

Acta Technologica Agriculturae 2
Nitra, Slovaca Universitas Agriculturae Nitriae, 2024, pp. 84–91

EXTENSION EXPERTS' INTENTIONS TO USE PRECISION AGRICULTURAL TECHNOLOGIES, A TEST WITH THE TECHNOLOGY ACCEPTANCE MODEL

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Precision agriculture (PA) is a farm management strategy that relies on various technologies to improve the productivity and sustainability of farming operations. The adoption of PA entails on-farm and off-farm benefits; however, the adoption rates remain low in Iran. Using the socio-psychological framework of the technology acceptance model (TAM), this study examined agricultural extension experts' intentions to use precision agricultural technologies (PATs) in Ardabil province, Iran. Structural equation modelling (SEM-PLS) was used to map the components of the TAM (perceived usefulness, perceived ease of use, and attitudes toward PATs). All the components of the TAM showed a significant effect on experts' intentions, confirming the importance of socio-psychological variables in predicting agricultural experts' decision to apply PATs. Experts perceived PATs as helpful and relatively easy to use. In addition, they had positive attitudes toward PATs and intended to use most PA technologies. The TAM posits that two attitudinal components of perceived usefulness (PU) and perceived ease of use (PEU) determine acceptance and use. PU is the degree to which one believes using technology would enhance job performance, while PEU is the degree to which using technology is free of effort. The results showed that PEU and PU had a positive impact on attitudes. The three constructs positively affected behavioural intention toward the application of PATs and explained 68.8% of the variance of this construct. Due to the novelty of PA in the country, PEU was the most critical determinant of intention.

Keywords: extension experts; precision agriculture; technology acceptance model; intention

Efforts to increase agricultural products to meet the food security for world's growing population in recent decades have led to excessive pressure on natural resources. An injudicious use of agrochemicals, overutilisation and contamination of surface and groundwater resources, and colossal soil erosion were the consequences of conventional agricultural systems that jeopardised the long-term sustainability of resources. Scientists and government officials have taken many initiatives to conserve natural resources while increasing productivity (Röling and Pretty, 1997). Agricultural systems in the future must develop and adopt technologies that address sustainability and support greater productivity (Pathak et al., 2019). One approach to addressing the environmental impact of agriculture while ensuring long-term productivity and food security is the application of precision agricultural technologies (PATs) (Kolady et al., 2021).

Precision agriculture (PA) is a farm management strategy that relies on a range of technologies to collect, process, and analyse spatiotemporal data for guiding targeted actions that improve the quality, efficiency, productivity, profitability, and sustainability of farming operations (ISPA, 2018). The adoption of PA entails some on-farm and off-farm benefits. Cost reduction, increased yields, and profits are the on-farm private benefits; at the same time, improved

water, soil, and air quality are the off-farm benefits of PA (Far and Rezaei-Moghaddam, 2017; Ammann et al., 2022; Aljaafreh et al., 2023; Reichardt and Jürgens, 2009). To capture the environmental and economic benefits of PATs for agricultural operations, an understanding of the factors influencing the adoption of these technologies is essential (Pathak et al., 2019).

Numerous studies have been conducted to elucidate factors influencing the adoption of PATs. However, the adoption rates remain low (Barnes et al., 2019; Gandorfer et al., 2018; Kolady et al., 2021; McBride and Daberkow, 2003; Paustian and Theuvsen, 2017; Reichardt and Jürgens, 2009). Socio-economic perspectives have been given much attention in previous studies (Adrian et al., 2005). The failure may have been due to the lack of a sound theoretical basis to include socio-psychological issues in the analysis (Borges and Lansink, 2016). Therefore, there is a growing tendency to include socio-psychological variables to better understand the users' decision-making process (Adnan et al., 2017; Floress et al., 2017).

Several theories have explained users' intention toward the acceptance of new technologies, such as the Theory of Diffusion of Innovations (Rogers, 2010), the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB) (Ajzen, 1991), and the Technology Acceptance Model

(TAM) presented and developed by (Davis, 1993; Davis et al., 1989; Davis and Venkatesh, 1996). The TAM is a modification of the TPB. While the model has been developed to explain the adoption of information-communication technologies, it was later found to have application in PATs adoption (Adrian et al., 2005; Far and Rezaei-Moghaddam, 2017; Pathak et al., 2019; Schukat and Heise, 2021). The TRA suggests that individual's attitude toward technology is an essential determinant of their behaviour towards its adoption. This is a basis for the TAM. The TAM posits that two attitudinal components of perceived usefulness (PU) and perceived ease of use (PEU) determine acceptance and use. PU is the degree to which one believes using technology would enhance their job performance, while PEU is the degree to which one believes using technology is free of effort. PU has a direct effect on behavioural intention. This model has been used to explain both short-term (acceptance and adoption) and long-term (usage) behaviours (Silva, et al., 2017). Studies show that the TAM has more potential than TPB to explain users' behavioural intentions (Jokar et al., 2017). While the TAM is widely used in information technologies (Mun et al., 2006; Venkatesh et al., 2003), few studies have employed it to explain the intention to use farming technologies (Bagheri et al., 2021; Flett et al., 2004).

After the period of inefficiency of the conventional agricultural extension system in Iran to achieve the goal of adopting new farming technologies for maintaining sustainability and productivity, at the same time employing agricultural graduates, officials decided to reform the extension system of the country. A new agricultural extension system was developed in 2015 (Jafari et al., 2020). The new extension system is a set of policy-making, program planning, executive, and monitoring mechanisms that are designed and managed to promote farmers' job skills and improve agricultural productivity and sustainability (Rezaei-Moghaddam and Fatemi, 2019). Due to the smallness and dispersal of exploitations' fragments, farmers' low literacy, and lack of knowledge about modern agricultural technologies, the new extension system has started zoning the agricultural areas and assigned the zones to recruited experts. The stakeholders of the new extension system include all the farmers of the zones. They were covered by experts in charge of the zones employed in agricultural and extension services centres of village groups (called Dehestans), except for industrial and agricultural units with specialised staff. Currently, 7700 production zones have been defined in the country and entrusted to recruited experts. At the same time, the presence of researchers of the provincial

agricultural research centres as assistant researchers for the zones has been provided (Ansari et al., 2019). The system had promised to equip the experts with ICTs, including PATs, to serve small-scale farmers, who make up the majority of country's farmers, in the zones under their supervision to benefit the farmers with these technologies. Therefore, understanding the behavioural intention of experts to use PATs is crucial in developing PATs in Iran. This study aimed to investigate the intentions of agricultural extension experts of the new extension system in Ardabil province, Iran to use PATs, using the TAM (Fig. 1). For this purpose, the following hypotheses were examined:

- H1-2. PU and PEU affect attitudes (ATT) toward PATs;
- H3-4. PU and PEU affect behavioural intentions (BI) towards the use of PATs;
- H5. PEU affects PU of PATs.
- H6. ATT affects BI toward the use of PATs.

Material and methods

Study area

This survey research was conducted in Ardabil province, Iran during four months in 2021. The TAM was used to investigate the behavioural intentions of agricultural experts working in the new extension system of the province toward the use of PATs (Fig. 1). The province is located in the northwestern region of Iran (37° 4'–39° 42' N and 47° 2'–48° 55' E). This province has 10 counties, 29 districts, and 71 village groups (Dehestans). In addition to cereals cultivated in 38,100 ha of arable land, beans, industrial crops, vegetables, and forage crops are the main crops of the province (Ahmadi et al., 2017).

Sampling, instrument, and data collection

The statistical population of the study includes all agricultural experts of the new extension system (N = 175) employed in 16 agricultural service and extension centres in Ardabil province. Using Morgan sampling table, the sample size was determined to be 125 experts. A pilot study was conducted using 30 experts, and Cronbach's alpha values were determined for the reliability of constructs. The alpha values indicated good reliabilities for all the constructs of the model. To increase reliability, except for experts who participated in the pilot stage, all the experts were included in the sample, and 142 experts voluntarily participated in the survey. Finally, 134 valid questionnaires were used for data analysis. The standard questionnaire of the TAM with necessary modifications based on study's

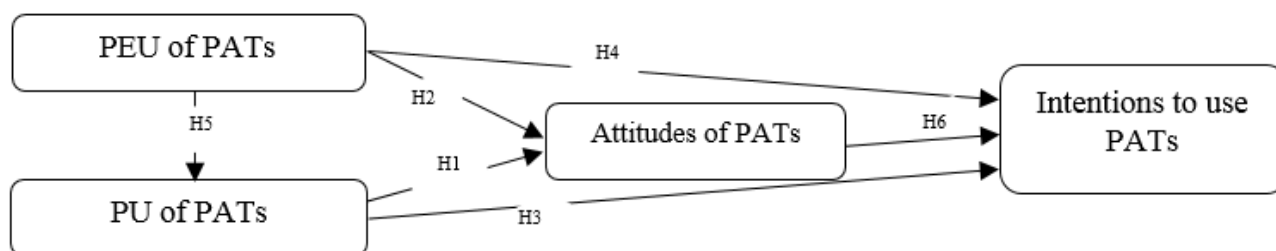


Fig. 1 Theoretical framework of the study (technology acceptance model)

Source: Davis et al. 1989; Venkatesh and Davis, 1996

objectives was used for data collection. In addition to demographic characteristics, the research tool consisted of four components of the TAM, i.e., the PU of PATs (six items), the PEU of PATs (three items), attitudes towards PATs (three items), and behavioural intentions toward PATs (five items), all in the form of 5-point Likert-type statements from one (totally disagree) to five (fully agree). To avoid face-to-face interviews due to the COVID19 pandemic, the data were collected virtually. For this purpose, the list and phone numbers of the experts were received from the agricultural organisation of the province. Then, they were contacted and invited to participate in the survey after receiving information about the aim of the study and about how to fill out and return the online questionnaires. After initial contacts and coordination with the experts, they were sent online questionnaires via WhatsApp and Telegram media.

Data analysis

The SPSS22 software was used for primary data analyses, i.e., frequencies, percentages, mean, and standard deviation. Then, structural equation modelling (SEM) using the PLS software was used to test the study's hypotheses. The variance-based PLS-SEM is used in various fields of study, including human resources (Wu, 2010). Using PLS-SEM, standard regression coefficients for paths, the coefficients of determination for internal variables, and the size of indices for the conceptual model can be measured. The reliability of the model was confirmed using composite reliability (CR) and Cronbach's alpha that absolute reliability lies in the two values. Alpha values above 0.7 are acceptable, and CR values between 0.6–0.7 are assumed acceptable, while high values are assumed excellent. Alpha values and CR values were above 0.7 (Table 1). The average variance extracted (AVE) shows the influence of indicator variables in explaining the variance of model's constructs. The AVE was used to assess the convergent validity of constructs (Fornell and Larcker, 1981). According to MacKenzie et al. (2005), a minimum value of 0.5 is acceptable for AVE. All the AVE values of the model were above 0.5 (Table 1). The heterotrait-monotrait ratio of correlations (HTMT) (Henseler et al., 2015) was used to assess discriminant validity. While the exact threshold value of the HTMT is debatable, the values of 0.85–0.9 were proposed by some authors (Clark and Watson, 1995; Teo et al., 2008). All the examined HTMT values were less than 0.85 (Table 2). The goodness of fit (GOF) was used to examine the overall fit of the model (Henseler and Sarstedt, 2013; MacKenzie et al., 2005). While the values above 0.35 indicate robust values of GOF (Wetzels et al., 2009), the calculated value of GOF was 0.645.

Table 1 Experts' familiarity with selected PATs

Technologies	Mean
Global positioning system (GPS)	5
Remote sensing	4.04
Yield mapping	3.95
Soil sampling	3.80
Variable rate technology	3.47
Weed mapping	3.16

Results and discussion

Socio-economic profile

The respondents were in middle age (41 ± 6 years). Their average career experience was 13.2 ± 5.2 years. About 29% of them were women, and the remaining were men. Regarding the education level, except for one PhD degree, the experts had a BSc or MSc degree in agricultural sciences. The disciplines of the majority (74%) were agronomy and horticultural sciences. The others were graduated from other disciplines of agricultural sciences.

Experts' familiarity with selected PATs

The experts had good familiarity with the global positioning system (GPS) (mean = 5) and remote sensing (mean = 4.04). Such familiarity was because they were usually using these technologies in farming systems of their zones under supervision, but they were moderately familiar with other selected technologies. They put familiarity with weed mapping at the lowest rank (Table 1).

Experts' perceptions of the constructs of the TAM

The TAM components and scores of their items are listed in descending order in Table 2. The experts perceived that PATs are relatively easy to use, with the overall mean score of perceived ease of use (PEOU) 3.8. The item "How to use precision farming tools is easy" (3.95 ± 0.76) was placed in the top rank, while the item "Applying PATs does not require much mental effort" (3.66 ± 0.79) was the lowest-ranked item. Based on the mean (3.77) and item scores of perceived usefulness (PU), experts perceived that the application of PATs is useful. The items "The use of PATs saves time working on the farm" (3.91 ± 0.9) and "The use of PATs leads to better control of pests and diseases" (3.61 ± 0.96) were the highest- and lowest-ranked items, respectively. The respondents had positive attitudes toward PATs (mean = 3.70). "The use of PATs is beneficial for farmers" (3.79 ± 0.94) and "Farmers have a positive attitude towards the use of PATs" (3.68 ± 0.87) were the highest- and lowest-ranked items, respectively. Finally, the mean score of behavioural intention towards the application of PATs (3.45) showed that respondents had relatively positive intentions toward applying PATs in their agricultural zones. The top-ranked item was "I intend to recommend topical spraying using variable-rate technology to farmers of my zone" (3.85 ± 0.93), while the item "I intend to train farmers on how to address topical crop nutrient deficiencies using targeted soil sampling" (3.20 ± 1.12) was the lowest-ranked item.

Discriminant validity

The measure of similarity between latent constructs of the model (HTMT) (Henseler et al., 2015) was used to assess discriminant validity. Based on the results of HTMT (Table 3), all the constructs of the model were less than 0.85, indicating the acceptable threshold levels (Clark and Watson, 1995; Teo et al., 2008), and the discriminant validity was confirmed.

Table 2 Mean and standard deviations of experts' perceptions towards PATs (n = 134)

Components	Items	Mean	SD
PEU of PATs: $\alpha = 0.928$, mean: 3.80 CR = 0.954, AVE = 0.847	how to use precision farming tools is easy	3.95	0.76
	applying PATs does not require much mental effort	3.80	0.77
	it is easy to apply the advice of PATs' experts	3.66	0.79
PU of PATs $\alpha = 0.904$, mean: 3.77 CR = 0.927, AVE = 0.681	the use of PATs saves time working on the farm	3.91	0.90
	the use of PATs leads to a reduction in pesticide use	3.85	0.91
	the use of PATs reduces agricultural waste	3.77	0.86
	the use of PATs leads to better control over farming activities	3.75	0.89
	the use of PATs leads to the optimal use of water	3.73	0.89
	the use of PATs leads to better control of pests and diseases	3.61	0.96
Attitudes of PATs $\alpha = 0.940$, mean: 3.70 CR = 0.961, AVE = 0.893	the use of PATs is beneficial to farmers	3.79	0.94
	the use of PATs protects soil and water resources	3.69	1.28
	the use of PATs conserves productivity	3.64	0.87
Behavioural intentions of PATs $\alpha = 0.969$, Mean: 3.45 CR = 0.976, AVE = 0.890	I intend to recommend topical spraying using variable rate technology to farmers	3.85	0.93
	I intend to guide farmers on using PATs	3.64	0.86
	I intend to recommend farmers the optimum use of inputs using PATs	3.29	1.12
	I intend to recommend farmers the topical fertiliser consumption using variable rate technology	3.26	1.13
	I intend to train farmers to address topical crop nutrient deficiencies using targeted soil sampling	3.20	1.12

Testing hypotheses of the study

Study's hypotheses were tested using the path analysis (Fig. 2). The impacts of PU and PEU on attitudes and the impact of the three constructs on behavioural intention towards the application of PATs were examined. The determination coefficients (R^2) were also calculated to show the total variance explained by model's constructs (Table 3). As illustrated in Table 3, PU ($\beta = 1.178$) and PEU ($\beta = 0.669$) showed significant impacts on attitude, respectively, and the two hypotheses (H1 and H2) were confirmed. Accordingly, these two constructs showed positive impacts on behavioural intentions, and the hypotheses H3 and H4 were confirmed. Therefore, the more positive perceptions of the ease of use and the usefulness of PATs, the more positive attitudes toward and the more positive behavioural intention to the use of PATs. PEU showed a positive and significant impact on PU ($\beta = 0.822$), and the H5 was confirmed. Finally, attitudes showed a positive and significant impact on behavioural intention ($\beta = 0.734$), and H6 was confirmed (Table 4). The three constructs of attitudes, PU, and PEU accounted for 68.8% of the variance of experts' behavioural intention toward using PATs. PEU and PU accounted for 89.7% of the variance of attitudes.

Using the TAM, this study examined agricultural extension experts' intentions to use PATs in Ardabil province, Iran. Valuable insights into the attitudes and intentions of experts of the new extension system toward the use of PATs were obtained that could be used to increase small-scale farmers' productivity and profitability. This is because farmers appear to be hesitant to adopt these technologies (Aubert et al., 2012) and the adoption rates remain low (Barnes et al., 2019; Gandorfer et al., 2018; Kolady et al., 2021; McBride and Daberkow, 2003; Paustian and Theuvsen, 2017). According to the results, all the model hypotheses were validated, confirming the importance of socio-psychological drivers on agricultural experts' decision to apply PATs (Edwards-Jones, 2006; Mills et al., 2017).

The experts were relatively familiar with selected PATs. They had also positive intentions toward applying PATs in their agricultural zones. The item "I intend to recommend topical spraying using variable-rate technology to farmers of my zone" was the top-ranked intention item, while the item "I intend to train farmers on how to address topical crop nutrient deficiencies using targeted soil sampling" was the lowest-ranked item. This finding indicates that the easier-to-understand technology for farmers, i.e., topical spraying,

Table 3 Discriminant validity (HTMT criteria)

Latent constructs	PU	PEU	Attitude
PEU	0.840		
Attitude	0.736	0.826	
Intention	0.605	0.708	0.749

Table 4 Path coefficient of the research hypotheses

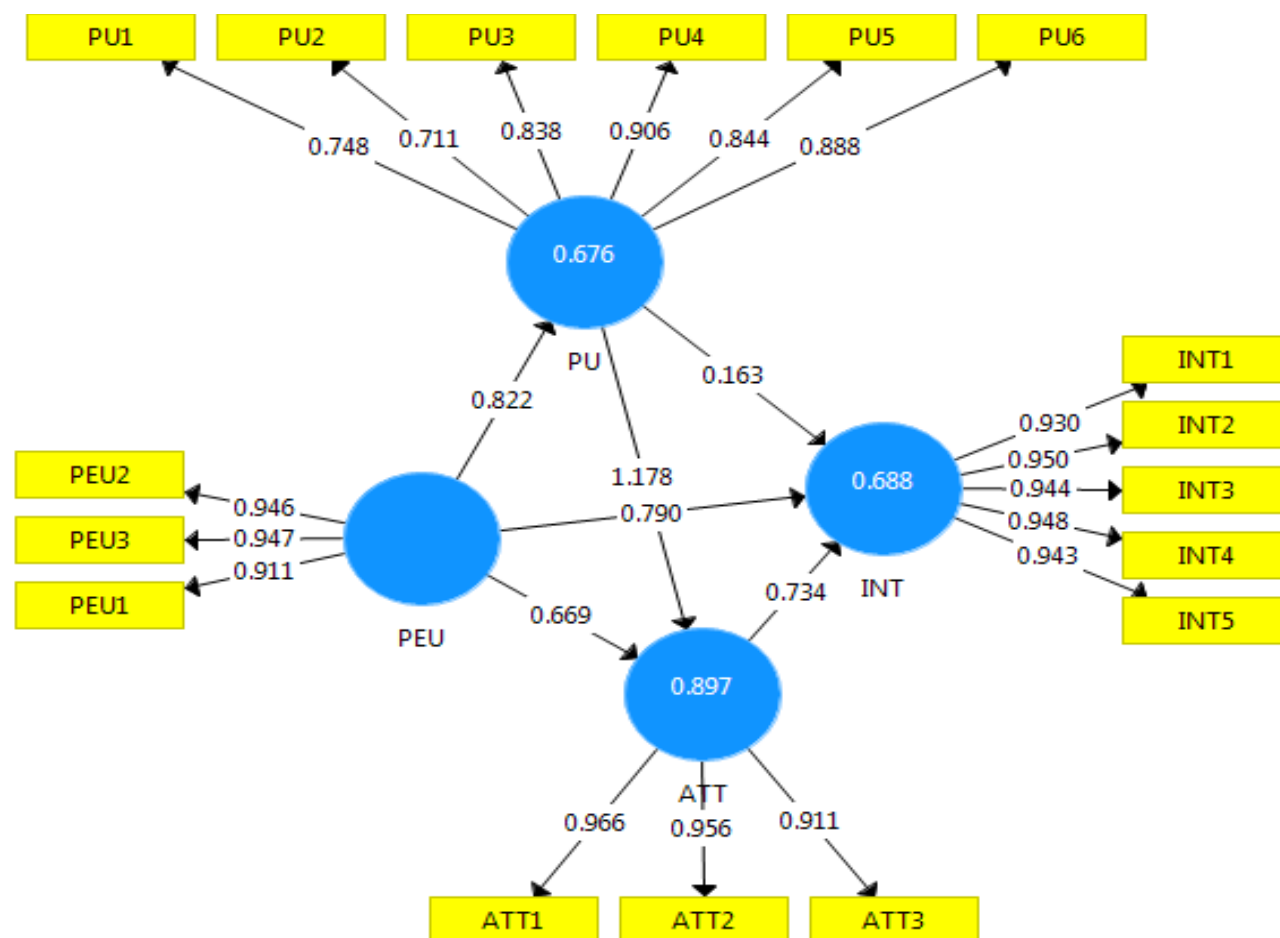
Dependent	Independent	Direct	Indirect	Total	t-value	R ²
Intention	Attitude	0.734	–	0.734	5.689**	0.688
	PU	0.163	0.82	0.938	1.816**	
	PEU	0.790	0.625	1.415	5.488**	
Attitude	PU	1.178	–	1.178	22.876**	0.897
	PEU	0.669	0.968	1.637	4.999*	
PU	PEU	0.822	–	0.822	17.442**	0.676

*, ** significant at $P < 0.05$ and $P < 0.01$

was highly intended by experts because soil sampling is not so easy for farmers to understand and use, and due to the lack of soil testing facilities in the study area, this technology was moderately intended and placed in the last priority of the experts. Based on this result, infrastructural investment is needed to promote the use of PATs in Iran.

According to the original TAM (Davis et al., 1989; Venkatesh and Davis, 1996), PU has a direct impact on the intention to use technology. PEU has a direct impact on PU and an indirect impact on intention through PU (Lee et al., 2003). The two constructs directly affect attitude toward PATs and indirectly affect intention through attitudes. Later studies also found similar results for PU and attitudes, but

conflicting results for PEU (Flett et al., 2004; Fu et al., 2006; Koufaris, 2002; Rezaei-Moghaddam and Salehi, 2010; Wu and Wang, 2005). Because of the novelty of PATs in Iran, a direct impact of PEU on intention was examined. Experts who believe that a PAT is easy to use are more likely to find it useful and more likely to use it (Adrian et al., 2005). Based on the results of the present study, the PEU was the most important determinant of intention, followed by attitudes. This result is contrary to previous TAM studies that emphasised the crucial impact of attitudes on intention. It may be because of the knowledge-intensive nature of these information-based technologies (Vecchio et al., 2020) and the newness of PATs for agricultural experts.

**Fig. 2** Path model of attitudes and intentions toward the use of PATs

While experts perceived that the technologies were useful, they were not sure that farmers could easily apply all the technologies. In contrast, the PU was the most important predictor of attitudes toward PATs. Based on this result, if experts perceive technology is useful but is not easy to use, they may not intend to use it. The results also showed that the experts perceived that PATs are relatively easy to use. They perceived that the application of PATs is useful for farming systems of their zones. Furthermore, experts had relatively positive attitudes toward the PATs. This construct showed a significant impact on intention. Several previous studies also found that attitude is a crucial determinant of behavioural intention toward the adoption of PA (Adrian et al., 2005; Granić and Marangunić, 2019; Rezaei-Moghaddam and Salehi, 2010). Therefore, providing successful experiences for experts could provide better insight into PATs and make positive attitudes toward these technologies. In this regard, visiting experts with farms successfully using PA, especially in developed countries, and participating in national and international seminars and training courses are essential.

Infrastructural barriers and economic constraints are the main obstacles to the development and adoption of these technologies (Ammann et al., 2022; Gandorfer et al., 2018). Agricultural policymakers are required to take initiatives to develop PATs. Internet coverage, especially for remote areas, is the essential step to using PATs by agricultural field experts; providing facilities for the experts is the second necessary step to the development of PATs in all agricultural zones.

This study comes with some limitations. Precision agriculture is a novel technology especially in developing countries like Iran. Some of the technologies were not seen or applied in the country, and others are currently used only by agricultural experts while farmers are not informed about them. As discussed above, the adoption and use of these technologies requires equipment, good infrastructure, and extension campaign by well-trained experts who are working with these technologies in their agricultural zones. This cross-sectional study examined experts' intention in a specific region and a short period. Because of potential susceptibility to sampling bias and changing intentions over time, longitudinal studies with larger samples of experts can provide better insights for policymakers to develop PA. Future studies examining the relationship between experts' intention and the number of technologies applied would be quite interesting. Because of expensive and knowledge-intensive nature of PATs, it is better for future studies to focus on the adoption of situation-specific PATs introduced by the research stations of each region. Lastly, due to the COVID 19 pandemic, the data were collected using a self-reporting method through virtual questionnaires, where consistency and validity may have some degree of uncertainty.

Conclusion

- Experts needed more knowledge to disseminate PATs among farmers. Due to the increasing development of precision agriculture, agricultural universities should include courses in their curricula to familiarise future experts with these technologies.

- The experts were aware of the importance of these technologies and intended to use them for the agricultural development of the areas under their supervision. Agricultural officials should provide them with the necessary facilities.
- Considering the poor infrastructure of rural areas for utilising PATs, agricultural policymakers should provide the necessary infrastructure.
- Considering the importance of attitudinal factors of PU and PEU, agricultural experts should highlight the usefulness of precision agriculture and make it easy for farmers to understand and use PATs.

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