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Progressive farmers' Perceptions of Barriers to the Utilization of Precision Agricultural Technologies

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Abstract

Precision agricultural technologies (PATs) are economically efficient and environmentally sound. However, their on-farm utilization by smallholders is still at a low level. Using a sample of 130 volunteer farmers, the current study investigated progressive farmers' perception of the barriers to adopting and effectively using PATs in Ardabil province, Iran. Due to the COVID-19 pandemic, an online survey was adopted to avoid close contact. A questionnaire was used as the instrument for data collection. A panel of experts validated the questionnaire. The reliability of the research instrument was confirmed in a pilot study on 30 progressive farmers. The results indicated that progressive farmers had moderate knowledge about PATs. The lack of extension courses for farmers concerning the operation of these technologies and the need for high investment costs were regarded as the main barriers to adopting these technologies. Based on factor analysis, four factors, namely information barriers, economic barriers, infrastructural barriers, and lack of access, accounted for 74.23% of the variance in the barriers. The results have implications for policymakers and extension services. Progressive farmers as the early adopters of new technologies and the reference group of other farmers should be trained and encouraged to adopt PATs. Because PATs are costly and knowledge-intensive, providing low-interest loans and credits for buying PATs' equipment, farmers' precision agriculture associations for buying and collaboratively using these technologies, as well as extension campaigns, Radio-TV programs, and extension courses to train farmers about PATs are essential for utilizing these technologies.

Keywords: Precision agriculture, adoption, small-scale farmers, information technologies.

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Introduction

The increasing world population growth, and consequently the increasing demand for food, fiber, feed, and energy, has put significant pressure on the environment and production resources; therefore, the challenges of the agricultural sector are expected to become more complex over time (Pathak et al., 2019; Suresh et al., 2022). To meet these challenges, advanced and environmentally friendly technologies that manage all resources efficiently are to be realized

so that sustainable agriculture is achieved. One of the strategies proposed for this purpose is precision agriculture (PA) (Kolady et al., 2021, Lee et al., 2021,). PA, which is based on sustainable agriculture and healthy food production, is a state-of-the-art method in agriculture. Reliance upon specialized equipment, software, and information technology (IT) services leads to proper implementation in the right place and at the right time (Vecchio et al., 2020); besides, it serves for the application of IT in agriculture (Mitchell et al., 2021). PA has been defined as a management strategy that collects, processes, and analyzes spatiotemporal data and incorporates that with some other information to guide site, plant, or animal-specific management decisions toward improving productivity, profitability, and sustainability of agricultural systems (ISPA, 2018). This technology, strengthening whole-farm management strategies via IT, highlights possible improvements in production and reduces environmental impacts, thereby getting to changes in land use (European Parliament, 2014). In addition, several studies have emphasized the economic and environmental benefits of precision agricultural technologies (PATs) (Finger et al., 2019). Precision farming might decrease input costs and increase crop yields by reducing input consumption, maximizing crop yields, and boosting strategic crop production by farmers (Koutsos and Menexes, 2019). The critical impact of PATs is the realization of sustainable agriculture, which can be achieved by reducing the use of inputs, such as chemical fertilizers and pesticides, which would reduce environmental pollution, especially groundwater pollution (Weersink, 2018; Mitchell et al., 2021). Despite the importance of PATs, there are some barriers to their adoption, which have hindered significant progress in their use. So far, several studies have been conducted on the adoption and use of PATs and the challenges they face. The literature shows that factors such as low income, lack of enough capital needed for initial investment (Griffin et al., 2018; Bolfe et al., 2020; Mitchell et al., 2021), high costs of using PATs and farmers' inability to pay for these costs (Bosompem, 2015; Gandorfer et al., 2018; Barnes et al., 2019; Ofori and Yeager, 2020), the lack of trust in these technologies (Busse et al., 2014), the lack of confidence in the return of the investment in these technologies (Schimmelpfennig and Ebel, 2016), the lack of technical knowledge and computer literacy (Long et al., 2016; Pivoto et al., 2019), and farmers' ignorance of the benefits of the adoption (Villa-Henriksen et al., 2020) were of the main barriers to their adoption.Despite the high potential of PATs to improve efficiency and productivity in agriculture, planning for the adoption and use of these techniques has not been globally satisfactory. Studies on the drivers and barriers to adopting PATs show that farmers' perceptions of the technologies are influenced by several factors. In this regard, to identify and prioritize the most critical barriers, the present study examined progressive farmers' perception of barriers to the adoption and use of PATs in Ardabil province, Iran. Iran is located in the arid and semi-arid belt and suffers from severe water shortages and soil erosion (Bagheri and Teymouri, 2022). Due to the unfamiliarity of farmers with the proper use of agrochemicals, they use fertilizers and pesticides indiscriminately (Bagheri et al., 2021). Precision farming promises the optimal use of soil and water resources, pest and plant disease management, and the proper supply of nutrients to crops. Adopting and using these technologies can lead to a fundamental change in Iran's agricultural sector. Ardabil province has witnessed the development of agricultural mechanization as one of the agricultural regions in the northwest of Iran over the past years. GIS and GPS are the technologies most widely used in smart farming. Despite the introduction of smart farming systems in the province, they have not received a suitable level of acceptance. The leading farmers in smart farming are seen as role models in the province due to a large portion of the province's agriculture. It seems essential to identify the leading problems for an acceptable level of smart farming application. To achieve this, the following objectives were also considered: a) Identifying farmers' knowledge of PATs and b) identifying farmers' information sources.

Materials and Methods

Study area. This study was conducted in Ardabil province, Iran, during the cropping year of 2021. The province consists of 10 counties, including Parsabad, Bilesvar, Germi, Meshkinshahr, Namin, Ardabil, Sarein, Nir, Kowsar, and

Khalkhal. Population and Sample. The statistical population of the study included all progressive farmers of the province (N = 295). The progressive farmers have larger farms, are better educated, are members of farmers' organizations and cooperatives, and have families with a modern lifestyle. They generally have a higher social status (Van den Ban, 1957; Haryanto et al., 2018). In this study, progressive farmers are those who, compared to the other farmers, have a better yield because of better technical knowledge or modern farming techniques and varieties. In addition, they are active in social participation and have close collaboration with peers and extension agents, too. They are chosen and encouraged annually by the county's agricultural offices. They constitute about 3% of the total farmers in this area. Using a convenience sampling approach, the data were collected from a sample of 130 progressive farmers who were voluntarily willing to participate in the study.

Instrument and data collection. After a comprehensive literature review and contacts with agricultural experts, the main barriers to the utilization of PATs were extracted. Then, a questionnaire was developed as the main research tool. Due to the COVID-19 pandemic, to prevent physical contact with respondents, the questionnaire was provided to farmers online; for this purpose, the list and contact numbers of the progressive farmers were received from the Agricultural Organization of the province. They were then contacted. The questionnaires were sent to them through WhatsApp messenger and text messages. The questionnaire consisted of two sections. The first section was related to the socioeconomic characteristics of the respondents (gender, age, marital status, agricultural experience, level of education, etc.). The second section dealt with their perception of barriers to the adoption and use of PATs consisting of 20 Likert-type items organized in a range of five options varying from strongly disagree (1) to strongly agree (5) and their knowledge of five PATs and their information sources on these technologies ranging from very low (1) to very much (5). A panel of university faculty members and agricultural experts validated the questionnaire. The estimated reliability, using Cronbach's Alpha, was 0.899, which was acceptable.Data analysis. The cross-sectional survey research method was used in this study. The data were analyzed using SPSS22 software. After primary analyses, i.e., frequencies, percentages, mean, and standard deviation, exploratory factor analysis was done to reduce variables (barriers) to minimum factors to get a better understanding of barriers to the utilization of PATs. Principal component analysis along with Varimax rotation was applied for factor extraction. A minimum Eigenvalue of 1, minimum factor loading of 0.5 for each indicator item, simplicity of factor structure, and exclusion of single item factors were the common rules for factor extraction decisions. By using Bartlett's test and KMO test, it was determined whether the research variable was appropriate for factor analysis (KMO = 0.833, Bartlett = 2280.109, p-value<0.01).

Results

The respondents were 46.40 ± 11.71 years, and their farming experience was 35.13 ± 13.52 years. The majority of respondents (90.8%) were men. Thirty percent of individuals lived in urban areas. 43.8% of the respondents were eager to use technologies. 51.5% had higher education, 30% had a secondary high school diploma, and the rest of the respondents had primary education. The area under cultivation of 24.6% of respondents was 1-2 hectares, 10.8% owned 2-3 hectares, and 64.6% owned beyond 3 hectares (Table 1).

Table 1. Socioeconomic characteristics of the participants

Variables	Category	Frequency (Percentage)
Gender	Male	118 (90.8)
	Female	12 (9.2)
Residence	Rural area	91 (70)
	Urban area	39 (30)
Marital status	Married	119 (91.5)
	Single	11 (8.5)
Willingness to use PATs	Yes	57 (43.8)
	No	73 (26.4)

Cultivated area (ha)	1-2	32 (24.6)
	2-3	14 (10.8)
	More than 3	84 (64.6)
Family members (people)	1-2	31 (23.8)
	3-6	72 (55.4)
	More than 6	27 (20.8)
Level of education	Illiterate and elementary	17 (13.1)
	Under diploma	7 (5.4)
	Diploma	39 (30)
	Higher education	67 (51.5)
Variable	-	Mean ± SD
Farmers' Age (years)	-	46.4 ± 11.71
Farming experience(years)	-	35.13 ± 13.52

Farmers' knowledge of PATs. Progressive farmers' knowledge about five widely used PATs was examined. They answered the question "what extent do you know about the following PATs?" The results showed that their knowledge of the global positioning system was relatively high, followed by aerial photography, while they had insufficient knowledge of yield mapping (Table 2).

Table 2. Farmers' knowledge of precision agricultural technology

PA Technologies	Mean	SD
Global positioning system (GPS)	3.96	1.12
Aerial photography	3.62	1.31
Remote sensing	3.64	1.38
Drawing and demarcation	3.45	1.24
Yield mapping	2.67	1.32

Mean scores from 1 (very low) to 5 (very high)

Progressive farmers' information sources on PATs. The results showed that agricultural extension experts were the primary references for information seeking for progressive farmers on PATs (4.11±1.17), followed by TV agricultural programs (3.93±1). Getting information from users of these technologies (1.35±0.86) and also, extension training courses (1.22±1.06) were among the least important information sources (Table 3).

Table 3. Progressive farmers' information sources

Information sources	Mean	SD
Agricultural extension experts	4.11	1.17
TV programs	3.93	1
Internet and virtual networks	3.75	1.09
Visit from sample farms using PAT	3.5	1.13
Other farmers using these technologies	3.45	1.24
Users of PAT in nearby villages	1.35	0.86
Extension programs related to PAT	1.22	1.06

Mean scores from 1 (very low) to 5 (very high)

Correlation and comparison analyses. Pearson correlation analysis was used to examine the relationship between progressive farmers' knowledge of PATs and the other variables. Based on the results, positive and significant correlations were found between knowledge of PATs and variables of information sources (r = 0.538) and cultivation areas (r = 0.766). This

result indicates that progressive farmers with more information sources and larger cultivation areas had better knowledge of PATs. No significant relationships were found between knowledge and other variables of the study. The results of the chi-square test showed a significant relationship between progressive farmers' knowledge of PATs and their willingness to use these technologies, indicating that knowledge affects their willingness to use PATs. Based on these results, willingness to use showed positive relationships with education and cultivated area, indicating that farmers with more education levels and with larger cultivated areas were more willing to use PATs (Table 4).

Table 4. Pearson correlation and chi-square test between knowledge, willingness to use PATs, and other variables.

Knowledge			**Willingness to use**		
Variables	**r**	**p-value**	**Variables**	**χ^2**	**p-value**
Farmers' age	0.033	0.709	Knowledge	3.818	0.050*
Family members	0.044	0.623	Education	8.282	0.041*
Education	0.019	0.831	Cultivation area	50.119	0.000**
Farming experience	0.079	0.371			
Information sources	0.538**	0.000			
Cultivation area	0.766**	0.000			

*, ** Significant at $p<0.05$ and $P < 0.01$

Barriers to the use of PATs. Lack of extension courses for farmers concerning how to work with technologies (4.4±1.20), and the need for high investment costs (equipment, infrastructure, training, research) (4.4±1.26), followed by old age, insufficient knowledge of most farmers (4.34±0.82), and the lack of training programs on precision agriculture for farmers (4.03±1.11) were regarded as the essential barriers to adopting PATs. Lack of technical knowledge in using software related to these technologies (3.06±1.19) and lack of familiarity of farmers with the English language to use PA tools (2.88±1.26) were the least significant barriers to the adoption (Table 5).

Table 5. Mean, standard deviation, and factor analysis of barriers of using PATs

Items	M	SD	Factors			
			Informative	Economic	Infrastructural	Accessibility
Poor links of farmers-researchers-extension agents	3.33	1.06	0.874			
Lack of essential information and weak general knowledge of experts about PA	3.19	1.21	0.867			
The high percentage of low literacy and illiteracy among farmers	3.33	1.14	0.822			
Lack of technical knowledge in using software related to PATs	3.06	1.19	0.818			
Lack of information on how to use PATs	3.28	1.14	0.80			
Lack of familiarity of farmers with the English language to use PA tools	2.88	1.26	0.778			
Farmers' insufficient literacy and the lack of understanding of scientific materials of PA	3.53	1.12	0.765			
Lack of extension programs for farmers to work with PATs	4.4	1.20	0.717			

Farmers' ignorance of the benefits of PATs	3.53	1.23	0.715			
Insufficient information from the relevant authorities	3.15	1.30	0.699			
Old age and the low level of knowledge of most farmers	4.34	0.82	0.694			
Lack of PA experts	3.37	1.17	0.658			
Lack of training programs on PA for farmers	4.03	1.11	0.636			
Financial constraints on the use of PATs	3.4	1.26		0.850		
Incompatibility of PATs with conditions of subsistence farmers	4.17	1.00		0.819		
High cost of using PATs	3.35	1.16		0.794		
High investment costs (equipment, infrastructure, training, research)	4.4	1.26		0.704		
The poor financial strength of farmers	4.32	0.96		0.612		
Small farm size					0.533	
Lack of access to PATs tools	3.54	1.35				0.779
Variance explained (Total: 74.23%)	-	-	40.67	18.72	9.04	5.79
Eigenvalues	-	-	8.13	3.74	1.80	1.15

Factor analysis. All 20 items of the scale were realized to be appropriate for the analysis (Tabachnick and Fidell, 2007). Factor loadings of greater than 0.5 were assumed to be significant. According to the Kaiser criterion, four factors with eigenvalues of greater than one were extracted and explained 74.23% of the variances in barriers to the use of PATs (Table 5). The first factor, which was named information barriers, had the highest share of the explained variance of barriers to the adoption and use of PATs (40.67%). Ignorance about the benefits of these technologies, lack of information on how to use the technologies, insufficient information by the relevant authorities, lack of training programs on PA for farmers, lack of extension courses for farmers, lack of understanding of scientific materials of PA, lack of farmers' familiarity with the English language to use PA tools, lack of precision agricultural experts, a high percentage of low literacy among farmers, poor links of farmers, researchers and extension experts, farmers' old age and low level of knowledge, lack of essential information and general knowledge of experts on PA, and eventually lack of technical knowledge in the use of software related to these technologies were included in this factor. The second factor, called economic barriers, accounted for 18.72% of the total variance. The need for high investment costs (equipment, infrastructure, training, research), high cost of using technologies, financial constraints for using PA, incompatibility of the technology with the conditions of subsistence farmers, and poor financial ability of farmers were included in this factor. Infrastructural barriers and accessibility of PATs were the third and fourth factors that captured 9.04% and 5.79% of the total variance, respectively. Small farm sizes and lack of access to PA tools were included in this factor.

Discussion

The spread of new agricultural information and knowledge using modern technologies increases the ability of farmers to perform agricultural activities in a better way. With the improvement of knowledge and quality of agricultural products and the abilities of farmers, along with the increase in productivity, natural resources would be used properly. This study investigated progressive farmers' perceptions of barriers to the adoption of PATs. While Iran suffers from severe water shortage, soil erosion, and the overuse of agrochemicals, no study has been conducted to elicit and categorize the barriers to the adoption and use of PATs despite their crucial role in addressing these problems. Therefore, this is the first study that investigated the barriers to using PATs in Iran. The results extended the literature on the adoption behavior of PATs in developing

countries, especially Iran.The results showed that progressive farmers had moderate knowledge of selected PATs. Their primary information sources were extension agents and TV agricultural programs currently providing low information about PA to farmers. They are yet considered traditional sources of agricultural information. Increasing farmers' awareness and knowledge about these technologies is an essential factor in the acceptance and use of PATs (Vecchio et al., 2020). Accordingly, it is necessary to provide agricultural radio and television programs to introduce the benefits and methods of using PATs. Moreover, extension campaigns are needed to be implemented to introduce these technologies and their acceptance by farmers. Progressive farmers, whose farming methods are usually the models of other farmers, are considered the early adopters of new technologies (Blasch et al., 2022). Therefore, encouraging this group of farmers to adopt these technologies has a significant effect on their dissemination among other farmers and acceptance. So, to develop the adoption and use of PATs, these results should be considered.

Based on the results of factor analysis, four barrier factors were extracted. The first factor, information barriers, indicates a lack of information and weakness in extension educational activities. Lack of a proper public perception of a particular technology leads to an adverse reaction from people to it. This issue emphasizes the importance and necessity of farmers' information and awareness programs, which have always been considered one of the main components of the technology development process by policymakers. Farmers' low level of education and their low literacy mean that they neither are aware of new methods and technologies nor receive information about the benefits of their implementation. Consequently, they do not consider these technologies appropriate. Owing to farmers' unfamiliarity with the howness of using and maintaining PATs, they might think that these technologies are challenging to work with and are therefore not appropriate for their occupations. This result is in line with previous studies (Long et al., 2016; Pivoto et al., 2019; Villa-Henriksen et al., 2020), which confirmed the impact of lack of knowledge and information on the non-acceptance and use of PATs. The second factor is economic barriers. Most smallholders are economically weak. The low income of smallholders, along with the high costs of preparing and using these technologies, prevent the acceptance of PATs. This result is consistent with the findings of other studies (Bosompem, 2019, Gandorfer et al., 2018; Barnes et al., 2019; Ofori and Yeager, 2020; Bolfe et al., 2020; Mitchell et al., 2021). In this regard, providing long-term and low-interest loans and credits for purchasing and utilizing PATs could be effective for acceptance and use. The third factor is infrastructural barriers. This factor indicates the lack of suitable infrastructure for PATs in the region. Undoubtedly, one of the crucial requirements for developing emerging technologies, including PATs, is the appropriate infrastructure and facilities necessary for their development, which must be identified, strengthened, and used optimally. The small size of farms is one of the infrastructural problems that has been considered in the present study, which is consistent with the findings of previous studies (Paustian and Theuvsen, 2017). Land consolidation and the establishment of mechanization cooperatives for the collective use of these technologies by farmers is a suitable solution to solving this problem. The last factor is the lack of access. The impact of the lack of access to PA tools and technologies on the non-adoption and use of these technologies is in line with the findings of previous studies (Bolfe et al., 2020). Therefore, The tools and technologies required for the application of PA must be available for progressive farmers who are technical leaders of traditional farmers of the region.

Conclusion

Planning to create a robust information-communication network among people active in the field of PA to share information could provide the necessary conditions for farmers' extensive participation in the development and utilization of PATs. Given that developing countries and less developed regions are in the early stages of PAT development and application, the establishment of reliable and up-to-date databases in the agricultural sector might effectively provide stakeholders with relevant information on PA.

This study has implications for policymakers and agricultural extension services. However,

because the study was conducted among a specific group of farmers in a specific area, policy interventions could not be generalized to other farmers and regions. However, to reduce production costs, conserve soil and water, and protect the environment, barriers to the dissemination and adoption of PATs should be addressed. Progressive farmers are the early adopters of new agricultural technologies. They are a reference group of other farmers. Therefore, they should be first trained and encouraged to adopt. PATs are costly and knowledge-intensive. Extension campaigns and Radio-TV agricultural programs for informing and extension courses to train farmers about PATs are needed. It is also essential that farmers' PAT associations contribute to buying and collaboratively using these technologies and governments provide low-interest loans and credits for buying and implementing PATs.

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