0.00	0.71
36	The community encourage the use of new technologies including WSNs.	1.61	0.91*	0.00*	1.65
37	High initial cost of WSNs is beyond the economic reach of farmers.	−0.90*	1.61*	0.79	−0.02
38	This plan prevents some farmers from leaving agriculture.	−0.60	−0.33	1.58*	−0.37

Note: Significance of distinctiveness of statement is indicated for p-values:
* $p \leq 0.05$.

Table 5
Consensus statements across all factors.

No.	Statement	Grid position			
		F1	F2	F3	F4
16	Use of WSNs can significantly increase the quality of production.	0	0	0	0
21	The governmental support WSN application.	−1	−2	−2	−1
28	Farmers have enough information about WSNs.	−2	−2	−2	−2

are quite expensive for farmers and the price of WSNs is a challenge for implementing this technology". This group insisted that it is too difficult to interpret the data collected by WSNs (1: +2). They therefore believe that WSNs could not be used as an alternative information source in agriculture (34: −2). Farmers grouped in this factor referred to the difficulty and complexity of WSN usage. Based on these statements, we label these farmers as resistance-adherents.

4.3.3. Factor 3: Optimists

Table 8 shows the statements that stood out for the farmers included in the third factor. They believed that WSNs decrease the production costs (10: +2) and that using WSNs would enable farmers to accomplish farming tasks more quickly (20: +2). They added that a WSN application causes the society to move toward sustainable agriculture (2: +2) and it prevents some farmers from leaving agriculture (38: +2). However, they accepted that farmers do not have enough information (28: −2) and money to afford WSNs in their farm (23: −2). This perception was also expressed during the post sort interviews where one respondent stated that: "*increasing information dissemination and awareness among all WSN stakeholders, especially farmers and policymakers, about WSN systems is an important factor to overcome cultural biases in conventional farm management*". The farmers of this group are optimists and they believe that the use of WSNs will have positive impacts.

4.3.4. Factor 4: Adoptive-adherents

Table 9 lists the most extreme ranking statements expressed by the five farmers in the last factor. They stated that the application of WSNs is understood as an effective way for utilizing resources and enhancing crop productivity (12: +2). They believed that the WSNs decrease the production costs (10: +2). Moreover, they thought the community encourages the use of new technologies including WSNs (36: +2). They therefore believe that WSNs could be applied as an alternative information source in agriculture (34: +2) and they will use it in their fields (9: +2). These farmers are considered adoptive-adherents. They believed that WSNs could be used as an information source in agriculture and they would apply WSNs in their field.

4.4. Discriminant analysis

Table 10 shows the results obtained through the classification after having applied a discriminant analysis. The table indicates the consistency of the classification obtained and the number of farmers correctly categorized. Based on the classification results, 100% of the originally grouped farmers were correctly classified.

The value of the Wilkis' Lambda and its related Chi-square, the degrees of freedom and the significance level of the discriminant functions are given in Table 11. The discriminability of the two discriminant functions is statistically significant, which confirms the

Table 6
Top 6 most-agree/ least-agree statements for Factor 1.

No.	Statement	Grid position	Z score	Rank
Most-agree				
36	The community encourages the use of new technologies including WSNs.	+2	1.606	1
34	WSNs could be used as an alternative information source in agriculture.	+2	1.433	2
25	WSNs are appropriate for all farm contexts and sizes.	+2	1.428	3
5	The implementation of WSNs will lead to intergenerational and intragenerational justice.	+2	1.394	4
24	WSNs reduce water losses in the farming system.	+2	1.320	5
6	Monitoring by the implementation of WSNs could provide more precise data to assist the farmers in their decision making.	+2	1.209	6
Least-agree				
11	Data security of WSNs is high.	−2	−0.96	33
18	Necessary resources to install WSN system are available.	−2	−1.20	34
27	WSNs are available and accessible to farmers.	−2	−1.57	35
35	WSN installation can reduce the amount of product due to lower input consumption.	−2	−1.63	36
4	Farmers have enough knowledge and skills to implement WSNs in their farms.	−2	−1.69	38
28	Farmers have enough information about WSNs.	−2	−1.69	38

Table 7
Top 6 most-agree/ least-agree statements for Factor 2.

No.	Statement	Grid position	Z score	Rank
Most-agree				
14	I would find the WSN system to be complex for the farmers.	+2	1.74	1
36	WSN installation can reduce the amount of product due to lower input consumption.	+2	1.74	1
32	High initial cost of WSNs is beyond the economic reach of farmers.	+2	1.61	3
1	It is too difficult to interpret data collected by WSNs.	+2	1.49	4
5	The implementation of WSNs is as an effective way for field monitoring.	+2	1.48	5
11	The data security of WSNs is high.	+2	1.40	6
Least-agree				
25	WSNs are appropriate for all farm contexts and sizes.	−2	−0.87	34
21	The government supports the WSN application.	−2	−0.87	34
28	Farmers have enough information about WSNs.	−2	−1.74	38
34	WSNs could be used as an alternative information source in agriculture.	−2	−1.74	38
7	Learning to apply the WSN system would be easy for farmers.	−2	−1.74	38
23	Farmers have enough money to afford WSNs on their farm.	−2	−1.74	38

Table 8
Top 6 most-agree/ least-agree statements for Factor 3.

No.	Statement	Grid position	Z score	Rank
Most-agree				
25	WSNs are appropriate for all farm contexts and sizes.	+2	1.58	3
31	Agriculture extension establishments and initiatives support WSN application.	+2	1.58	3
38	This plan prevents some farmers from leaving agriculture.	+2	1.58	3
2	WSN application causes the society to move towards sustainable agriculture.	+2	1.54	4
10	WSNs decrease the production costs.	+2	1.41	6
20	Using WSNs would enable farmers to accomplish the farming tasks more quickly.	+2	1.41	6
Least-agree				
19	The WSN system makes farming activates more enjoyable.	−2	−1.12	33
21	The government supports WSN application.	−2	−1.47	34
12	The application of WSNs is understood as an effective way for utilizing resources.	−2	−1.54	35
28	Farmers have enough information about WSNs.	−2	−1.58	38
13	Installing WSNs as an economic policy tool can play an effective role in controlling the free use of resources in the agricultural sector.	−2	−1.58	38
23	Farmers have enough money to afford WSNs on their farms.	−2	−1.58	38

significant differences across the groups. The first discriminant function has an eigenvalue of 21.72, and the rate of variance contribution (discrimination efficiency) is 94.70. The correlation coefficient is positive and large (0.97). By using the two discriminant functions, 100% of the sample variance can be explained.

Fig. 5 plots the groupings mapped over the first and second discriminant functions using their discriminant coefficients as coordinates for all the analysed farmers. The classification results in small distances within groups and large distances between groups. Hence, this suggests that the classification obtained through the Q-factor analysis could be successfully validated by the discriminant analysis. Therefore, the Q-factor analysis could efficiently predict and classify the farmers' perception regarding the application of WSNs.

Table 10
Classification results of the Fisher discriminant functions.

Actual group	n	Predicted group membership			
		Support seekers	Resistance-adherents	Optimists	Adoptive-adherents
Support seekers	7	7 (100%)	0	0	0
Resistance-adherents	7	0	7 (100%)	0	0
Optimists	4	0	0	4 (100%)	0
Adoptive-adherents	6	0	0	0	6 (100%)
Ungrouped cases	1	0	1 (100%)	0	0

5. Discussion

Based on the analysis of the Q-sorts, four different groups of farmers were identified representing the ways in which they perceive the application of WSN technology. A first result is that perceptions considerably differed amongst the farmers we interviewed, while many investigations have considered farmers to be homogeneous groups. This concurs to previous studies that also acknowledge the heterogeneity among farmers (Daxini et al., 2019; Dela Rue et al., 2019; Stringer et al., 2020; Amadu et al., 2020). Our study confirms that farmers have different views on applying WSNs. It is important to note that these are perceptions which do not have any formative value. Before entering a more detailed discussion, we recall the main traits of each factor.

The first group of farmers are "support seekers". They believed that the most important factors which limit WSN adoption include the lack of WSN availability and accessibility as well as the lack of technological facilities, information, knowledge and skills to implement WSNs. In this context, our findings are in line with the findings of other scholars such as McNairn and Brisco (2004), Dube (2013) and Verburg et al. (2019) who attribute the limited application of WSNs in small-scale farming to a lack of access, information, awareness, training material, and resources. Therefore, WSNs could potentially be adopted by the farmers represented by this group, if they receive the requested support. Similarly, several studies reported that substantial financial, training and technical supports are necessary in order to secure the development of applicable technology and to facilitate the adoption among farmers (Zheng et al., 2018; Barnes et al., 2018; Verburg et al., 2019). The support seekers would be slower than the adoptive-adherents but faster than the resistance-adherents in the adoption process of WSNs.

The second group "resistance-adherents" refers to farmers who fear the complexity of the use WSNs, the difficulty to interpret the data

Table 9
Top 6 most-agree/ least-agree statements for Factor 4.

No.	Statement	Grid position	Z score	Rank
Most-agree				
12	The application of WSNs is understood as an effective way for utilizing resources.	+2	1.65	3
25	WSNs are appropriate for all farm contexts and sizes.	+2	1.65	3
36	The community encourages the use of new technologies including WSNs.	+2	1.65	3
34	WSNs could be used as an alternative information source in agriculture.	+2	1.56	4
9	I will apply WSNs.	+2	1.49	5
10	WSNs decrease the production costs.	+2	1.40	6
Least-agree				
11	Data security of WSNs is high.	−2	−1.02	33
24	WSNs reduce water losses in their farming system.	−2	−1.29	34
8	WSNs help to improve the environmental quality.	−2	−1.46	35
33	The implementation of WSNs is as an effective way for field monitoring.	−2	−1.49	36
28	Farmers have enough information about WSNs.	−2	−1.65	38
18	The necessary resources are avaible to install a WSN system.	−2	−1.65	38

Table 11
Eigenvalues and statistical indicators of the Fisher discriminant functions.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation	Wilks' Lambda	Chi-square	df	Sig.
1	21.72	94.70	94.70	0.97	0.02	74.60	12	0.00
2	1.22	5.30	100.00	0.74	0.44	15.25	6	0.01

collected by WSNs, the high initial cost of WSNs and the potentially negative effect on crop production due to the lower input use as a result of WSN applications. They therefore believe that this technology could not be used as an information source in small-scale farming systems. Similarly, Wang et al. (2006) found that WSN technology was considered as a complex and high cost technological intervention. In addition, McNairn and Brisco (2004) attribute the limited application of WSNs in small-scale farming to the costs, timing, knowledge barriers, and interpretation of the data. Moreover, it is a challenge for a farmer to interpret WSN data (Dube, 2013). These limitations create challenges in the design of WSN applications, especially for resistance-adherent farmers. They would probably be the last farmers to adopt WSNs; their perceptions are difficult to address and solve in the short term and the time of adoption will probably be significantly longer than that for other groups.

The third group are farmers who are “optimists”. They focus on the impacts of WSNs and believe that the use of WSNs will result in positive impacts including decreasing the production costs, accomplishing farming tasks more quickly, preventing some farmers from leaving agriculture, and causing society to move toward sustainable agriculture. Brooke and Burrel (2013) and Cao et al. (2008) have also pointed out that the WSN applications increase productivity, efficiency and profitability while reducing unintended impacts on wildlife and the environment. Therefore, concurring to many scholars, WSNs can provide good opportunities for farmers (Mafuta et al., 2012; Ali, 2015; Byamukama, et al., 2018). Farmers in this group are willing to take risks and apply WSNs in the case they receive extra support.

Finally, “adoptive-adherents” believed that WSNs could be used as an alternative information source in agriculture and they will apply this technology in their field. In this regard, Rezaei and Ghofranfarid (2018) argued that if people have a favourable perception towards a new technology, they could mentally be ready to adopt the technology and could react to it more correctly. This mental preparation may lead farmers to show higher willingness to use the technology. In addition, several studies have shown that these perceptions appeared to be a reasonable predictor of behaviour at the early stages of technological adoption (Cheung and Vogel, 2013). Given that WSN technology has recently been introduced in Iran albeit still in its infancy, the adoptive-adherents might be the early adopters of it.

Fig. 6 plots the four groups along two axes of levels of confidence and activity. The farmers’ perceptions range from feeling more active agents to those feeling passive bystanders, and from confident to ambivalent about the WSN application. Resistance-adherents and adoptive-adherents considered the farmers’ ability in adopting WSNs. In contrast, support seekers and optimists hold a passive bystander perspective by which farmers felt a need for external help to support them in adopting WSNs. Adoptive-adherents and optimists were reasonably positive about the consequences of WSN application. However, resistance-adherents and support seekers raised questions regarding the implementation of WSNs, including (i) whether this technology will be successful, and (ii) what consequences and implications may be implied by the implementation of a WSN. Worth mentioning is also that the WSN technology is new to most farmers interviewed and they all felt a risk for the outcomes to be expected.

6. Conclusion

This study is, to the best of our knowledge, one of the first to use a Q-methodology to explain the farmers’ perception of WSN application as a smart farming technology. The results of this study suggest that there are four different groups of farmers to distinguish: support seekers, resistance-adherents, optimists and adoptive-adherents. Each group clusters farmers whose perceptions of the WSN application are significantly similar. The results indicate three main features: i) Farmers did not form homogeneous groups but included different groups with differeing perception patterns of WSN applications, but

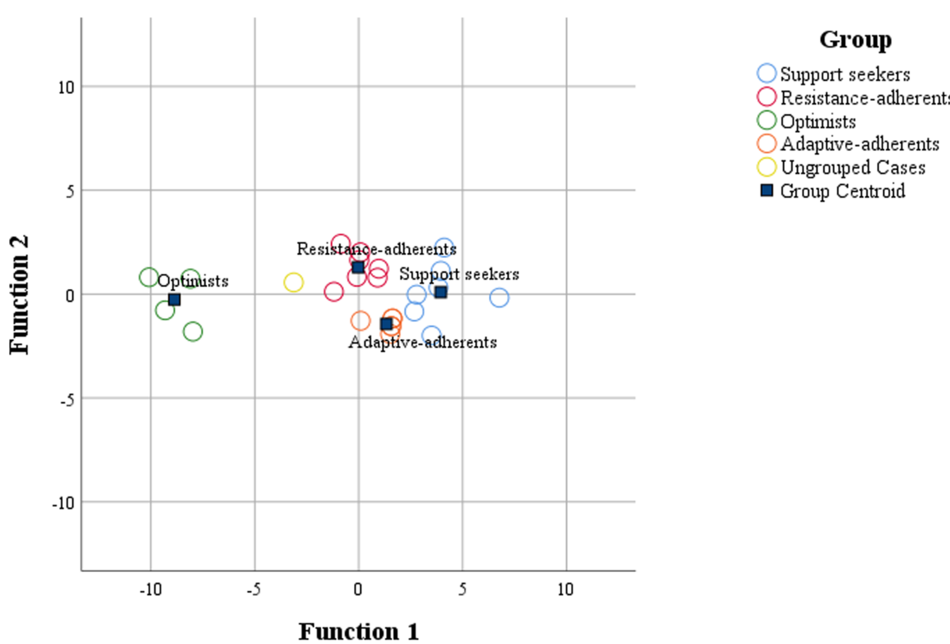

Fig. 5. Groupings of farmers using the first and second discriminant functions.

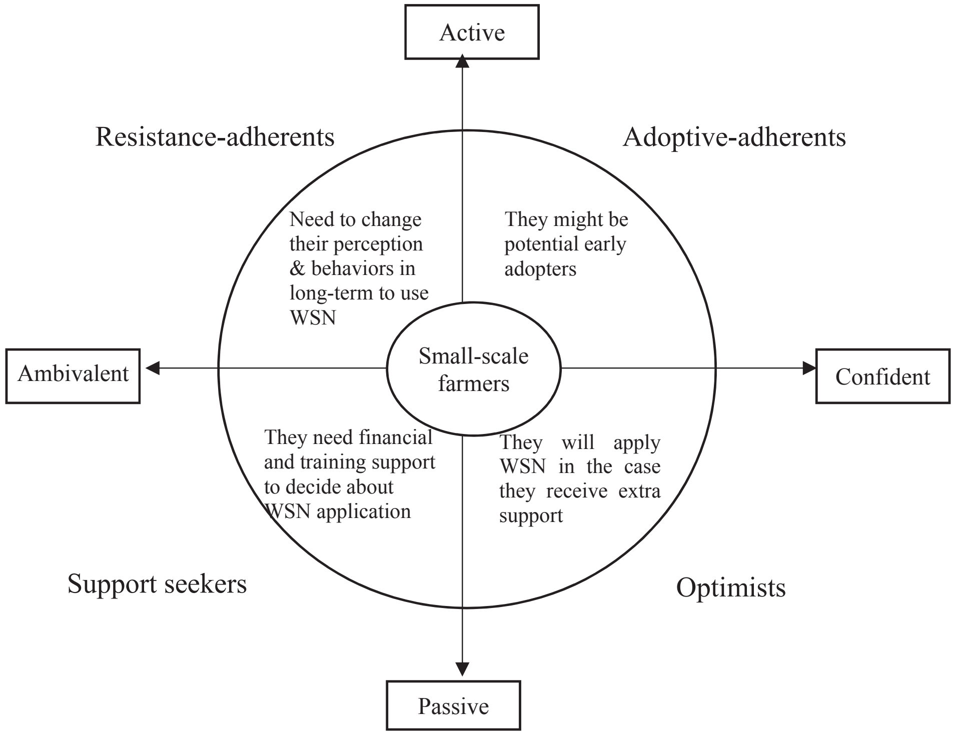

Fig. 6. Different perceptions on WSN application.

there was some degree of shared concerns between them. ii) Amongst farmers there were different perceptions including those who are characterized as passive farmers and who felt a need for external support in order to adopt WSNs (support seekers and optimists), active agents who considered the farmers' ability to adopt WSNs (resistance-adherents and adoptive-adherents), those who were positive about the consequences of a WSN application (adoptive-adherents and optimists), and finally, ambivalents who were somewhat unsure about the consequences of a WSN application (resistance-adherents and support seekers). iii) There were groups among farmers who reflected simple and superficial perceptions about WSN applications (adoptive-adherents) as well as those who had more complex perceptions on WSN applications (resistance-adherents).

The results of this study are expected to be used as a basis for the promotion of WSN technology in the agricultural sector. Perceptions are a systematic way of presenting ideas for constructive decision-making. Awareness of the identified perceptions can therefore provide a valuable frame for policy and decision-makers to address the concerns of farmers and develop appropriate and specific strategies for each group. Yet, additional research is needed to analyze how policy makers, decision makers, and other stakeholders can use the perception of farmers in a decision-making process. The results further extend the current body of knowledge on agricultural technologies adoption by investigating Q-methodology in a new field of agricultural technology (i.e., WSNs technology) and offering a guide for a better understanding of farmers' perception.

Accepting the fact that Iran has increasingly faced challenges and constraints affecting its agricultural productivity, adoption of digital and improved technologies including WSNs has been of great concern in Iranian agriculture. The findings of our study highlight a need for further studies in order to identify the different perceptions of policy makers as well as their opinions on the most effective policies. Qualitative research activities are needed to study the attitudes of policy and decision makers and other stakeholders toward the solutions and management strategies for WSN application. Their perceptions and attitudes about WSNs may directly affect the provision of better solutions and managing interventions. Although this study has identified the farmers' perception of WSN adoption in Iran, some limitations should be noted. A primary limitation could be the small number of participants. Given that WSNs in Iran are passing through a research stage and there are not many farmers who have tried WSN technology in practice, approaching a large number of respondents who were able to participate in the Q-sorting was not possible. Future studies may increase the sample by including a few country case studies at the same development status which would allow us to understand the differences in perceptions towards the application of WSNs. As this study focuses on the identification of the perceptions, a follow up study may consist of a quantitative survey to assess the distribution of the identified perceptions. This could possibly focus on the main limiting constraints we have identified or target a specific cluster of farmers if the budget is limited.

CRediT authorship contribution statement

Fatemeh Taheri: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Data curation, Investigation. **Marijke D'Haese:** Conceptualization, Writing - original draft, Writing - review & editing, Validation, Supervision, Project administration. **Dieter Fiems:** Funding acquisition, Writing - review & editing, Supervision. **Gholam Hossein Hosseininia:** Validation, Writing - review & editing. **Hossein Azadi:** Validation, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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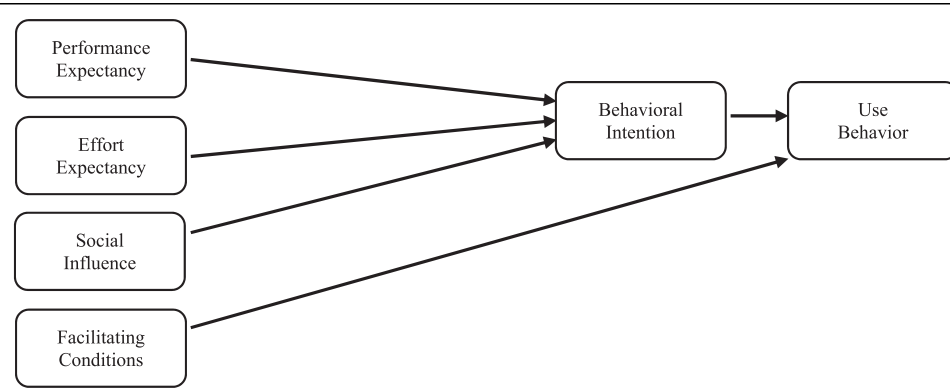
Annex A

The characteristics of the agricultural specialists and farmers who participated in the interviews and focus groups.

	Participants																																
Features	Specialists (n = 12)												Farmers (Focus group = 4)																				
	no. 1	no. 2	no. 3	no. 4	no. 5	no. 6	no. 7	no. 8	no. 9	no. 10	no. 11	no. 12	Group 1 (n = 8)								Group 2 (n = 5)					Group 3 (n = 4)				Group 4 (n = 4)			
													no.1	no.2	no.3	no.4	no.5	no.6	no.7	no.8	no.1	no.2	no.3	no.4	no.5	no.1	no.2	no.3	no.4	no.1	no.2	no.3	no.4
Age (mean)/year	32	48	54	52	53	28	50	32	53	49	38	35	68	50	38	80	50	52	58	35	32	20	60	43	38	27	32	45	58	35	30	36	43
Sex (1: Male; 2: Female)	1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Job Experience (mean)/ year	12	20	30	26	30	2	25	12	28	29	13	7	30	5	15	60	30	25	30	13	15	5	30	25	20	7	15	20	27	12	10	8	25
Education1: Illiterate2: Elementary3: High school4: Bachelor5: Master6: Doctoral	5	6	5	5	6	5	5	5	4	5	6	6	4	3	3	3	2	2	3	3	2	2	1	3	4	3	4	4	3	3	2	4	4
Main Crops1: Wheat2: Vegetables3: Rice	–	–	–	–					–	–	–	–	1	1	1	1	1	1	1	1	3	3	3	3	3	1	3	1	1	2	2	3	2
Major1: Agronomy2: Irrigation3: Agricultural mechanization4: Agricultural extension and education5: Plant protection	5	2	4	1	4	1	5	5	1	1	3	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Level of management:1: Expert2: Academic3: Administrator	1	2	3	1	3	1	3	1	1	1	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–



Annex B Theoretical framework of UTAUT (Venkatesh et al., 2003).

Annex C Q- statements of farmers' perception analysis on WSN adoption

Theme	Definition		Statements	No.
Performance expectancy	Performance expectancy is defined as the degree to which a farmer believes that using WSNs will help him attain gains in farming performance.	Economic benefits	WSNs decrease the production costs.	10
			The application of WSN is understood as an effective way for utilizing resources.	12
			Use of WSNs can significantly increase the quality of production.	16
			Use of WSNs can significantly increase the quantity of production.	17
			Using WSNs would enable farmers to accomplish farming tasks more quickly.	20
			WSN installation can reduce the amount of product due to lower input consumption.	35
			Installing WSNs as an economic policy tool can play an effective role in controlling the free use of resources in the agricultural sector.	13
			The implementation of WSNs is as an effective way for field monitoring.	33
			Cost–benefit and added value of WSNs is clear.	22
		Social benefits	The WSN system makes farming activates more enjoyable.	19
			Monitoring by the implementation of WSNs could provide more precise data to assist the farmers in their decision making.	6
			WSNs could be used as an alternative information source in agriculture.	34
			Data security of WSNs is high.	11
			WSNs prevent or reduce potential human problems.	26
			This plan prevents some farmers from leaving agriculture.	38
			The implementation of WSNs will lead to intergenerational and intragenerational justice.	5
			The implementation of WSNs involves a mandatory change in the traditional farming.	30
		Environmental benefits	WSNs enable farmers to reduce waste.	3
			WSNs reduce water losses in farming system.	24
			WSN application causes society to move toward sustainable agriculture.	2
			WSNs help to improve environmental quality.	8
			WSNs lead to sustainable resource management.	32
Effort expectancy	Effort expectancy is defined as the degree of ease associated with the use of WSNs system.		It is too difficult to interpret data collected by WSNs.	1
			Learning to apply the WSNs system would be easy for farmers.	7
			I would find the WSN system to be complex for the farmers.	14
			WSNs are appropriate for all farm context and size.	25
			Farmers have enough knowledge and skills to implement WSNs in their farm.	4
			Farmers have enough money to afford WSNs in their farm.	23
			Farmers have enough information about WSNs.	28
			High initial cost of WSNs is beyond the economic reach of farmers.	37
Social influence	Social influence is defined as the degree of social pressure perceived by farmer to use WSNs system.		The governmental support WSN application.	21
			I feel like being under social pressure to use WSNs in my farm.	29
			The community encourage the use of new technologies including WSNs.	36
Facilitating conditions	Facilitating conditions are defined as the degree to which a farmer believes that an organizational and technical infrastructure exists to support the use of WSNs system.		There exist necessary resources to install WSN system.	18
			WSNs are available and accessible to farmers.	27
			Agriculture extension establishments and initiatives support WSNs application.	31
Behavioral intention	Behavioral intention is defined as farmer's intention to use WSNs.		I will apply WSNs.	9
			I will recommend other farmers to try WSNs.	15

Annex D. Factor arrays for each of the four factors (ideal Q sort scores).

No.	Statement	Grid position			
		F1	F2	F3	F4
1	It is too difficult to interpret data collected by WSN.	0	2	1	0
2	WSN application causes society to move toward sustainable agriculture.	1	0	2	1
3	WSNs enable farmers to reduce waste.	1	1	0	1
4	Farmers have enough knowledge and skills to implement WSNs in their farm.	−2	0	0	−1
5	The implementation of WSN will lead to intergenerational and intragenerational justice.	2	1	0	−1
6	Monitoring by the implementation of WSN could provide more precise data to assist the farmers in their decision making.	2	−1	1	−1
7	Learning to apply the WSN system would be easy for farmers.	−1	−2	1	−1
8	WSNs help to improve environmental quality.	0	1	−1	−2
9	I will apply WSNs.	1	1	−1	2
10	WSNs decrease the production costs.	−1	−1	2	2
11	Data security of WSNs is high.	−2	2	1	−2
12	The application of WSN is understood as an effective way for utilizing resources.	1	0	−2	2
13	Installing WSN as an economic policy tool can play an effective role in controlling the free use of resources in the agricultural sector.	1	1	−2	1
14	I would find the WSN system to be complex for the farmers.	0	2	−1	−1
15	I will recommend other farmers to try WSNs.	0	−1	0	1
16	Use of WSNs can significantly increase the quality of production.	0	0	0	0
17	Use of WSNs can significantly increase the quantity of production.	0	0	−1	0
18	There exist necessary resources to install WSN system.	−2	0	−1	−2
19	The WSN system makes farming activates more enjoyable.	1	0	−2	0
20	Using WSNs would enable farmers to accomplish farming tasks more quickly.	0	−1	2	−1
21	The governmental support WSN application.	−1	−2	−2	−1
22	Cost–benefit and added value of WSNs is clear.	−1	−1	1	1
23	Farmers have enough money to afford WSNs in their farm.	−1	−2	−2	1
24	WSNs reduce water losses in farming system.	2	0	−1	−2
25	WSNs are appropriate for all farm context and size.	2	−2	2	2
26	WSNs prevent or reduce potential human problems.	1	0	1	−1
27	WSN are available and accessible to farmers.	−2	−1	−1	0
28	Farmers have enough information about WSNs.	−2	−2	−2	−2
29	I feel like being under social pressure to use WSNs in my farm.	0	−1	1	0
30	The implementation of WSN involves a mandatory change in the traditional farming.	−1	1	0	0
31	Agriculture extension establishments and initiatives support WSNs application.	0	−1	2	0
32	WSN leads to sustainable resource management.	0	0	−1	1
33	The implementation of WSNs is as an effective way for field monitoring.	1	2	0	−2
34	WSNs could be used as an alternative information source in agriculture.	2	−2	0	2
35	WSN installation can reduce the amount of product due to lower input consumption.	−2	2	0	1
36	The community encourage the use of new technologies including WSN.	2	1	0	2
37	High initial cost of WSNs is beyond the economic reach of farmers.	−1	2	1	0
38	This plan prevents some farmers from leaving agriculture.	−1	0	2	0

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