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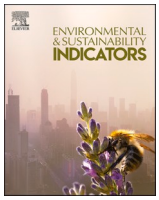

Conservation agriculture measures as a strategy to create sustainable social and psychological changes in agricultural communities

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ABSTRACT

The main aim of this study was to investigate the potential of encouraging intention to use conservation agriculture technologies to create sustainable social and psychological changes in agricultural communities. The study was carried out using a cross-sectional survey using 384 Iranian landowner farmers as the sample. The research instrument was a researcher-made questionnaire. Furthermore, its validity and reliability were evaluated using different quantitative and qualitative indices. The results revealed that the basic variables of Theory of Planned Behavior including attitude towards conservation agriculture (ACA), subjective norms of conservation agriculture (SNCA), and perceived behavioral control on conservation agriculture (PBCCA) positively and significantly affected the intention towards application of conservation agriculture technologies and practices (IACATP). Comparison of the original and extended versions of Theory of Planned Behavior showed that the inclusion of the variables perceived risk conventional agriculture (PRCA), knowledge about conservation agriculture (KCA), level of education, farm size, and income level in the original Theory of Planned Behavior could increase its explanatory power from 66.4% to 77.3%. This result was one of the most important contributions of the present study that can be considered a turning point for social change interventions in rural and agricultural communities. The study also led to new insights into the mechanisms of encouraging IACATP and social-psychological changes in agricultural communities. These innovative insights can be used by different users such as governmental policy-makers, technology developers, social change interventionists, environmental decision-makers, and researchers.

1. Introduction

Agriculture, as one of the oldest production activities, has been of particular importance in the growth and development of different countries. The increasing development of farming systems has recently led to the depletion of water and soil resources and environmental pollution by various pollutants, including heavy metals, plastics, and chemicals (Kour et al., 2021). Therefore, adapting growing food demand to sustainable farming practices is one of the world's significant challenges (FAO, 2017; Skaf et al., 2019; Calicioglu et al., 2019; Laurett et al., 2021; AE AbdelRahman et al., 2022). Sustainability is one of the main components of agricultural production that will lead to food security and the maintenance of production resources for current and future generations (Bijani et al., 2017; Janker and Mann, 2020; Valizadeh and Hayati, 2021; Valizadeh et al., 2022a).

One of the best ways to improve or increase agricultural sustainability is to accept and apply conservation agriculture (Nandan et al., 2021; Parajuli et al., 2021; Nyaga et al., 2021; Valizadeh et al., 2023). Conservation agriculture or conservation farming system is a sustainable perspective to agricultural production that ties conserve soil resources from erosion and degradation. It also improves biodiversity, preserves natural resources, and optimizes crop yields (Rodenburg et al., 2020; Mutuku et al., 2021a,b). Conservation farming/agriculture depends on the three fundamental principles, including minimum soil erosion during practicing agriculture (using minimum tillage and no-tillage methods), maintaining the vegetation on the soil surface, and using crop rotation (FAO, 2019; Descheemaeker, 2020; Shrestha et al., 2020; Cueff et al., 2021; Mutuku et al., 2021a,b). The most essential benefits of conservation agriculture are increasing irrigation efficiency by reducing soil erosion and maintaining soil moisture content (Bondarovich et al.,

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2021) and minimizing wind and water erosion using leaving agricultural crops' residues on the soil surface (Sun et al., 2019; Das et al., 2020; Seitz et al., 2019; Gozubuyuk et al., 2020). Conservation agriculture also contributes to the management of energy consumption and reduction of environmental pollution (Jat et al., 2020; Nandan et al., 2021), preserves soil nutrients, increases soil organic matter, reduces pests and diseases, and controls weeds using crop rotation (Kanatas, 2020; Tiwari et al., 2021; Pardo et al., 2021). Therefore, this conservation agriculture system creates an opportunity to reduce cultivation costs, improve resource productivity, and reduce fertilizers and pesticides in agricultural production, which aims to make optimal use of all agrarian resources (Dhar et al., 2018; Tama et al., 2021).

Despite such benefits, some researchers showed that landowner farmers in practice are reluctant to use this type of agriculture. For example, studies by Dhar et al. (2018), Delaroche (2020), Tama et al. (2021), and Bazrafkan et al. (2022) have revealed that only 8–10 % of farmers worldwide have adopted conservation agriculture system. The highest acceptance rates of conservation agriculture have been reported in the United States of America, Brazil, Argentina, Canada, Australia, and Paraguay (Tama et al., 2021). In contrast, acceptance rates are relatively low in most African and Asian countries such as Bangladesh, China, Iran, etc. (Andersson and Giller, 2012; Ndah et al., 2018).

Brown et al. (2017) have reported that more than thirteen years after introducing conservation agriculture, this approach has not been extensively accepted by small-scale landowner farmers in sub-Saharan Africa. The low acceptance rate indicates that conservation agriculture has been negatively assessed by many smallholder farmers. However, the reasons for the low acceptance rate have not been adequately and thoroughly investigated (Brown et al., 2017). Although Bangladesh has established several national and international organizations to educate and raise awareness of landowner farmers about conservation agriculture, the acceptance rate of this agricultural system is low yet (Tama et al., 2021). Due to the lack of awareness about the importance of environmental protection and the excessive desire for higher incomes among some Chinese farmers, the application of chemical fertilizers, pesticides, plastics, and other chemicals has increased. This has exacerbated soil contamination and consequently diminished the role of conservation agriculture (Yang et al., 2018; Sun et al., 2019; Zhou et al., 2020).

Iran is a developing country with an arid and semi-arid climate. Therefore, Iranian landowner farmers have always been faced with a challenge namely lack of suitable soil and water in conventional agriculture (Fallah-Alipour et al., 2018). One of the best exit strategies to overcome this problem is to use conservation agriculture; however, Iranian landowner farmers are mainly unwilling to use this type of agriculture. Unwillingness to use conservation agriculture by many landowner farmers has led to various consequences such as soil erosion and water and air pollution (Koocheki et al., 2014; Yaghoubi Farani et al., 2016; Farani et al., 2019). The Iranian governmental and private sectors have planned many pro-environmental interventions in past two decades. Most of these interventions have been focused on the subjects such as reducing the use of agricultural pesticides and fertilizers, improving on-farm water management practices, facilitating environmental technologies to reduce the adverse impacts on agriculture, and protecting biodiversity (Yaghoubi Farani et al., 2016). However, the loss of biodiversity and soil and water resources is still a primary concern for environmentalists in Iran (Maleksaeidi and Keshavarz, 2019). Abadi et al. (2020) investigated the contribution of various incentives to join soil conservation initiatives in the East Azerbaijan province of Iran and the role of conservation agriculture characteristics in landowner farmers' decisions. The results showed that only 29.58% of landowner farmers had a high acceptance rate, and 70.42% had low soil conservation behavior (Abadi et al., 2020). Therefore, identifying and analyzing the main variables influencing the intentions and behavior of landowner farmers can lead to positive behavioral changes in this area. In other words, a deep understanding of the determinants of landowner farmers' intentions toward the application of conservation agriculture technologies and practices can reduce environmental problems and concerns about the degradation of natural resources (Yaghoubi Farani et al., 2016; Bijani et al., 2019). Such understanding can stimulate the development and implementation of some effective policies aiming at protecting the agricultural environment and soil and resources (Kolinjivadi et al., 2019).

Savari and Gharechaee (2020) used Theory of planned behavior (TPB) to conceptualize the landowner farmers to intention for safe use of chemical fertilizers. Their results revealed that the three main variables of the TPB including attitude, perceived behavioral control, and subjective norms had significant positive influences on landowner farmers' intention for the safe use of chemical fertilizers. The results of this study also revealed that the extended theoretical framework by adding risk perception and moral norms improves the model's predictive power by 11.2%. In this study, the most significant variables of TPB included attitude and subjective norms. However, in the extended version of the theory, moral norm and risk perception were the important variables (Tama et al., 2021).

Ataei et al. (2019) studied the social interaction of farmers in applying the principles of conservation agriculture. According to the results of this study, the farmers are more likely to interact with local actors, and they interact less with the government and the actors outside the rural community. Ataei and his colleagues (Ataei et al., 2021) in another research studied the challenges of applying conservation agriculture in Iran from the perspective of experts and farmers. Their results revealed that the challenges of applying conservation agriculture in Iran can be categorized into six main strata, including institutional infrastructural, economic, training-research, environmental, mechanization, and cognitive challenges. In addition, Ashoori et al. (2017) studied the adoption of conservation farming practices for sustainable rice production among small-scale paddy farmers in northern Iran. Their study demonstrated that up to 42.6 % of the variance regarding the adoption of conservation practices could be predicted by a stepwise multiple regression model. Access to machinery, access to farming inputs, the use of canals as the main source of irrigation, and farm income had the greatest share in predicting adoption.

Reviewing these studies reveals that they mainly have a partial perspective to conservation agriculture and are focused on one single conservation method (for example safe use of chemical fertilizers). In other words, most of them suffer from having a comprehensive perspective to conservation agriculture. This is one of the first gaps that present study is trying to bridge. In addition, most of these studies have been done in a geographical region where soil degradation is not of significance. However, present study has been done in Fars Province of Iran where soil degradation is considered as great threat for the livelihood of the local communities. Not validating the models with reliable statistical methods is another point that has been neglected in most of the previous studies. In present study, different statistical indices were employed to validate the model. Finally, it should be mentioned that most of the previous studies have not specifically focused on socio-psychological determinants of intention and behavior. However, this study tries to have a comprehensive perspective on conservation farming practices. In other words, this study is not focused on one single conservation practice/behavior and theoretically contributes to extending the TPB by incorporating some new variables into it and validating it by a comparative analysis between the original and extended versions of the theory. It is also worth mentioning that this study introduces some practical and step-by-step guidelines and implications for behavioral change in the field of adopting conservation agricultural practices. Helping to understand the socio-psychological mechanism of behavioral changes in the context of applying conservation agriculture measures is another contribution of this study that can be used globally by agricultural policy-makers, managers of social change programs, field workers, and be intervenors.

Preliminary evaluations show that not many studies (e.g., Bijani

et al., 2017; Latifi et al., 2018; Ataei et al., 2019) have been conducted on the factors affecting the application of conservation technologies and practices in Iran. In other words, there is a research gap in this area. However, such studies can play a crucial role in formulating agricultural policies and facilitating behavioral changes in the field of application of conservation agriculture technologies and practices. Therefore, the analysis and understanding Iranian landowner farmers' intention to use conservation agriculture technologies and practices through the lens of TPB was selected as the main goal of the present study.

2. Theoretical framework: From TPB to extended TPB

Reasoned Action Theory (TRA) is one of the well-known theories used to predict people's behavior. This theory was first proposed by Fishbein and Ajzen (Fishbein and Ajzen, 1975). In this theory, it is assumed that behavioral intention towards a specific behavior is determined by two variables, namely attitude and subjective norms. Attitude refers to the favorable or unfavorable evaluation of a specific behavior (Valizadeh et al., 2022b). This is while the subjective norms of a person refer to people's opinions about what others think he/she should do (Savari and Gharechaee, 2020). Ajzen developed TRA in 1991 by introducing the construct perceived behavioral control and renamed it as the TPB (Ajzen, 1991). TPB tries to predict involuntary behaviors by considering perceptions of performance control as one of the predictors of intention. TPB focuses on perceptual determinants of behavior (Goli et al., 2020). It is one of the most widely used theories of social psychology that is widely applied to analyze environmentally friendly behaviors in various fields of water conservation (Kilic and Dervisoglu, 2013; Kumar Chaudhary et al., 2017; Zhong et al., 2019; Mohammadi-nezhad and Ahmadvand, 2020), soil conservation (Wauters et al., 2010), chemical inputs (Savari and Gharechaee, 2020; Bagheri et al., 2021), energy consumption (Canova and Manganelli, 2020; Bhutto et al., 2021; Liobikienė et al., 2021; Ali et al., 2021), and carbon consumption (Hou and Hou, 2019; Jiang et al., 2019). Tama et al. (2021) stated that TPB is the most appropriate model for predicting and understanding landowner farmers' willingness to use conservation agriculture. In general, the intention to apply conservation agriculture technologies and practices in TPB is influenced by three psychological constructs, which include ACA, PBCCA, and subjective norms of conservation agriculture (SNCA) (Tama et al., 2021). ACA refers to the landowner farmers' positive or negative orientation towards conservation agriculture technologies and practices. While SNCA refers to social pressures from external and internal sources to determine the landowner farmers' conservation behavior. These social pressures can be applied to landowner farmers by friends, acquaintances, family members, the agricultural community, and etc. It should be emphasized that the effect of social pressures can be positive or negative in different contexts. In fact, PBCCA refers to landowner farmers' perceived (not observed) ability to apply technologies and practices (Tama et al., 2021). Although the TPB provides a rational framework for analyzing landowner farmers' intention toward conservation agriculture, it is open for further extension. Therefore, to increase the explanation of the model, two variables, perceived risk of conventional agriculture (PRCA) and KCA, were included in the TPB (Tama et al., 2021). Since there is a lot of evidence of the positive effects of PRCA and KCA on landowner farmers' soil and water conservation intentions in the literature (e.g., Dumitrescu et al., 2011; Whitfield et al., 2015; Razzaghi Borkhani and Mohammadi, 2018), an attempt was made to provide an extended version of TPB in this study by including these two variables. Also, in this study, an attempt was made to test the effect of the three variables of education level, income, and farm size on farmers' knowledge of conservation agriculture. Then, the validity of the extended TPB was compared with the original TPB. Finally, the theoretical framework of the research was configured as Fig. 1. Based on this framework, the main hypotheses of present study are as follows.

1. ACA positively and significantly affects IACATP.
2. SNCA positively and significantly affects IACATP.
3. KCA positively and significantly affects IACATP.
4. PBCCA positively and significantly affects IACATP.
5. PRCA positively and significantly affects IACATP.
6. KCA positively and significantly affects ACA.
7. KCA positively and significantly affects SNCA.
8. KCA positively and significantly affects PBCCA.
9. KCA positively and significantly affects PRCA.
10. High education positively and significantly affects KCA.
11. Farm size positively and significantly affects KCA.
12. Income positively and significantly affects KCA.

3. Methodology

3.1. Research design, statistical population, and sampling approach

This study is an applied and quantitative analysis. Therefore, its results can be used by various stakeholders such as landowner farmers, academic researchers, planners, and decision-makers at different levels of agricultural and soil and water resources management.

This cross-sectional survey was carried out among landowner farmers in Fars province, Iran. A multi-stage random sampling approach was used to select the samples. According to the Statistical Center of Iran (2019), the total number of landowner farmers in Fars province was 278464 (N = 278464). The sample size was estimated using Krejcie and Morgan's (1970) table (n = 384). In order to selection of a representative sample, the study area was divided into 31 counties, each of which

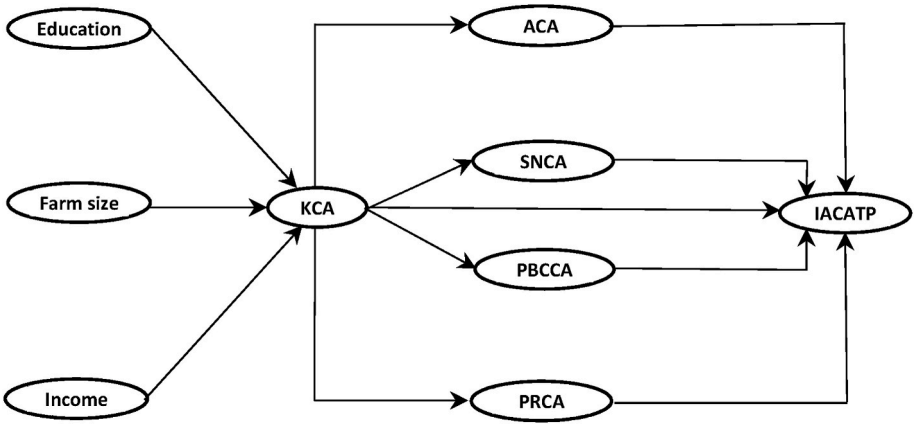

Fig. 1. Theoretical framework of the study.

represented a stratum. In the second stage, the names and characteristics of the sub-counties existing in each county were determined, and at least one sub-county was proportionally selected as a sample from each county. In the third stage, the villages within each sub-county were identified, and one village from each sub-county was randomly selected. In the fourth stage, the required sample size for each village was estimated in proportion to the total agricultural population and the sample chosen. Finally, landowner farmers (samples) were randomly selected from the villages.

3.2. Research instrument

The instrument used to collect the required information was a researcher-made and close-ended questionnaire. At first, we extracted a list of these activities and technologies using interview with experts of conservation agriculture. In the next step, research literature was reviewed to complete this list. Finally, 20 soil conservation technologies and activities were extracted and used to assess the landowner farmers' intention. The instrument's face and content validities were approved by the opinions of a group of experts in the field of conservation agriculture, bio-systems engineering, and environmental psychology. Nine specialists were selected to this end from the academic and executive areas of agriculture and environment. The pilot study was conducted with 30 landowner farmers in Fars province. At this stage, Cronbach's alpha coefficients were used to confirm the reliability of the instrument. Table 1 demonstrates the reliability scores of items measuring the variables in the extended TPB. At this stage, several weaknesses and problems were identified in the research tool. After eliminating these weaknesses, the questionnaire was prepared for the primary cross-sectional survey. After the cross-sectional survey and face-to-face interviews to collect the required data, composite reliability (CR), factor loadings of items (in first-order factor analysis), convergent validity or average variance extracted (AVE), the average shared squared variance (ASV), and maximum shared squared variance (MSV) were employed to appraise the different parts of the questionnaire in terms of the reliability and validity. Finally, it should be mentioned that all items in the questionnaire (Table 1) were measured using a five-point Likert scale (One (1): strongly disagree to fine (5): strongly agree).

Theoretically, ACA should include indicators (items) that show the positive and negative orientation of farmers to a phenomenon such as conservation agriculture. In this regard, in this study, the orientation of farmers towards basic terms such as "necessity of conservation agriculture and water and soil protection strategies", "the wiseness of using conservation agriculture", "the value of using conservation agriculture and protecting natural resources", and " the usefulness of conservation agriculture measures" was used to measure this variable. PBCCA basically refers to the difficulty and ease of applying conservation agricultural measures. Since this difficulty and ease in many cases depends on the facilities and capabilities of farmers, an effort was made to measure the level of difficulty and ease of using conservation agriculture activities. Also, availability of various necessary capabilities or facilities was also considered as another dimension of this variable. Therefore, the indicators measuring this variable were designed in such a way that they can measure "ease of applying conservation agriculture measures", "having the necessary time and skill to apply conservation agriculture", "economic ability of farmers", "having the necessary knowledge in the field of conservation agriculture", and "autonomy in the application of conservation agriculture measures". SNCA actually refers to the social pressures or the influence of the environment and the surrounding farmers on the application of conservation agriculture measures. These influences were evaluated in present study by evaluating "acquaintance effects", "importance of approval by others", "importance of expectations of acquaintances and friends", "importance of approval by fellow farmers", and "importance of approval by agricultural operators". IACATP shows the level of interest in the application of conservation agriculture technology in the near future. At this stage, some of the most

Table 1
Cronbach's alpha coefficients for the study measures.

Var.	No.	Items	Source
ACA		**Attitude towards conservation agriculture (ACA): (α = 0.77)**	Self-developed
	1	Conservation agriculture and the development of soil and water conservation strategies are very critical in agriculture.	
	2	Conservation agriculture and preventing the reduction of production capacity on agricultural lands is wise.	
	3	It is a valuable endeavor to use conservation agriculture and improve the state of natural resources.	
	4	Using effective conservation technologies and measures is helpful for the sustainability of agricultural activities.	
PBCCA		**Perceived behavioral control on conservation agriculture (PBCCA): (α = 0.82)**	Self-developed
	1	Ease of application of conservation agriculture technologies and measures.	
	2	Having the time and skills needed to apply conservation technologies and agricultural practices.	
	3	Having the necessary economic capacity to apply conservation agriculture technologies and measures.	
	4	Possessing the knowledge required to apply conservation technologies and measures.	
	5	Whether or not to use conservation farming technologies and practices is entirely up to me.	
SNCA		**Subjective norms of conservation agriculture (SNCA): (α = 0.83)**	Self-developed
	1	My acquaintances and those around me believe that I should be committed to using conservation agriculture technologies and practices.	
	2	Commitment to the application of conservation farming technologies and practices leads to my endorsement by those around me.	
	3	My acquaintances and friends expect me to be as committed as I can to the use conservation agriculture technologies and practices.	
	4	If I use conservation farming technologies and practices, practitioners developing sustainable agricultural activities will approve my work.	
	5	If I use conservation farming technologies and practices, colleagues or friends I emulate will approve of my work.	
IACATP		**Intention towards application of conservation agriculture technologies and practices (IACATP): (α = 0.71)**	
	1	Improving soil organic matter	Azimi Zadeh et al. (2019)
	2	Using direct cultivation	Souri Damirchi Sofla et al. (2021)
	3	Avoiding continuous tillage	Azimi- Nejadian (2021)
	4	Preventing soil from compaction	Souri Damirchi Sofla et al. (2021)
	5	Preservation of vegetation and remnants of previous products	Souri Damirchi Sofla et al. (2021)
	6	Tillage speed optimization	Azimi-Nejadian et al. (2019)

(continued on next page)

Table 1 (*continued*)

Var.	No.	Items	Source
	7	Adjust the depth of tillage tool optimization	Azimi-Nejadian et al. (2019)
	8	Non-use of very heavy tillage machines and tools	Rahmatian et al. (2021)
	9	Using compound tillage tools (such as combined)	Mohammadi et al. (2020)
	10	Using Comparison of Fiber Reinforced Polymer (FRP) in chisel plows and composite tillage tools instead of steel blades	Rahmatian et al. (2021)
	11	Replacement of Dulled blades	Self-developed
	12	Connecting and adjusting the devices correctly before starting work	
	13	Using tillage perpendicular to the slope	
	14	Using modern irrigation methods and optimizing water consumption	
	15	Wastewater treatment and recycling to the water consumption loop	
	16	Irrigation during the hours of the day and night when evapotranspiration is minimal	
	17	Alternative crops with less water consumption	
	18	Crop rotation	
	19	Intelligent irrigation management and laser farm leveling	
	20	Creating small stacks on the farm	
PRCA	**Perceived risk of conventional agriculture (PRCA): (α = 0.77)**		Tama et al. (2021)
	1	Continuous tillage is harmful to soil health.	
	2	Excessive use of groundwater resources will lead to a future irrigation water crisis.	
	3	Excessive tillage by fossil fuel-based tools leads to increased greenhouse gas emissions.	
	4	The use of chemicals in conventional agriculture increases soil and climate pollution.	
KCA	**Knowledge about conservation agriculture (KCA): (α = 0.81)**		Tama et al. (2021)
	1	I know all three characteristics of conservation agriculture.	
	2	I know the necessity and importance of conservation agriculture.	
	3	I have enough information that conservation agriculture can increase farmers' profits.	
	4	I know that conservation agriculture produces more output in the long run than traditional agriculture.	
	5	I know that conservation agriculture improves soil fertility.	

Source: Findings of present study

important conservation agricultural technologies and measures in the studied area such as "improvement of soil organic matter", "direct cultivation", "avoidance of continuous plowing", "prevention of soil compaction", "preserving vegetation and residues of previous plant productions", "optimization of plowing speed", "optimization of plowing depth", "not using heavy tillage tools", "using compound tillage tools", "using Comparison of Fiber Reinforced Polymer (FRP) in chisel plows and composite tillage tools instead of steel blades", "replacement of Dulled blades", "connecting and adjusting the devices correctly before starting work", "using tillage perpendicular to the slope", "using modern irrigation methods and optimizing water consumption", "wastewater treatment and recycling to the water consumption loop", "irrigation during the hours of the day and night when evapotranspiration is minimal", "alternative crops with less water consumption", "crop rotation", "intelligent irrigation management and laser farm leveling", and "creating small stacks on the farm" were evaluated in terms of intention to apply by farmers. Finally, PRCA refers to the level of farmers' awareness of the risks that conventional agriculture can have for them. This variable is based on the evaluation of farmers' views on "the level of continuous plow damage to soil health", "consequences of excessive exploitation of water resources", "the effect of excessive tillage by fossil fuel-based tools on the increase of greenhouse gases", and "The effect of using chemical substances on soil and air pollution" was measured.

3.3. Data gathering and analysis

Face-to-face interviews were applied to collect the required data. In collecting information, they used an experienced data gathering group. Data collection was performed in two months. According to the estimated sample size, 384 landowner farmers in different villages were interviewed. Since 37 landowner farmers refused to fill out the questionnaire, 347 questionnaires were collected. Seventeen questionnaires were discarded due to deficiencies in the answers. Finally, 330 questionnaires were analyzed. Data analysis was performed using $SPSS_{24}$, $AMOS_{20}$, and $SMART\text{-}PLS_3$. Mardia's coefficients of skewness and kurtosis were used to measure the normality of the data (Mardia,1970). First-order confirmatory factor analysis models were used to run the measurement models of the TPB and its extended version. The maximum likelihood method was used to measure measurement models. Direct/total and mediation/indirect structural models were employed to test the original and extended versions of TPB, respectively.

4. Results

4.1. Demographic characteristics

The analysis of the demographic characteristics of farmers in the region showed that about 94% of the respondents are men and only 6% of them are women. The analysis of the age of the respondents also shows that their average age is 46 years. Also, nearly 70 percent of respondents are between 30 and 60 years old. In terms of education, most of the respondents (about 60%) had low education (did not enter high school). Nevertheless, more than 26% of them had high school education. The division of farmers in terms of participation or non-participation in training courses related to conservation agriculture revealed that more than 90 percent of the respondents had not participated in training classes related to conservation agriculture. This highlights the need to develop conservation agriculture training among farmers in the study area. Also, they have an average annual income of 700 million Rials from each hectare of their land.

4.2. Correlation results

Correlation analysis results demonstrated that the variables ACA ($r = 0.558$; $p = 0.01$), SNCA ($r = 0.590$; $r = 0.01$), PBCCA ($r = 0.685$, $p = 0.01$), and PRCA ($r = 0.684$; $p = 0.01$) positively and significantly correlated with IACATP (Table 2). In addition, KCA had positive and significant correlation with ACA ($p = 0.391$; $r = 0.01$), SNCA ($p = 0.476$; $r = 0.01$), PBCCA ($r = 0.456$; $> p\ 0.461$; $= r$). These findings indicate that the predicted hypotheses regarding the correlation of variables in the extended TPB were confirmed. Also, the results revealed that the characteristics including education level ($p = 0.352$; $r = 0.01$), farm size ($p = 0.332$; $r = 0.01$), and income level ($p = 0.312$; $r = 0.01$) have significant positive relationships with KCA (Table 2).

4.3. Results of measurement models' estimation

Table 3 summarizes the results of the measurement models. Based on the results, factor loadings for all the extended TPB variables were higher than the acceptable value of 0.4. This result emphasizes that the

Table 2
Correlations among the study variables.

	IACATP	ACA	SNCA	PBCCA	PRCA	KCA	Education	Farm size	Income
IACATP	1+	**0.558**[a]	**0.590**[a]	**0.685**[a]	**0.684**[a]	0.695[a]	0.395[a]	0.348[a]	0.294[a]
ACA	**0.558**[a]	1	0.309[a]	0.386[a]	0.385[a]	**0.391**[a]	0.351[a]	0.298[a]	0.299[a]
SNCA	**0.590**[a]	0.309[a]	1	0.359[a]	0.381[a]	**0.476**[a]	0.257[a]	0.271[a]	0.198[a]
PBCCA	**0.685**[a]	0.386[a]	0.359[a]	1	0.465[a]	**0.456**[a]	0.326[a]	0.311[a]	0.280[a]
PRCA	**0.684**[a]	0.385[a]	0.381[a]	0.465[a]	1	**0.461**[a]	0.337[a]	0.341[a]	0.309[a]
KCA	0.695[a]	**0.391**[a]	**0.476**[a]	**0.456**[a]	**0.461**[a]	1	**0.352**[a]	**0.332**[a]	**0.312**[a]
Education	0.395[a]	0.351[a]	0.257[a]	0.326[a]	0.337[a]	**0.352**[a]	1	0.277[a]	0.213[a]
Farm size	0.348[a]	0.281[a]	0.271[a]	0.311[a]	0.341[a]	**0.332**[a]	0.277[a]	1	0.182[a]
Income	0.294[a]	0.299[a]	0.198[a]	0.280[a]	0.309[a]	**0.312**[a]	0.213[a]	0.182[a]	1

Abbreviations: Intention towards application of conservation agriculture technologies and practices (IACATP), Attitude towards conservation agriculture (ACA), Subjective norms of conservation agriculture (SNCA), Perceived behavioral control on conservation agriculture (PBCCA), Knowledge about conservation agriculture (KCA), Perceived risk of conventional agriculture (PRCA).
Point: Colored numbers are relationships that are defined in the conceptual framework (Fig. 1) in the form of hypotheses.
[a] Sig. Level: 0.01 error.
Source: Findings of present study

Table 3
Loading factors of items, reliability and validity assessment results, and normality evaluation results for the extended TPB.

Items/Variables	IACATP	ACA	SNCA	PBCCA	PRCA	KCA	skewness	kurtosis
IACATP1	0.90[a]						−1.226	−0.258
IACATP2	0.90						1.328	1.857
IACATP3	0.91						0.618	0.922
IACATP4	0.92						0.186	1.454
IACATP5	0.92						0.978	1.457
IACATP6	0.91						−0.891	0.551
IACATP7	0.93						−0.355	0.229
IACATP8	0.92						0.167	−0.766
IACATP9	0.97						0.639	−1.114
IACATP10	0.90						0.396	0.947
IACATP11	0.93						−0.398	0.698
IACATP12	0.93						1.089	−0.781
IACATP13	0.98						1.518	1.074
IACATP14	0.94						0.489	1.524
IACATP15	0.92						0.378	0.418
IACATP16	0.91						0.693	−0.247
IACATP17	0.95						0.378	0.789
IACATP18	0.92						0.508	−1.177
IACATP19	0.85						0.628	−0.781
IACATP20	0.93						0.759	0.632
ACA1		0.86[a]					−1.211	0.827
ACA2		0.91					0.433	0.489
ACA3		0.79					0.671	1.123
ACA4		0.93					1.088	−0.170
SNCA1			0.91[a]				0.694	0.581
SNCA2			0.95				0.417	0.967
SNCA3			0.79				0.890	0.355
SNCA4			0.85				−0.513	1.155
SNCA5			0.93				1.220	−0.287
PBCCA1				0.85[a]			1.392	0.890
PBCCA2				0.93			0.049	0.327
PBCCA3				0.94			0.450	0.681
PBCCA4				0.90			−0.859	0.527
PBCCA5				0.86			0.329	0.277
PRCA1					0.79[a]		0.556	0.258
PRCA2					0.91		0.399	0.634
PRCA3					0.93		0.877	−1.221
PRCA4					0.86		−0.121	0.799
KCA1						0.93[a]	0.215	0.437
KCA2						0.95	0.558	−0.580
KCA3						0.79	1.674	−1.228
KCA4						0.85	0.287	0.972
KCA5						0.86	−0.850	0.195
CR	0.99	0.92	0.94	0.95	0.92	0.94	–	–
AVE	0.85	0.76	0.78	0.80	0.76	0.77	–	–
MSV	0.48	0.31	0.34	0.46	0.46	0.48	–	–
ASV	0.41	0.17	0.19	0.23	0.24	0.25	–	–

[a] Fixed item in confirmatory factor analysis.
Source: Findings of present study

items designed in this study can well measure all model variables. The values obtained for CR and AVE indices for all variables are higher than the acceptable values of 0.7 and 0.5, respectively. This result means that the CR and convergent validities of the research tools are at the appropriate level. However, the results of the two ASV and MSV indices, which assessed the divergent validity of the questionnaire, showed that the values reported for them were less than the AVE. Therefore, the divergent validity of the research tool is at an acceptable level. The multivariate normality assessment confirmed that the coefficients of multivariate skewness and kurtosis fall into the range −1.96 to +1.96. It can be concluded that the data are of normal distribution and have no extreme values. Taken together, the results of Table 3 demonstrate that the collected data can be applied for structural analysis.

4.4. Testing total structural model of the original TPB

At this stage, the total or direct structural model was used for testing the original TPB (Fig. 2; Table 4). The results of the direct impacts of independent variables on IACATP revealed that ACA ($\beta = 0.276$; $p < 0.001$), SNCA ($\beta = 0.341$; $p < 0.001$), and PBCCA ($\beta = 0.456$; $p < 0.001$) positively and significantly affected IACATP (the first, second, and third hypotheses were confirmed). Comparing the effects of these three variables shows that PBCCA and SNCA have the highest predictive power in the original TPB. In addition, the original TPB was able to predict 66.4% of the variance in IACATP (Fig. 2; Table 4).

4.5. Testing mediation structural model of the extended TPB

A mediation or indirect model was applied to test the structure of extended TPB (Fig. 3; Table 4). The results revealed ACA ($\beta = 0.213$; $p < 0.001$), SNCA ($\beta = 0.264$; $p < 0.001$), KCA ($\beta = 0.196$; $p < 0.008$), PBCCA ($\beta = 0.321$; $p < 0.001$), and PRCA ($\beta = 0.345$; $p < 0.001$) positively and significantly affected IACATP (the first, second, third, fourth and fifth hypotheses were confirmed). Comparing the direct effects on IACATP shows that PRCA and PBCCA have the highest predictive power, respectively. Un-like the original TPB, PRCA was the strongest determinant of IACATP in the extended TPB. However, in the extended TPB, SNCA was no longer the second strong predictor. Because, PBCCA had more explanatory power. The results showed that KCA had positive and significant impacts on ACA ($\beta = 0.391$; $p < 0.001$), SNCA ($\beta = 0.476$; $p < 0.001$), PBCCA ($\beta = 0.456$; $p < 0.001$), and PRCA ($\beta = 0.461$; $p < 0.001$). Therefore, the sixth, seventh, eighth, and ninth hypotheses were supported. Overall, the extended TPB was able to explain 77.3% of the variance changes in IACATP. These results indicate that the amount of variance explained in the extended TPB is greater than the original TPB (Fig. 3 and Table 4). Analysis of the effects of education level ($\beta = 0.129$; $p < 0.05$), farm size ($\beta = 0.123$; $p < 0.05$), and income level ($\beta = 0.117$; $p < 0.05$) on conservation agriculture knowledge showed that these variables have positive and significant effects on knowledge. In other words, the 10th, 11th, and 12th research hypotheses were also confirmed (Fig. 3 and Table 4).

4.6. The indirect and total effect of KCA, education level, farm size, and income level on IACATP in extended TPB

Evaluation of indirect effects showed that KCA has significant indirect effects on IACATP (Table 5). This high indirect effect value is originated from the direct effects of KCA on ACA, SNCA, PBCCA, and PRCA. Because these variables mediate the effects of KCA on IACATP in the extended TPB. The calculation of total effects also demonstrated that KCA, PRCA, and PBCCA have the highest total effects on IACATP, respectively. Although the total effects of ACA and SNCA on IACATP are significant, they have lower total effects than other variables (Table 5). In addition, the results of this section (Table 5) revealed that the three variables education level, farm size, and income level have significant positive indirect effects on IACATP.

5. Discussion, global policy implications, and limitations

The results showed that PBCCA in the original and extended versions of TPB is the strongest predictor of IACATP. In other words, PBCCA has a positive effect on the application of conservation agriculture technologies and practices. PBCCA refers to landowner farmers' perceived ability to use conservation agriculture. This ability in many cases stems from the difficulty or ease of using conservation agriculture technologies and practices. In other words, if farmers feel that using conservation

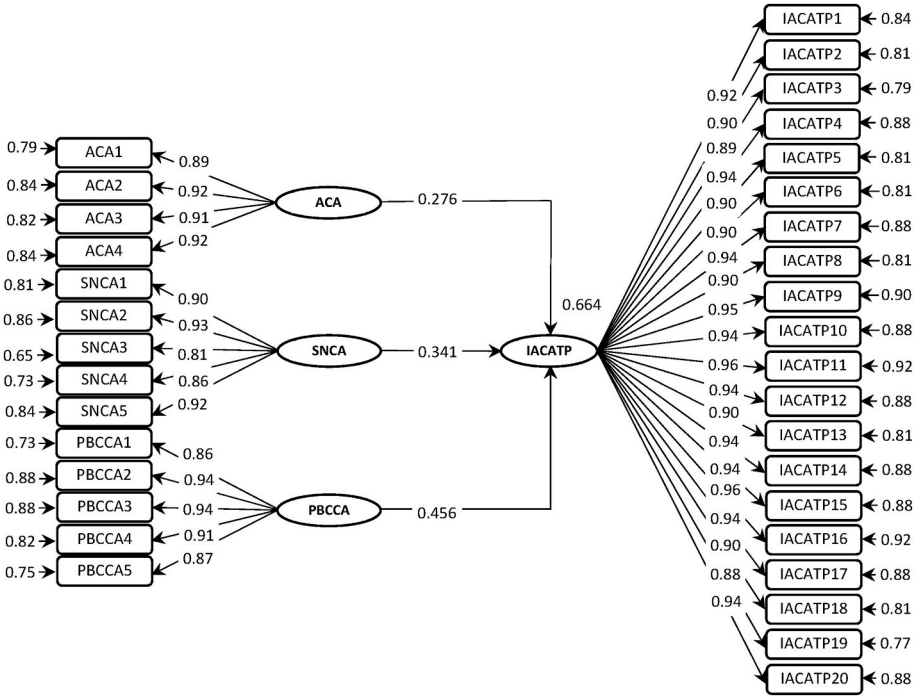

Fig. 2. Structural model for the original TPB.

Table 4
The results of testing original and extended versions of PBT to predict farmers intention towards application of conservation agriculture technologies and practices.

Theory	Hypothesis	Unstandardized coefficients	S.E.	Standardized coefficients	Sig.	The result of hypothesis*
Original PBT	ACA → IACATP	1.50	0.192	0.276	0.001	S
	SNCA → IACATP	1.75	0.180	0.341	0.001	S
	PBCCA → IACATP	2.47	0.196	0.456	0.001	S
Extended PBT	ACA → IACATP	1.58	0.186	0.213	0.001	S
	SNCA → IACATP	1.36	0.154	0.264	0.001	S
	KCA → IACATP	1.482	0.158	0.196	0.008	S
	PBCCA → IACATP	0.491	0.139	0.321	0.001	S
	PRCA → IACATP	1.302	0.218	0.345	0.001	S
	KCA → ACA	0.279	0.127	0.356	0.001	S
	KCA → SNCA	1.250	0.521	0.449	0.001	S
	KCA → PBCCA	0.725	0.096	0.425	0.001	S
	KCA → PRCA	1.361	0.188	0.428	0.001	S
	Education → KCA	0.587	0.218	0.129	0.037	S
	Farm size → KCA	0.411	0.329	0.123	0.021	S
	Income → KCA	0.294	0.481	0.117	0.046	S

Abbreviations: Intention towards application of conservation agriculture technologies and practices (IACATP), Attitude towards conservation agriculture (ACA), Subjective norms of conservation agriculture (SNCA), Perceived behavioral control on conservation agriculture (PBCCA), Knowledge about conservation agriculture (KCA), Perceived risk of conventional agriculture (PRCA).
S: Supported hypothesis.
Source: Findings of present study

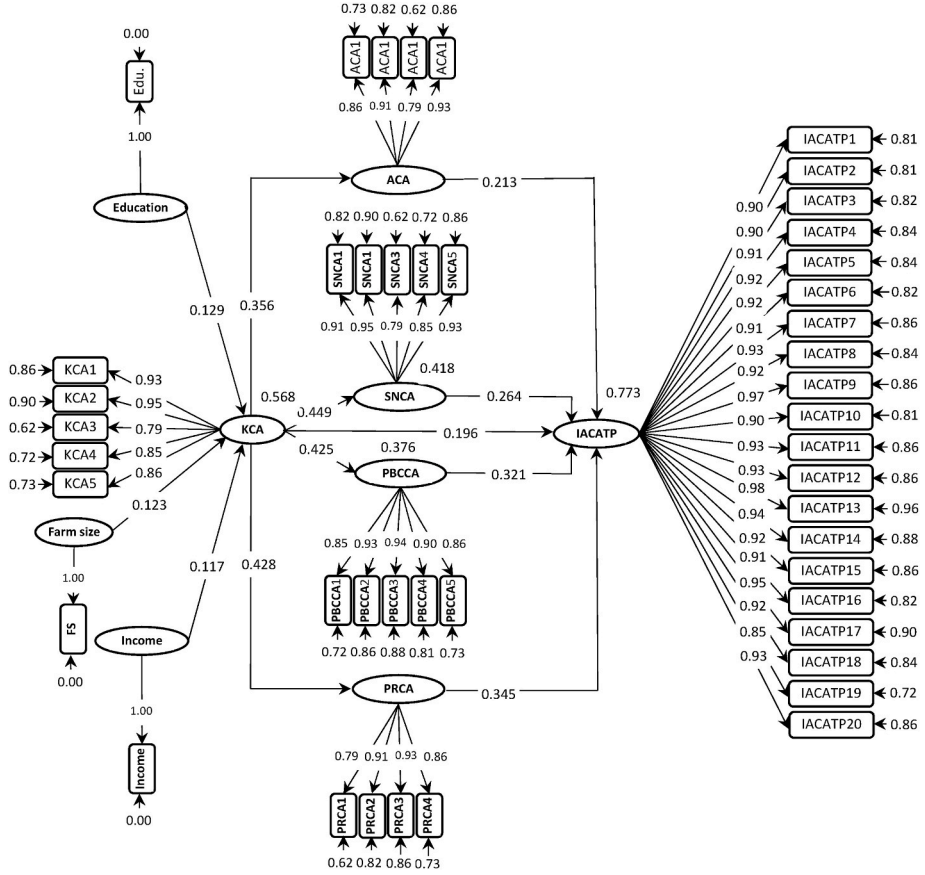

Fig. 3. Structural model for the extended TPB.

agriculture is a challenging and time-consuming process, they will be reluctant to accept it. Conversely, if they perceive conservation agriculture as an easy and user-friendly agricultural system, they will be interested in using it. These findings are consistent with the results of others, including Yazdanpanah and Forouzani (2015), Tama et al. (2021), Mohammadinezhad and Ahmadvand (2020), and Valizadeh et al. (2024) Based on these results, it is recommended that conservation agricultural activities in agricultural communities be taken out of the academic forms and presented to landowner farmers in the form of simple and applicable activities by agricultural experts who are constantly interacting with landowner farmers.

According to the results, PRCA was the second most vital variable in predicting IACATP. PRCA refers to landowner farmers' understanding of the dangers of conventional agriculture. The more landowner farmers' feel the risks of conventional agriculture, the more they tend to use conservation agriculture practices. Similar findings have been reported

Table 5
Calculating (in)direct and total effects of KCA on IACATP in the extended versions of PBT.

Theory	The name of variable	Direct effects (DE)	Indirect effect (IE)	Total or causal effects
Extended PBT	**ACA**	0.213	–	0.213
	SNCA	0.264	–	0.264
	PBCCA	0.321	–	0.321
	PRCA	0.345	–	0.345
	KCA	0.196	0.476	0.672
	Education	–	0.084	0.084
	Farm size	–	0.081	0.081
	Income	–	0.075	0.075

Abbreviations: Intention towards application of conservation agriculture technologies and practices (IACATP), Attitude towards conservation agriculture (ACA), Subjective norms of conservation agriculture (SNCA), Perceived behavioral control on conservation agriculture (PBCCA), Knowledge about conservation agriculture (KCA), Perceived risk of conventional agriculture (PRCA).
Source: Findings of present study

by the previous researcher including Tama et al. (2021) and Mohammadinezhad and Ahmadvand (2020). Some landowner farmers do not adopt conservation agriculture because they are not aware of the adverse impacts of conventional agriculture and its dangers. However, increasing awareness of the adverse consequences of conventional agriculture in the short and long term can play an important role in improving IACATP. In this regard, it is suggested that the level of perceived risk to conventional agriculture be increased through methods such as enlightenment programs.

SNCA had a positive and significant effect on IACATP. This result means that the social environment of landowner farmers has a key role in encouraging farmers to use conservation agriculture. Because landowner farmers' intention toward conservation agriculture is influenced by their social settings (such as friends and acquaintances, peers, and informal groups); in this regard, it is suggested that before any intervention to encourage IACATP, informal networks in the agricultural community and their key members be identified. After identifying these informal networks and communicating with key members, they can be encouraged over conservation agriculture by explaining the advantages and disadvantages of conservation agriculture. After justifying key members, in many cases, there is no need for direct intervention by behavioral change actors. In other words, informal networks and associations will automatically and positively shape the behavioral intention of landowner farmers towards conservation agriculture. It should be noted that informal organizations and networks are not the only way to change the behavioral intention of landowner farmers. The family, thought leaders, and innovators of the agricultural community can also be influential in forming positive social norms towards conservation agriculture and thus strengthening the IACATP.

Based on the results, ACA had a positive effect on IACATP. This result means that a positive ACA can play a decisive role in strengthening IACATP. But it should not be forgotten that positive ACA depends on various antecedents such as KCA. In this regard, to change the IACATP using attitudinal factors, it is necessary first to be aware of the extent of farmers' knowledge in the field of conservation agriculture. Similar findings can be found among the results of Taqipour et al. (2015) and Tama et al. (2021). If their knowledge is low, their communication and knowledge acquisition channels should be identified. This helps to transfer knowledge content precisely through the channels that landowner farmers use to obtain information. For example, some landowner farmers may acquire their knowledge of agriculture from mass media such as television or radio. In this case, knowledge content in the field of conservation agriculture should be provided through these channels. In contrast, some landowner farmers may receive their agricultural knowledge from field practitioners. In such a case, field practitioners should be used as the arms for attitudinal and behavioral changes in the field of conservation agriculture. It should be mentioned that KCA is a key variable that, in addition to strengthening the ACA, has a crucial role in reinforcing the main predictors of behavioral intention (SNCA, PBCCA, and PRCA). This highlights the importance of KCA in social interventions aiming at strengthening IACATP, which should be considered by planners, decision-makers, and change agents in agricultural communities. Knowledge directly and significantly influenced the IACATP. Similar results have been reported by Cottrell and Graefe (1997), Zareie and Navimipour (2016), Saari et al. (2021), and Liu et al. (2020). There are different strategies for improving the knowledge of farmers in the field of conservation agriculture. Perhaps one of the best ways to increase farmers' knowledge of conservation agriculture is through education. Education has been proposed by various researchers (Tianyu and Meng, 2020; Suárez-Perales et al., 2021; Mónus, 2022; Faghani et al., 2024) as key strategies in the development of environmental conservation knowledge. Trainings based on increasing the knowledge of farmers in the field of conservation agriculture can be provided to them in person on agricultural land or online and in their free time. It is also suggested that in order to strengthen the knowledge of farmers regarding conservation agriculture, agricultural extension approaches such as method demonstration be employed.

The results showed that the level of education has a positive and significant effect on conservation agriculture knowledge. This result shows that the higher the level of education of farmers, the higher their agricultural knowledge. In fact, a high level of education allows farmers to obtain useful information about conservation agriculture and its consequences. This information helps to develop their knowledge in the field of conservation agriculture. As a result, it is suggested to focus more on the development of formal education in order to develop the use of conservation agricultural measures in the long term. Especially, the results related to demographic characteristics showed that many farmers do not have high level of education. Therefore, investing in the development of formal education among farmers and villagers can pave the way for the cultivation of more educated farmers in the future. This can provide the basis for the development of conservation agriculture knowledge and thus increase the willingness to use conservation agriculture measures. Also, the results showed that farm size has a positive and significant effect on conservation agriculture knowledge. This result means that the larger the size of the farmers' farm, the more their conservation agriculture knowledge increases. Many farmers who have a large agricultural land are generally looking for the latest and most sustainable farming methods so that they can both increase their production level and be able to use their agricultural land sustainably. These farmers are more inclined to develop their knowledge in conservation agriculture than small-scale farmers. Therefore, there is a positive relationship between the size of agricultural land and the knowledge of farmers in the field of conservation agriculture. At the same time, some small farmers do not have much desire to increase their knowledge in the field of conservation agriculture systems due to the smallness of their agricultural land and considering agriculture as their second or third job. Based on this, focusing on land consolidation can be one of the policy implications for agricultural managers and land management. The results showed that income has a positive and significant effect on conservation agriculture knowledge. This result shows that as farmers' income increases, their agricultural knowledge increases. One of the most important justifications for such a result is that farmers with higher incomes can easily participate in non-free courses of sustainable agricultural approaches. Also, farmers with higher incomes have easier access to conservation agricultural inputs and technologies. Meanwhile, such options are less affordable for farmers with low income. In this regard, it is suggested that the government and policy-makers focus more on providing financial and educational assistance in the field of conservation agricultural inputs and technologies to low-income farmers.

In general, the results of this study showed that the inclusion of two variables PRCA and KCA, in TPB could increase its explanatory power from 66.4% to 74.4%. As a result, it is suggested that agricultural

managers and planners use the extended TPB to encourage landowner farmers to use conservation agriculture technologies and activities.

This study had limitations that provide opportunities for further research on the behavioral intentions of landowners in conservation agriculture. First, in this study, two variables of knowledge and perceived risk were added to the TPB as direct and indirect predictors of landowner farmers' intention towards soil conservation. However, there may be other variables that were outside the scope of this research, however, including them in TPB can end up increasing the explanatory power of this theory and help to gain new insights on how to create positive behavioral changes in farmers. In this regard, it is suggested to add other variables to the version of the theory developed in this study in future researches. Second, in this study, the relationship between the variables was investigated in the form of a mediated model. However, it seems that some variables may be able to moderate the relationships assumed in this study. In this regard, it is suggested that future researchers develop moderated versions of the TPB. For example, variables such as level of education can moderate the relationship between awareness with intention and attitude with willingness. Investigating these relationships in future research can be very useful for developing our understanding of the behavioral intention of landowners towards soil protection. Third, in present study, it was assumed that the respondents' answers were completely honest, and the research results were analyzed and deduced accordingly. However, it is possible that the respondents refused to reflect their real answers due to moral and social pressures. Therefore, it is suggested that methods such as observation and in-depth interviews be used in future researches to validate their opinions. Fourthly, due to economic constraints, the designed framework was tested only among land-owning farmers in this study. However, the implementation of this method among farmers who do not own land can give new insights and understanding in the field of applicability of TPB. Thus, it is suggested that this research gap be investigated in future researches.

6. Conclusion

In general, this study ended with some general conclusions that can be presented in the form of some bullet points. First, PBCCA in the original and extended versions of TPB is the strongest predictor of IACATP. Second, PRCA is an important variable that should be considered as one of the main constructs of TPB. Because, it was the second most vital variable in predicting IACATP. Third, social environment of farmers (subjective norms) has a key role in encouraging farmers to use conservation agriculture. Fourth, KCA is a key variable that, in addition to strengthening the ACA, has a crucial role in reinforcing the main predictors of behavioral intention (SNCA, PBCCA, and PRCA). Fifth, the extended TPB predicts farmers' intention to use conservation agriculture practices 8 % more than its original version. These conclusions can provide the basis for facilitating social changes in the field of conservation agriculture technologies. Also, environmental policy-makers, farmers, interventionists of agricultural extension and rural development activities, and other users can employ the results of this study to achieve their goals in agricultural and rural communities.

This study theoretically and practically helps to develop the body of knowledge by establishing the mediating role of variables attitude, subjective norms, perceived behavioral control, and perceived risk in TPB. Therefore, one of the most important theoretical contributions of this study is that the variables attitude, subjective norms, perceived behavioral control, and perceived risk can mediate the relationship between the knowledge of conservation agriculture and the intention of landowners towards conservation agriculture. Therefore, present study has contributed to the development of a theory (TPB) that already existed. The development of TPB from a theory with direct relationships to a theory with several mediating variables, in addition to being a theoretical contribution, can also be considered a practical contribution. Because by establishing the mechanism of new relationships between variables, the strategies related to behavioral interventions also change a lot. Therefore, new strategies are presented to change the behavioral intentions of farmers. For example, one of the practical contributions of this study is that in order to make positive changes in the behavioral intentions of landowners, change agents should first focus on increasing their knowledge and awareness, and then on strategies that strengthen attitudes, perceived behavioral control, and perceived risk. The order of using strategies is one of the key points in intervention programs related to changes in behavioral intentions which can affect the success or failure of the program. This study helps to improve the behavioral intentions of landowners in practice by developing a systematic mechanism of relationships between variables and providing practical strategies based on them. This study also guides policy-makers and decision-makers to switch to conservation agriculture which is actually beneficial for environmental protection and agricultural sustainability. This study also helps improve the intentions of landowner farmers towards conservation agriculture and therefore has a positive effect on soil resources, the environment, and the livelihood of farmers in Iran and internationally.

CRediT authorship contribution statement

Naser Valizadeh: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Hadi Azimi-Nejadian:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Conceptualization. **Hossein Azadi:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Methodology.

Declaration of competing interest

This manuscript has been read and approved by all the authors. The criteria for authorship have been met. The authors also do not have any financial interest or any other conflict of interests.

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Data availability

Data will be made available on request.

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