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Famers' intention to use precision farming technologies, application of the extended technology acceptance model: A case in Ardabil province

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Abstract

Precision agriculture promises to enhance economic benefits while maintaining more environmentally friendly farming practices. Despite the efforts to facilitate the adoption of precision farming technologies (PFTs), the adoption remains low. Using an extended version of the technology acceptance model (TAM) with two external constructs of personal innovativeness (PI) and compatibility (COM), this study investigated pioneer farmers' intention (INT) to use PFTs. In this survey research, a questionnaire was used for data collection from a sample of 295 farmers (N=295). The results showed that the extended model could promote the explanatory power of the TAM and explain 72.6% of the variation in farmers' INT to use PFTs. Respondents were relatively innovative (mean=3.25), had positive attitudes (ATT) (mean=3.53), and had relatively positive INT to use PFTs (mean=3.24). In contrast, they perceived that PFTs are challenging to use (mean=2.7), relatively useful (mean=2.93), and lowly compatible with their small-scale farming systems (mean=2.66). COM was the most critical factor affecting INT, followed by perceived ease of use (PEU), perceived usefulness (PU), PI, and ATT. At the same time, PEU had no significant effect on ATT, indicating that when farmers assess PFTs, ease of use is not a problem, but PEU is essential when they intend to use these technologies. Considering the high initial investment requirement and knowledge-intensive nature of PFTs, policy, and educational interventions are required to facilitate farmers' utilization of these technologies. To achieve the best results, they should begin with pioneer farmers.

Keywords: Precision agriculture, technology acceptance model, pioneer farmers, innovativeness, compatibility, PLS-SEM.

Introduction

Farmers' decision to uptake new farming technologies is critical to agricultural development and essential to policymakers. Future agricultural systems should develop and adopt technologies that address sustainability and support greater productivity (Pathak et al., 2019). Several precision farming technologies (PFTs) have been developed in recent decades, and the number of technologies available for farmers has proliferated (Gandorfer et al., 2018). PFTs promise to enhance economic benefits, such as higher yields at lower costs, while maintaining more environmentally friendly farm management by spatially targeting inputs to which points of the farm they are more productive (DeLay et al., 2022). PFTs have the potential to address the environmental impact of agriculture while ensuring long-term productivity and food security (Kolady et al., 2020). For example, the EU Green Deal utilized PFTs to reduce chemical pesticide use by 50% by 2030 (Tataridas et al., 2022). These technologies have been developed to guide farmers to do the right thing at the right time and place (Gebbers & Adamchiuk, 2010). Precision farming provides farmers with a large amount of data for farm management; however, using these data requires high interpretation capability (Vecchio et al., 2020), which can challenge farmers to synthesize them. Many efforts have been initiated in developed countries since the 1980s and recently in developing countries to facilitate the adoption of PFTs. However, despite the evident benefits and considerable promotion, the adoption remains below expectations (Paustian & Theuvsen, 2016; Kolady et al., 2020). Therefore, understanding the factors underlying the adoption of PFTs is essential.

Several studies have been conducted to explain the factors influencing the adoption of PFTs. Socioeconomic variables were suggested in the literature to examine the adoption of PFTs (Vecchio et al., 2020); however, they cannot fully capture farmers' intentions toward using new technologies, especially factors behind the low adoption of PFTs. For example, Kernecker et al. (2020) noted that while European farmers perceived smart farming technologies as useful, the adoption rate increased with farm size. However, Takagi et al. (2020) found that socio-demographic characteristics were not crucial for the adoption decision of smart farming technology, while perceived attributes, such as compatibility of new technology to their farm, ease of learning and use, the expected increase in yields and farm income, and triability were the crucial factors. Therefore, there is an increasing shift towards incorporating socio-psychological frameworks to understand farmers' decision-making and use these insights to develop better policy designs (Daxini et al., 2019).

The technology acceptance model (TAM) (Davis et al., 1989; Hess et al., 2014) is a theoretical framework that has received growing attention in the literature. The TAM has primarily been developed to explain the users' acceptance of information-communication technologies (Davis, 1989). Because PFTs assume the meaning of information-based management (Vecchio et al., 2020), the TAM was later employed in PFTs adoption (Adrian et al., 2005; Tohidyanfar & Rezaei-Moghaddam, 2015; Pathak et al., 2019). The TAM asserts that two attitudinal components of perceived usefulness (PU) and perceived ease of use (PEU) and a mediating variable of attitude (Naspetti et al., 2017) determine the intention to use technology. PU and PEU refer to beliefs that applying a technology would enhance job performance and be free of effort (Davis, 1989). They are principal determinants that directly or indirectly explain the intention to use technologies (Hess et al., 2014). Despite the usefulness of the original TAM, it is not a holistic model to comprise all variables affecting users' intention to use technologies, and the indirect effects are ignored. Therefore, several studies have tried to promote the model's explanatory power using external variables (Adrian et al., 2005; Tohidyanfar & Rezaei-Moghaddam, 2015; Takagi et al., 2020). There is still inadequate information on how farmers adopt and use PFTs, particularly in small-scale farming operations. Most studies have been conducted in developed countries and focused on socio-economic characteristics. Therefore, there is a research gap in the field of sociopsychological variables affecting the adoption of PFTs, especially in developing countries. Using an extended version of the TAM, the current study aimed to investigate small-scale farmers' intention to use PFTs. The specific aim was to explore how personal innovativeness (PI) and perceived compatibility (COM) measures could be integrated into the TAM.

PI refers to the degree to which farmers embrace new ideas or technologies more quickly and make innovation decisions independently of the communicated experience of others. Early adopters and innovators may be technology advocates when agricultural extension services disseminate new technologies (Rogers, 1995). Farmers with higher PI are more likely to have positive attitudes toward new technologies and can overcome uncertainties related to using the technology (Agarwal & Prasad, 1998; San Martín & Herrero, 2012). Several studies in agriculture and other fields have found a positive effect of PI on the intention to use new technologies (San Martín & Herrero, 2012; Natarajan et al., 2017; Tohidyan-Far and Rezaei-Moghaddam, 2015; Okumus et al., 2018; Ciftci et al., 2021). COM is the degree to which using innovations is perceived as consistent with the existing sociocultural values and beliefs, past and present experiences, and needs of potential adopters (Rogers, 1995). Karahanna et al. (2006) compared the TAM and Rogers' theory of diffusion of innovation. They revealed that Rogers' relative advantage is equivalent to PU in the TAM; at the same time, complexity is equivalent to PEU. They concluded that only PU, PEU, and COM are significantly related to usage, while COM is an influential variable missing from the TAM. Therefore, the second external component, COM, was included in the extended TAM. Based on the extended model of the TAM (Fig. 1), the following hypotheses were examined:

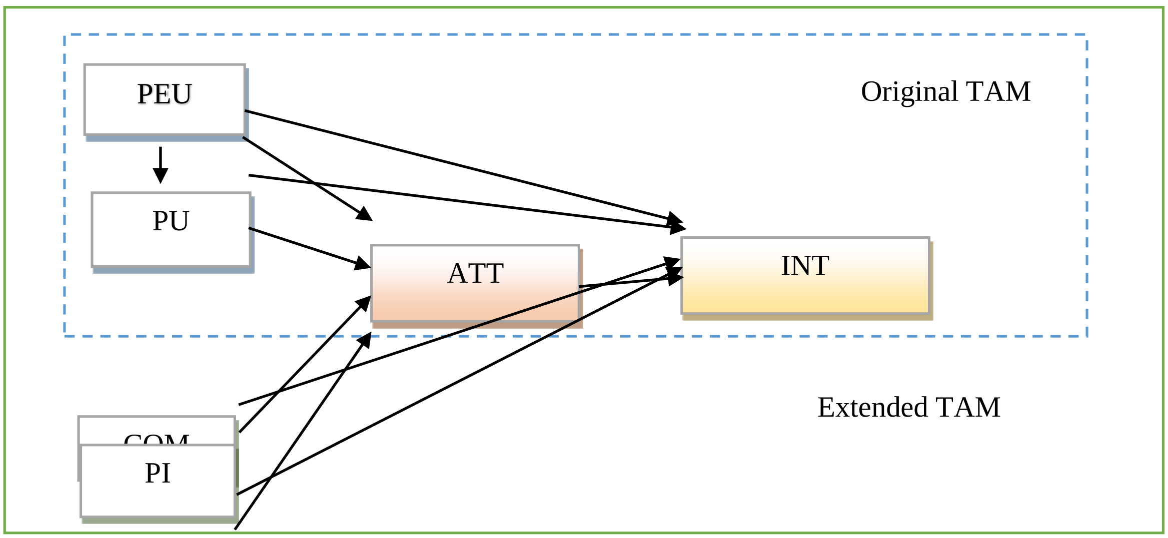

Figure 1. Theoretical framework of the study (The extended TAM).

H1-H4: PEU, PU, PI, COM affect ATT towards PFTs;

H5-H9: PEU, PU, ATT, PI, and COM affect INT toward the use of PFTs;

H10: PEU affects the PU of PFTs.

Materials and method

2. 1 Study area

This survey was conducted in Ardabil province, in the Northwestern region of Iran. The average height of the region is 2400 M above sea level (Department of Environment, 2022). Cereals, beans, industrial crops, vegetables, and forage crops are the main crops of the province (Ahmadi et al., 2017).

2.2 Method, population, and sample

The survey research method was used in this study. Because of the novelty of the PFTs in Iran, traditional farmers were not informed about these technologies. Therefore, the pioneer farmers who are more progressive and early adopters of new technologies (Van den Ban, 1957) were selected for this study (N=295). A sample of 130 volunteer pioneer farmers (Cochran, 1977) was selected for data collection.

2.3 *Instrument and data collection*

A questionnaire was developed based on the TAM. Then, items of the two external constructs of PI and COM were included in the questionnaire. In addition to demographic Variables, the instrument consisted of six constructs, i.e., INT, ATT, PU, PEU, PI, and COM. The constructs were measured using a five-point Likert scale ranging from 1 (completely disagree) to 5 (fully agree). University staff and agricultural field experts confirmed the content validity and a pilot study was conducted to determine the reliability of the questionnaire. A virtual survey method was employed. For this purpose, the sample farmers were contacted and informed about the study's objectives. Then, the online questionnaires were sent to them via WhatsApp media.

2.4. Data analysis

SPSS22 software was used for primary descriptive analysis of the data. Then, the PLS-SEM was employed to model farmers' INT to use PFTs. Composite reliability (CR) and Cronbach's alpha (α) confirmed the model's reliability. All measured CR values of the constructs are above 0.7 except 0.662 for the COM scale (Table 1). Validity was measured using convergent and discriminant validity. The average variance extracted (AVE) was used to assess convergent validity (Fornell & Larcker, 1981). All the AVE values are above 0.5. Based on the results of confirmatory factor analysis, the significant t-values ($P< 0.01$) of factor loadings of all the selected indicators for the target constructs (Table 1) confirmed that the indicators for measuring research constructs had been correctly selected (Hair et al., 2006).

Results

Socioeconomic profile

The respondents were in middle age (46 ± 11.71), had 35.13 (± 13.52) years of farming experience, and 90.8% were male. Seventy percent lived in rural areas. The vast majority of them were small-scale farmers (3.81±1.65 ha). Some half of them (51.5%) had higher education degrees, 30% had a diploma.

Descriptive statistics of the constructs' items

Table (1) presents an overview of all constructs' items, AVE, alpha, CR, factor loadings, and t-values of the original and extended TAM constructs. The mean score of INT was 3.24, indicating that they moderately intended to use PFTs. While their intention to take the risk for using PFTs was relatively high (mean=3.63), they moderately intended to use them. The mean score of ATT (=3.53) showed they have a positive ATT toward the PFTs. The mean values of PU (=2.93) indicated that they perceived PFTs as moderate to low applicable for their farming job. The mean value of PEU (=2.70) showed that they perceived PFTs as difficult to use. While they perceive "how to work with PFTs is clear and understandable" (=3.73), they had a weak understanding of "how to use them" (=2.45). Considering the two extended PI and COM constructs, the results showed that the respondents were relatively innovative (=3.25). They were highly willing to take the risk of using PFTs (=3.99). However, due to the high costs required to install of the technologies and insufficient knowledge and information, they had little desire to buy and use these technologies (=2.66). Finally, they perceived PFTs as relatively low compatible with their farming jobs (=2.66).

Table 1. Descriptive statistics of the TAM constructs and results of the measurement model.

Constructs and measurement items	Mean	SD	FL.o	t	FLe	t
Attitude: (Mean= 3.53, AVEe= 0.704, CRe= 0.799, α_e= 0.698; AVEo = 0.704, CRo = 0.800, α_o= 0.698)						
I will feel comfortable using PFTs	4.26	0.73	0.570	6.36	0.563	5.57
PFTs have many advantages for my farming job.	4.2	0.94	0.791	13.10	0.796	13.06
There is no problem for me to use PFTs	3.98	0.84	0.552	3.129	0.556	3.10
I have access to facilities needed for using PFTs	3.35	1.09	0.737	17.09	0.747	17.46
Using PFTs is suitable for protecting production resources.	2.74	1.14	0.712	14.47	0.713	10.52
The use of PFTs improves farm products' quality.	2.63	1.22	0.580	3.69	0.560	6.54
Perceived usefulness: (Mean= 2.93, AVEe= 0.795, CRe= 0.713, α_e = 0.663; AVEo= 0.728, CRo= 0.715, α_o = 0.663)						
The use of PFTs accelerates my agricultural works	3.28	1.13	0.883	3.31	0.883	3.48
The use of PFTs leads to increased productivity.	3.23	1.19	0.534	8.35	0.533	10.32
The use of PFTs will be economically viable	2.28	1.01	0.787	2.99	0.878	1.98
Perceived ease of use: (Mean=2.7, AVEe = 0.567, CRe= 0.786, α_e = 0.670; AVEo= 0.541, CRo= 0.787, α_o = 0.670)						
How to work with PFTs is clear and understandable	3.73	1.22	0.827	7.28	0.828	5.37
How to use of PFTs is easy	3.56	1.05	0.684	2.87	0,683	8.71
How to set up precision farming systems is easy	2.57	1,18	0.828	9.28	0.827	16.07
The use of PFTs reduces environmental impacts	2.53	1.14	0.651	7.72	0.651	8.36
I clearly understand how to use PFTs	2.45	1.15	0.520	6.32	0.552	3.62
Innovativeness: (Mean=3.25, AVEe = 0.552, CRe = 0.803, α_e = 0.709)						
I am willing to take risks in using PFTs	3.99	1.04	--	-	0.804	16.96
I am ready to get new experiences related to PFTs.	3.25	1.12	-	-	0.875	30.67

I am interested in the development and use of PFTs	3.08	1.07	-	-	0.885	43.61
In order to reduce production costs, I am ready to use PFTs	2.66	1.03	-	-	0.534	5.00
Compatibility: (Mean = 2.66, AVEe = 0.522, CRe = 0.662, α_e = 0.531)						
I can acquire the skill of using PFTs	4.04	0.85	-	-	0.655	6.721
My farm has suitable conditions for using PFTs	2.59	1.05	-	-	0.799	2.71
The use of PFTs is appropriate to my farming operations	2.53	1.01	-	-	0.575	4.39
PFTs are compatible with the climate of my region	1.45	1.15	-	-	0.828	21.56
Behavioral intention: (Mean= 3.24, AVEe= 0.558, CRe= 0.853, α_e = 0.791; AVEo= 0.585, CRo= 0.852, α_o = 0.791)						
If available, I accept the risk of using PFTs	3.63	0.98	0.726	9.34	0.721	10.52
The use of PFTs is necessary to improve my farm in the future	3.40	1.98	0.912	55.08	0.907	20.98
I would like to be among the people who dare to try PFTs	3.40	1.16	0.609	6.43	0.617	6.51
I would like to experience the use of new technologies (PFTs)	3.00	1.18	0.572	2.14	0.578	2.24
I would like to have the chance to install PFTs on my farm	2.76	1.39	0.884	32.04	0.880	40.20
If I have access to PFTs, I intend to use them	2.63	1.22	0.757	14,55	0.767	13.92

SD Standard deviation, Flo and FLe = Factor loadings of original and extended TAM. AVE, CR, and α are reliability and validity statistics of extended (e) and original (o) models, respectively.

Information about selected PFTs

The results (figure 2) showed that while their information about yield mapping was weak, they had relatively good information about remote sensing, aerial photography, and global positioning systems (GPS).

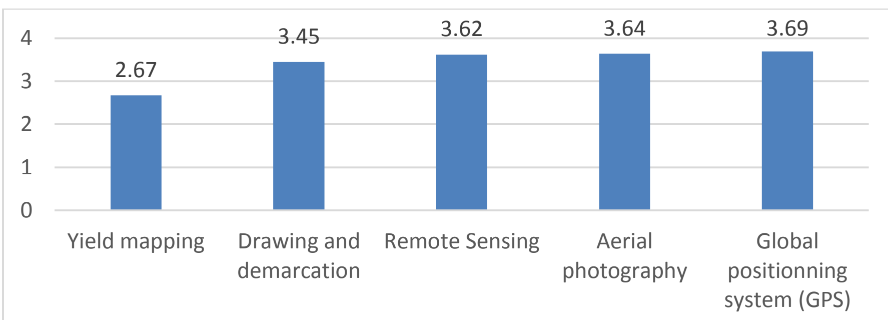

Figure 2. Farmers' information about selected PFTs.

Information sources

The results (Table 2) show that agricultural and extension experts were the primary information source of pioneer farmers about PFTs. Because PFT was not the aim of extension courses, it was the last information source for the farmers.

Table 2. Farmers' information sources on PFTs.

Information sources	Mean	SD
Agricultural and extension experts	4.11	1.17
Television agricultural programs	3.33	1.00
Internet and virtual networks	3.24	1.09
Other sample farmers familiar with PFTs	3.5	1.13
Other farmers who use PFTs	1.35	0.86
Participation in extension courses on PFTs	1.22	1.06

Mean range: 1 – 5.

Structural model

As illustrated in Figures 3 and 4 and Table 3, the measurement model was validated, and the original and extended TAM were employed to examine the study's hypotheses. The original TAM was tested in the first step. The results of SEM showed that the original model was well-fitted. The two components of PEU and PU significantly affected ATT and explained 73.4% of its variability. Similarly, ATT, PU, and PEU significantly affected and explained 66.9% of the variance of INT. Finally, PEU explained 54.8% of the variance of PU. ATT had the most significant effect on INT, followed by PU, while PEU showed a relatively weak significant impact. Therefore, concerning the original model of the TAM, all the related hypotheses were confirmed, indicating the suitability of the TAM to explain farmers' intention to utilize PFTs.

The extended structural model was tested with two external constructs of PI and COM. Based on the results of SEM, this model was well-fitted. The results showed that the extended constructs promoted the explanatory power of the model to predict the variances of both ATT and INT. As illustrated in Table 3, COM had the most significant impact on ATT, followed by PU and PI, while the impact of PEU was not significant ($t < 1.96$). These constructs accounted for 78.6% of the variance of ATT, which was 8.2% more than the variance explained by the original TAM.

On the other hand, the extended model promoted the original model's ability up to 5.7%, and the five constructs, i.e., PEU, PU, ATT, PI, and COM explained 72.6% of the variance of INT. As illustrated in Table 3 and Figure 3, COM and PI with significant coefficients of 0.308 ($t = 4.847$) and 0.239 ($t = 9.535$) have potent impacts on the intention to use PFTs, respectively. With a significant coefficient of 0.275, PEU had an excellent effect on INT after COM. Except for H1 (PEU→ATT), all hypotheses related to the extended model were confirmed, indicating the importance of PI and COM on INT to use PFTs. The effect of PEU on PU did not change in the extended model.

Table 3. Results of the structural models.

H	Path	Original TAM			Extended TAM		
		Beta	t value	R^2	Beta	t value	R^2
H1	PEU→ATT	0.454	3.804^{**}		0.102	0.105^{ns}	
H2	PU→ATT	0.361	2.157^{*}	0.734	0.225	2.267^{*}	0.786
H3	PI→ ATT	-	-		0.205	2.908^{*}	
H4	COM→ATT	-	-		0.450	7.920^{**}	
H5	PEU→INT	0.118	1.961^{*}		0.275	4.241^{**}	
H6	PU→INT	0.325	3.191^{**}	0.669	0.232	4.162^{**}	
H7	ATT→INT	0.335	10.797^{**}		0.213	2.142^{*}	0.726
H8	PI→INT	-	-		0.239	9.535^{**}	

H9	COM→INT	-	-		0.308	4.847**	
H10	PEU→PU	0.520	16.401**	0.548	0.521	16.899**	0.548

ns no significance, * significance at 5%, ** significance at 1%.

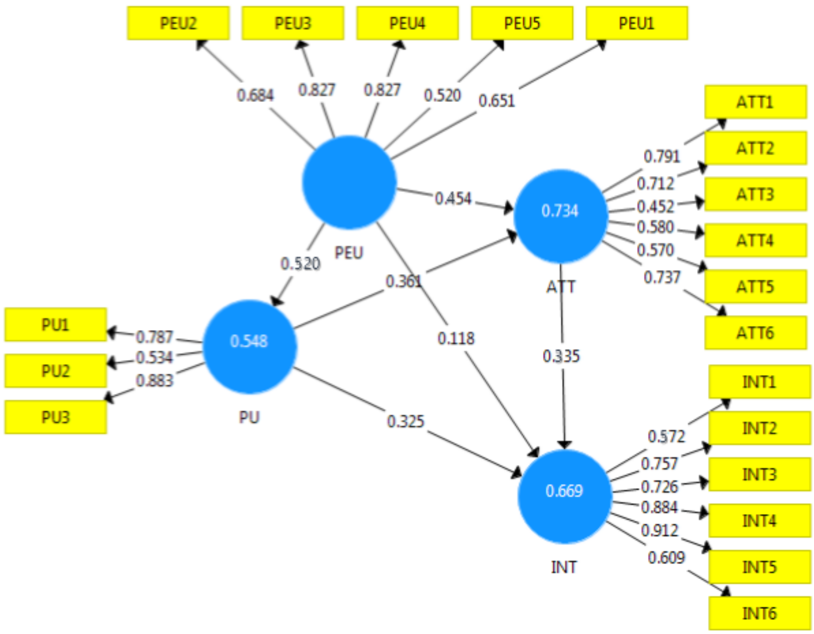

Figure 3. Path model intention to use PFTs (original TAM).

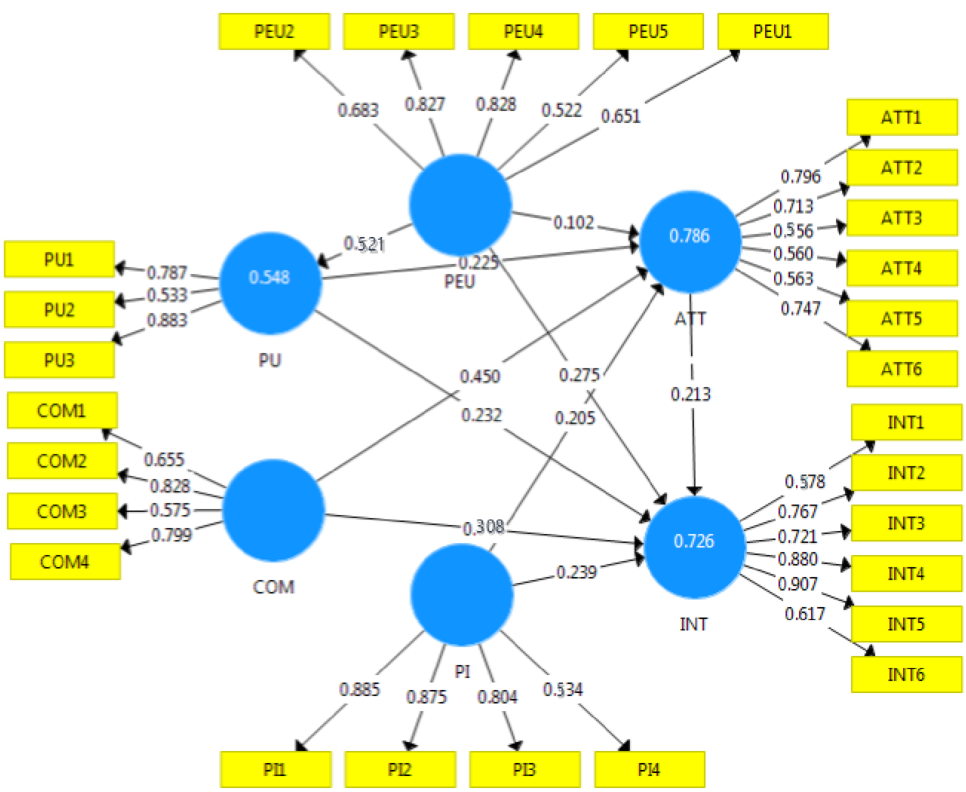

Figure 4. Path model intention to use PFTs (extended TAM).

Discussion

The results showed that the original TAM has good predictive efficiency and explained 73.4% of the variance in ATT and 66.9% in INT, indicating the importance of socio-psychological drivers of farmers' decision-making processes (Silva et al., 2018). However, the model ignored the impact of other influential variables, such as PI and COM. Therefore, this study extended the TAM to make some theoretical contributions to the literature and provide insights into farmers' behavioral intentions toward using PFTs that could be useful for agricultural policymakers and extension services. An extended version of the TAM with two external constructs, i.e., PI and COM, was tested for the first time. The results support that the model helps explain farmers' INT to use PFTs. The extended model could promote the explanatory power of the TAM.

The mean score of the extended construct of PI (=3.25) was higher than the construct average (=3), indicating that the respondents were relatively innovative. This construct showed significant effects on ATT and INT. Several studies on PFT adoption and other fields of information technologies confirmed the impact of PI on the intention to use technologies (San Martin & Herrero, 2012; Tohidyan-Far & Rezaei-Moghaddam, 2015; Natarajan et al., 2017; Okumus et al., 2018; Ciftci et al., 2021; Blasch et al., 2022). Early adopters and innovator farmers may serve as technology advocates when agricultural extension services disseminate new technologies (Rogers, 1995). Pioneer farmers are referent groups in their communities and are technically trusted by other farmers. They require little training and guidance, and after testing a technology, they may become co-extension agents and help other farmers adopt it (Agarwal & Prasad, 1998; San Martín & Herrero, 2012). People are often under the influence of other trusted and influential individuals in their community. It is because of empathy with others (Rogers, 1971) or fear of social exclusion due to not conforming to good behaviors or practices (Bamberg & Moser, 2007). Previous studies confirmed the influence of social pressure on farmers' behavioral intentions (Adnan et al., 2017; Daxini et al., 2019). According to Burton (2004), because farmers do not behave independently from social influences, they often follow referent groups in their behavior. Hence other farmers often trust and follow pioneer farmers as technical referent groups concerning the technologies in question. Farmers' trust in agricultural authorities and extension agents determine their decision to use PFTs (Jongeneel et al., 2008). Therefore, if policymakers and extension services want farmers to adopt and use PFTs, they should consider pioneer farmers' intention to use these technologies. They should train, support, organize, and persuade pioneer farmers to use PFTs. Then, considering other farmers' trust in pioneer farmers, they will evaluate the consequences of adopting PFTs and may adopt these technologies. Extension experts need to gain farmers' trust in PFTs at this stage. Extension courses and financial supports, such as low-interest loans and credits, are essential to adopt PFT by pioneer farmers.

Respondents had a positive ATT towards PFTs (=3.53). This result is consistent with previous PFT adoption studies (Adrian et al., 2005; Tohidyanfar & Rezaei-Moghaddam, 2015). The positive effect of ATT on INT implies that to improve pioneer farmers' INT to use PFT, field agricultural and extension experts should highlight the importance of PFT use for pioneer farmers. ATT is an essential determinant of farmers' commitment to particular behavior (McCarthy et al., 2007). Therefore, if experts provide farmers with more relevant information about the advantages of PFTs, they can better evaluate the technologies and gain positive INT to use PFTs. Mass media is essential in shaping attitudes (Rogers, 1995). Technical skill training through TV programs and educational films about each of the PFTs necessary for the region's farmers can play an essential role in improving the ATT of the pioneer farmers.

They showed relatively positive INT to use PFTs (=3.24), but due to technical and financial problems, they did not show a highly positive intention to use. Previous studies considered farmers' financial problems in installing and using PFTs as an essential barrier to the adoption because of requiring high initial capital investment and added maintenance costs (Gandorfer et al., 2018; Barnes et al., 2019). Considering the educational levels of most respondents that might be enough to understand the use of PFTs, they noted that PFTs require high skills to use, but they were not trained for it. This result is consistent with previous studies that showed that high knowledge and capabilities are required to use these technologies (Paustian & Theuvsen, 2016; Vecchio et al., 2020).

The mean score of PEU (=2.70) showed that they perceived using PFTs as challenging. PEU significantly affected ATT and PU in the original model. PEU also showed a positive effect on PU. Finally, PU, PEU, and ATT significantly positively affected INT. Therefore, all related hypotheses were validated, confirming the basic principles of TAM (Davis, 1989; Davis et al., 1989; Davis, 1993; Davis & Venkatesh, 1996). The effects of PU, PEU, and ATT on INT were reported in most previous TAM studies while conflicting results and weak effects were reported for PEU (Venkatesh

& Davis, 2000; Venkatesh et al., 2003; Flett et al., 2004; Hess et al., 2014). The current study found that PEU had no significant effect on ATT in the extended model, while it had a positive effect on INT that supports previous studies.

The mean score of PU (=2.93) was less than the construct average (=3), indicating they perceived PFTs as relatively low useful for their small-scale farming systems. Considering the significant impact of PEU on PU, this perception may be partly related to the complexity. PU showed a significant effect on INT that is consistent with the findings of the previous TAM studies (Adrian, 2005; Tohidyanfar & Rezaei-Moghaddam, 2015). While farmers perceived that PFTs accelerate jobs and increase productivity, economic viability was a problem for small-scale farmers. Considering the costly and knowledge-based nature of PFTs, this result is reasonable. It supports the findings of McCormack et al. (2022) that farmers with larger farms and more family income who use agricultural extension services are more likely to adopt an online nutrient management plan. This result has implications for agricultural policymakers and extension services. The economic issue is a barrier, and the low INT to use may be related to a low PU score. The average farm size of the farmers was 3.81 ha. The small farm size is a barrier to adopting PTFs. Government incentives and financial support are essential in this relationship. Low-interest loans and credits and establishing precision agriculture associations could be possible incentives, along with extension campaigns to remove the barriers.

Karahanna et al. (2006) found that PEU, PU, and COM are significantly related to usage, while COM is an influential variable missing from the TAM. Therefore, the construct of COM was added to the TAM in this study. The results showed that pioneer farmers perceived PFTs as low compatible (=2.66). COM showed the most significant effect on INT, followed by PEU, PI, and PU. Except for the effect of PEU on ATT, all the hypotheses related to the extended TAM were approved. These results indicate the importance of COM and PI in explaining the variability of INT. The conflict impacts of PEU indicate that knowing how to use PFTs is essential in the decision to use the knowledge-based technologies of precision agriculture. These results also indicate that COM and PU are vital variables forming an attitude toward the technologies. Innovative farmers consider compatibility and usefulness more than ease of use when evaluating new technologies. Flett et al. (2004) assert that farmers evaluate the usefulness of technology primarily in economic terms but also separately consider its ease of use. However, they give more weight to technology's usefulness than its ease of use (Davis et al., 1989; Naspetti et al., 2017). Based on these results, despite the positive ATT toward PFTs and the non-significant effect of PEU on ATT, when pioneer farmers decided to use the technologies, while COM and PU were important, PEU was very important. Technology may be perceived to be useful, but due to its complexity, it may require more effort to adopt, and farmers may not adopt and use it in practice (Rogers, 1995).

Previous studies have reported that incompatibility among precision technologies is a barrier to adoption (Gandorfer et al., 2018; Barnes et al., 2019); however, other barriers should also be considered. Small-scale farming systems of peasant farmers are another barrier that requires land consolidation, implementation of cropping patterns, establishment of precision agriculture associations for the collective use of PFTs, providing suitable internet infrastructures, especially for remote areas, providing low-cost loans and credits to facilitate the adoption and use of precision agriculture. Sociocultural structures, such as low literacy, technology phobia, and fatalism, require policy intervention and extension campaigns for information and sensitizing farmers and consumers of agricultural products about the effects of agricultural practices on the environment and human health, highlighting the need for food security while producing healthy products along with preserving production resources.

This study examined an extended version of the TAM with some contributions to the literature and implications for PFT developments; however, the limitations of this study should be considered. Because of the novelty of using PFTs and the unfamiliarity of traditional farmers, the study only comprised pioneer farmers, a small group of technical leaders in rural communities. The findings should not be generalized to all groups of farmers. Future studies should investigate the adoption of individual PFTs for different kinds of crops in different regions of the country. The explanation for not using a PFT is not always simply that the technology is inappropriate for their farms (Austin et al., 1998; Flett et al., 2004). The technologies may need to be more affordable for farmers, or they need more information about using PFTs. Using data about farmers' behavioral intention to use technologies as an index to design policy and programs may not be careful (Niles et al., 2016). More studies using other research frameworks and variables missed in this study, along with participatory extension methods, such as participatory technology development and focus group discussions, can provide better insights for policymakers. This study investigated only INT to PFTs use instead of capturing actual adoption behavior. What happens between the moments the intention is formed and the behavior is done is unknown (Bagheri et al., 2019). However, behavioral intention is widely considered an excellent predictor of actual behaviors (Savari &

Gharechaee, 2020). Finally, the findings may be susceptible to social desirability bias and consistency, common problems in self-reporting responses. The virtual survey method used in this study may prevent this problem.

Conclusion

Pioneer farmers' INT to use PFTs was examined in this study. The results provided valuable insights into applying the TAM to predict pioneer farmers' INT. The original model showed predictive efficiency in explaining the variance in INT and confirmed the basic principles of the TAM. However, the extended model could promote the explanatory power of the TAM. Respondents were relatively innovative, had positive ATT toward PFTs, and had a relatively positive INT to use. In contrast, they perceived PFTs as challenging, relatively low usage, and lowly compatible with their farming jobs. PI showed significant and positive effects on ATT and INT. Because pioneer farmers are a referent group of other farmers, they will act as co-extension agents if extension experts train and persuade them to use PFTs. Then, other farmers will follow them and adopt these technologies. The relationships of PEU with ATT and INT indicate that when farmers assess PFTs, ease of use is not a problem, but complexity or ease of use is essential when they intend to use these technologies. The relationship between PEU and PU indicates that the low mean score of PU may be related to the perceived difficulty, and the low mean of COM may be related to weak PU. The high initial investment requirement and knowledge-intensive nature of these technologies could be the main factors influencing low PEU, PU, and COM scores. These results may be helpful for agricultural policymakers and extension services for developing and disseminating PFTs in Iran.

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نیت کشاورزان نسبت به استفاده از فناوری¬های کشاورزی دقیق، کاربرد مدل توسعه یافته قبول فناوری، مطالعه موردی استان اردبیل

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چکیده

کشاورزی دقیق وعده افزایش منافع اقتصادی همراه با حفظ عملیات کشاورزی دوستدارتر محیط زیست را می دهد. علی رغم تلاش برای تسهیل پذیرش فناوری های کشاورزی دقیق ، (PFT) پذیرش پایین است. بااستفاده از نسخه توسعه یافته مدل قبول فناوری (TAM) با دو مؤلفه خارجی نوگرایی فردی و سازگاری، این مطالعه قصد کشاورزان نسبت به استفاده از PFTرا مورد بررسی قرار داد. این تحقیق به روش پیمایشی انجام شد و با انتخاب نمونه ای متشکل از 295 کشاورز داده های لازم جمع آوری گردید. نتایج نشان داد که مدل توسعه یافته توانست قدرت توضیحی مدل TAM را افزایش دهد و 72/6 % از واریانس قصد کشاورزان به استفاده از PFT را تبیین کند. پاسخگویان نسبتاٌ نوگرا بودند، نگرش مثبت و قصد مثبتی نسبت به استفاده داشتند. در مقابل، از نظر آنها استفاده از PFT چالش برانگیز ولی نسبتاً مفید بود و سازگاری کمی با نظام زراعی خرد آنها داشت. سازگاری مهم ترین عامل تاثیرگذار بر قصد بود و به دنبال آن مؤلفه های ادراک سهولت استفاده، ادراک مفید بودن، نوگرایی و نگرش قرار داشتند. در عین حال، ادراک سهولت استفاده تاثیر معنی-داری بر نیت نداشت که دلالت بر آن دارد که وقتی کشاورزان PFT را ارزیابی می کنند سهولت استفاه اهمیتی ندارد اما هنگامی که قصد استفاده از آنها را دارند مهم است. با توجه به دانش-بر بودن و سرمایه گذاری اولیه مورد نیاز، برای تسهیل کاربست

این فناوری ها، مداخلات سیاستی و آموزشی ضروری است. برای نیل به این نتیجه آنها باید از کشاورزان پیشرو شروع کنند

کلید واژگان: کشاورزی دقیق، مدل قبول فناوری ، کشاورزان پیشرو، نواگرایی، سازگاریPLS-SEM