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The Adoption of Variable-Rate Application of Fertilizers Technologies: The Case of Iran

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Precision agriculture technologies are designed to provide broad information to assist farmers when making site-specific management decisions. The paper aims to investigate the use of adoption of precision agriculture technologies among agricultural specialists in Bushehr province, Iran. A survey using multi stage random sampling was used to collect data. Structural equation modeling using LISREL software was used to analyze data. The results showed that individual innovativeness and attitude to use affect intention to use of variable-rate application technologies. Perceived ease of use and perceived usefulness influence the intention to use of the technologies. Attitude to use is the most important determinant of intention. Based on the results, some recommendations have been provided.

Key words: Precision agriculture technologies, Technology acceptance model, Individual Innovativeness, Intention to use, Attitude, Iran

Introduction

Application of new technologies based on "high-input and high-output" conventional strategy has caused fundamental changes in the process of production. Environmental technology is a major determinates for environmental improvement. Use of these technologies can decrease demands on natural systems and increase our ability to control the environmental consequences of production (Kumar, 2002).The key to sustainable agricultural growth is technology that produces little or no waste, coupled with careful management to maximize efficiency and safety. There is a general consensus among agricultural development practitioners in Iran that the goals of sustainable agriculture should include increasing production (for an ever increasing population), preventing soil erosion, reducing pesticide and fertilizer contamination, protecting biodiversity, preserving natural resources and improving well-being (Rezaei-Moghaddam et al., 2005).

Precision agriculture technologies, based on information technology, are the key to achieving sustainable agricultural development (Rezaei-Moghaddam et al., 2005). Precision agriculture is a comprehensive approach to farm management (Grisso et al., 2002). This is the goal of precision farming that implies the maturity of wisdom-oriented technologies and aims at "optimized input-output solution" (Shibusawa, 2002). The main activities of precision agriculture are data collection, processing and targeted application of inputs (Fountas et al.,

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2005). The central ideas of precision agriculture are understanding spatial variability of soil properties, crop status and yield within a field; identifying the reasons for yield variability; making farming prescription and crop production management decisions based on variability and knowledge implementing site-specific field management operations; evaluating the efficiency of treatment; and accumulating spatial resource information for further management decision making (Maohua, 2001).

Precision farming uses a set of technologies to identify and measure within-field variability and its causes, prescribe site-specific input applications that match varying crop and soil needs, and apply the inputs as prescribed. The use of soil sampling; yield monitoring; remote sensing; and variable-rate applications of herbicide, pesticide, and fertilizer, as well as the global positioning system (GPS) and a geographic information system (GIS) can be considered precision agriculture (Songa et al., 2010).

A significant body of research into the factors affecting information technology acceptance has as its foundation the Technology Acceptance Model (TAM). The "Technology Acceptance Model (TAM)" of Davis and his colleagues (1989) is perhaps the most widely applied to explain or predict application of information technologies (Yi *et al*., 2006). TAM has its theoretical grounding in Fishbein and Ajzen's (1975) theory of reasoned action (TRA). Based on this theory, behavior is best predicted by intentions, and are jointly determined by the person's attitude and subjective norm concerning the behavior. The theory of planned behavior (TPB) modifies the TRA by incorporating the construct perceived behavioral control to address situations in which individuals lack substantive control over a specific behavior (Ajzen, 1991). TAM adopts these theories into an information technology acceptance model (Fig. 1). This model delineates the causal linkages between two key beliefs: perceived ease of use and perceived usefulness, and users' attitude, intentions and actual adoption behavior (Davis *et al*., 1989).

Many researchers suggested that TAM needed to be given additional variables (Wu & Wang, 2005). Innovation Diffusion Theory (IDT) proposed by Rogers (1995) has been widely used for relevant information technologies. Based on this theory adoption of an innovation is dependent on an individual's perception about the innovation (Adrian *et al*., 2005). The constructs employed in TAM are fundamentally a subset of the perceived innovation characteristics and, if integrated, could provide an even stronger model than either standing alone (Porter & Donthu, 2006).

A few studies have been published relate to adoption of precision agriculture technologies using TAM. Adrian *et al*. (2005) demonstrated the impact of perception and attitudinal characteristics of farmers on the decision to adopt precision agriculture technologies. The results showed that attitude of confidence toward using the precision agriculture technologies positively influenced the intention to adopt precision agriculture technologies. Also, the perception of usefulness positively influenced perception of net benefit (Adrian *et al.*, 2005).

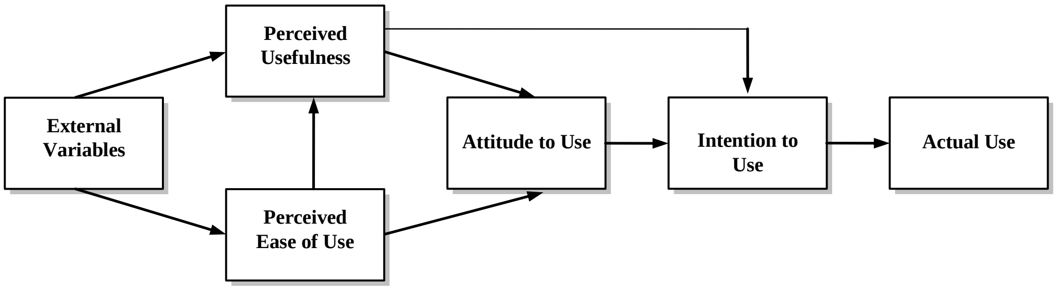

Fig. 1. Original technology acceptance model

In this study, we extended the TAM with new variable (Fig. 2). We extended and empirically tested the TAM with the addition of individual innovativeness (Fig. 3). The purpose is to predict the factors affecting intention to use of precision agriculture technologies among agricultural specialists in Bushehr province, Iran. The proposed hypotheses have been shown in table 1.

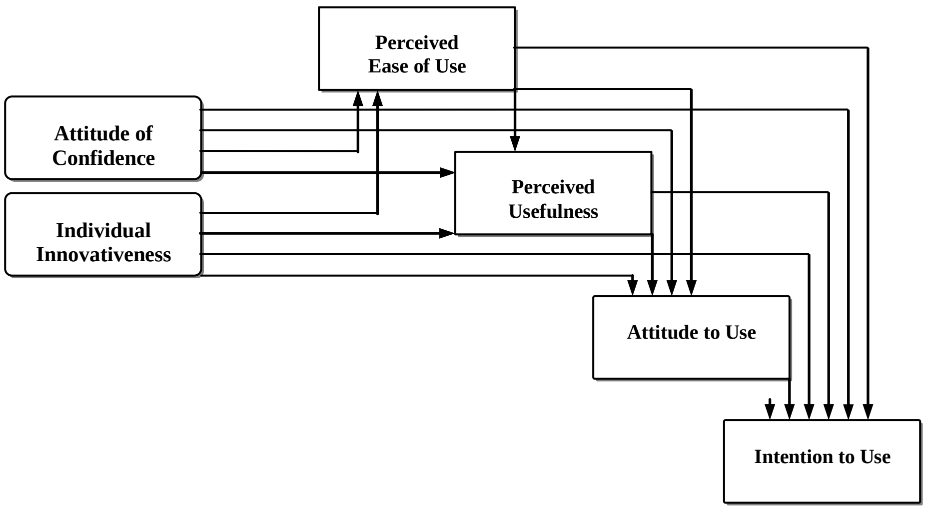

Fig. 2. Theoretical Framework

Table 1. Hypotheses of the research

Hypotheses
H1. Attitude of confidence has a direct effect on perceived ease of use of variable-rate application technologies.
H3. Attitude of confidence has a direct effect on attitude to use of variable-rate application technologies.

H2. Attitude of confidence has a direct effect on perceived usefulness of variable-rate application technologies.

H4. Attitude of confidence has a direct effect on intention to use of variable-rate application technologies.

H10. Perceived ease of use has a direct effect on attitude to use of variable-rate application technologies.

H9. Perceived ease of use has a direct effect on perceived usefulness of variable-rate application technologies.

H11. Perceived ease of use has a direct effect on intention to use of variable-rate application technologies.

H12. Perceived usefulness has a direct effect on attitude to use of variable-rate application technologies.

H13. Perceived usefulness has a direct effect on intention to use variable-rate application technologies.

H14. Attitude to use has a direct effect on intention to use of variable-rate application technologies.

H5. Individual innovativeness has a direct effect on perceived ease of use of variable-rate application technologies.

H6. Individual innovativeness has a direct effect on perceived usefulness of variable-rate application technologies.

H7. Individual innovativeness has a direct effect on attitude to use of variable-rate application technologies.

H8. Individual innovativeness has a direct effect on intention to use of variable-rate application technologies.

Research Method

A survey was used to collect data using questionnaire. Data to test the model was gathered among agricultural specialists in Bushehr, a southern province in Iran. A multi stage random sampling was used to gather data. Bushehr has a central organization in center of province and branches in center of counties. We stratified the counties to groups, base on the level of their agricultural development and compared the specialists' opinions. The sample consists of 156 agricultural specialists and it is estimated on Cochran's equation.

The study was conducted in two phases. In this study, variable-rate application of fertilizers tested as precision agriculture technologies. This variable tested with several items. The items were measured using a five-point Likert-type scale (ranging from 1 = strongly disagree to 5 = strongly agree). The questionnaire was refined through rigorous pre-testing with the establishment of content validity. The questionnaire was pilot-tested with 30 randomly selected agricultural specialists from out of sample. The questionnaire was refined and a revised final questionnaire was developed based on the feedback from the pilot test.

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Second, questionnaires were distributed to agricultural specialists in Bushehr province. Cronbach's alpha was used to assess the reliability for each scale and it is ranged from 0.67 to 0.88 (Table 2).

Table 2. Reliability of Scale Measures of the variables

Construct	Cronbach's Alpha
Perceived Usefulness	0.78
Perceived Ease of Use	0.88
Individual Innovativeness	0.85
Intention to Use	0.84
Attitude to Use	0.81
Attitude of Confidence	0.67

In each case, the reliability exceeds the critical value of 0.60 (Bagozzi & Yi, 1988). Data were analyzed using the LISREL software version 8.54. A LISREL type approach is appropriate to deal with the fit of the theoretical model to observed data (Gefen et al, 2000). Table 3 summarizes the definitions of the variables.

Table 3. Definition of the variables of the study

Variable	Reference	Definition
Attitude of confidence	Adrian et al. 2005	The confidence of a producer to learn and use precision agriculture technologies.
Individual innovativeness	Agarwal and Prasad 1998	Individual innovativeness is defined as "the willingness of an individual to try out any new technology".
		The belief that using a particular technology (precision agriculture technologies in this study) will be free of physical and mental effort.
Perceived ease of use	Davis, 1989	The extent to which a person believed that the precision agriculture technologies were capable of being used advantageously and provided expected outcomes.
Perceived usefulness	Davis, 1989	The prospective specialist's positive or negative feeling about the

		adopting precision agriculture technologies.
Attitude to use	Taylor and Todd, 1995	Specialist's intention to extension precision agriculture technologies among farmers.
Intention to use	Phillips, 1994	

Results

Descriptive statistics

The descriptive statistics of variables are in table 4. The mean of the variables are above 3 and shows the sympathetic opinion of specialists regarding variable-rate application technologies. Based on the table, intention to use received highest mean (4.45). Also, attitude to use is the second rank (4.38).

Table 4. Descriptive statistic of variables in the study

Variable	Mean	Std. Deviation
Intention to Use	4.45	0.34
Attitude to Use	4.38	0.37
Perceived Usefulness	3.78	0.28
Perceived Ease of Use	3.58	0.48
Individual Innovativeness	3.72	0.43
Attitude of Confidence	3.35	0.38

Model's goodness-of-fit

Measurement model

The proposed model was evaluated using Structural Equation Modeling (SEM). SEM comprises two aspects: the structural model in which hypothesized structural relationships between latent variables can be specified and tested, and the measurement model in which hypothesized relationships between latent variables and the observed variables designed to measure them can be specified and tested. SEM can also be used to test hypothesized structural relationships between observed variables, as in traditional path analysis (Marklaxcfnd, 2006). SEM used as traditional path analysis in this survey and tested model evaluation (the goodness-of-fit) and structural model.

Table 5 shows the results of goodness of fit measures. The measurement model test presented a good fit between the data and the proposed measurement model. The chi-square statistic divide to degree of freedom was not significant (0.51). The computation of NFI1, NNFI2, CFI3, GFI4 and AGFI5 statistics are above 0.90 criteria that recommended by Gefen et al. (2000) and Marklaxcfnd (2006). RMR6 and RMSEA7 are two goodness-of-fit measures, too. RMR shows assessing the residual variance of the observed variables and how the residual variance of one variable correlates with the residual variance of the other items and its measure recommended ≤0.05 (Gefen et al., 2000 and Markland, 2006) and it is 0.02 in this survey. The results showed that the goodness of fit indices such as χ^2/df, NFI, NNFI, CFI, GFI, AGFI, RMR and RMSEA are acceptable (table 5)

Table 5. Model evaluation overall fit measurements

goodness of fit measure	Measure recommended*	Results in this survey
chi-square/degree of freedom (χ^2/df)	≤3	1.12
p-value	≥0.05	0.63
Normed Fit Index (NFI)	≥0.90	1.13
Non-Normed Fit Index (NNFI)	≥0.90	0.96
Comparative Fit Index (CFI)	≥0.90	1.11
Goodness-of-fit (GFI)	≥0.90	0.92
Adjust Goodness-of-fit (AGFI)	≥0.90	0.94
Root Mean square Residual (RMR)	≤0.05	0.02
Root Mean Square error of Approximation (RMSEA)	≤0.1	0.03

Source: Gefen et al., 2000; Marklaxcfnd, 2006

Correlation coefficients between variables

Table 6 shows the correlation coefficients between the variables of the model. The correlations of the two central variables of TAM are positive and significant. The variable of individual innovativeness has significant relations with intention to use (r=0.54; p<0.01), perceived usefulness (r=0.46; p<0.01), perceived ease of use (r=0.54; p<0.01) and attitude to use (r=0.41; p<0.01) variables. The correlation coefficients between attitude of confidence with intention to use (r=0.23; p<0.01), perceived usefulness (r=0.31; p<0.01) and perceived ease of use (r=0.56; p<0.01) are significant. Attitude to use has the highest correlation with intention to use (r=0.68; p<0.01)

[1] *Normed Fit Index*
[2] *Non-Normed Fit Index*
[3] *Comparative Fit Index*
[4] *Goodness-of-fit*
[5] *Adjust Goodness-of-fit*
[6] *Root Mean square Residual*
[7] *Root Mean Square error of Approximation*

Table 6. Correlation coefficients of variables

	Intention to Use	Attitude to Use	Perceived Usefulness	Perceived Ease of Use	Individual Innovativeness	Attitude of Confidence
Intention to Use	1.00					
Attitude to Use	0.68**	1.00				
Perceived Usefulness	0.56**	0.48**	1.00			
Perceived Ease of Use	0.44**	0.36**	0.41**	1.00		
Individual Innovativeness	0.54**	0.41**	0.46**	0.54**	1.00	
Attitude of Confidence	0.23**	0.06	0.31**	0.56**	0.56**	0.16*

Structural model

Results and discussion

We see in fig. 3, that attitude of confidence has direct effect on perceived usefulness (γ= 0.34, p<0.05). Attitude of confidence has positive and direct effect on perceived ease of use (γ= 0.30, p<0.01) and attitude to use (γ= 0.12, p<0.05) of precision agriculture technologies. These are consistent with H1, H2 and H3. Adrian *et al*. (2005) indicated that attitude of confidence has direct effect on perceived ease of use of precision agriculture.

The attitude of confidence has direct effect on intention to use (γ= 0.15, p<0.05). This variable has an indirect effect on intention to use of precision agriculture technologies through attitude to use (fig. 34). This is consistent with H4. Adrian *et al*. (2005) indicated that attitude of confidence has indirect effect on intention to use precision agriculture through perceived usefulness and perceived benefit.

Fig. 3 shows that the variable individual innovativeness has significant direct effect on all dependent variables. We see that path coefficients between individual innovativeness and perceived ease of use (γ= 0.36, p<0.01), perceived usefulness (γ= 0.27, p<0.01), attitude to use (γ= 0.27, p<0.01) and intention to adoption (γ= 0.17, p<0.05) of precision agriculture technologies are significant (table 5). The results are consistent with H5, H6, H7 and H8. The importance of characteristics of innovation to adoption is emphasized (Rogers, 1995). Rezaei-Moghaddam & Salehi (2010) showed that individual innovativeness has direct effect on perceived ease of use, perceived usefulness, attitude to use and intention to extension of grid soil sampling technologies. Totally, the variables attitude of confidence and individual innovativeness accounted for 24 percent of changes in on perceived ease of use of precision agriculture (SMC=0.24).

Perceived ease of use positively and direct effect on attitude to use (β= 0.20, p<0.05) and perceived usefulness (β= 0.20, p<0.05). The results are consistent with H10 and H9.

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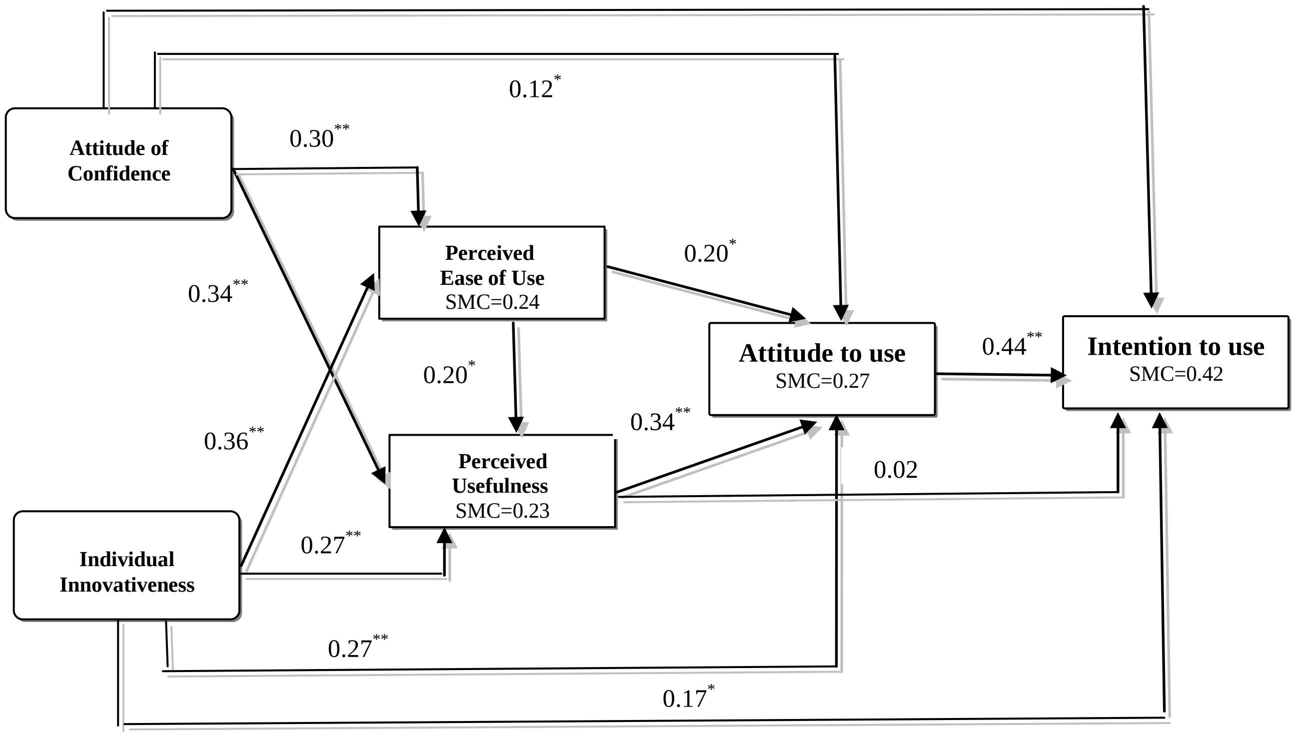
Perceived ease of use has not direct effect on intention to use of precision agriculture technologies. This is not consistent with H11. However, perceived ease of use indirectly affect on intention to use through attitude to use and also through perceived usefulness and attitude to use (fig.4). The direct effect of perceived ease of use on perceived usefulness is in accord with the findings of Fu *et al*. (2006) and Lee *et al*. (2007). Also, the results of Wu & Wang (2005) and Fu *et al*. (2006) indicated that perceived ease of use has indirect effect on behavioral intention to use through perceived usefulness. The variables attitude of confidence, individual innovativeness and perceived usefulness accounted for 23 percent of changes in on perceived usefulness of precision agriculture (SMC=0.23).

Perceived usefulness has positive direct effect on attitude to use (β= 0.34, p<0.01). This is in accord with H12. Perceived usefulness has not direct effect on intention to use. But, this variable through attitude to use has indirect effect on intention to adoption of precision agriculture technologies (fig.3). Lee *et al.* (2007) showed that perceived usefulness has significant effect on attitude to use. The results of Adrian *et al*. (2005) showed that perceived usefulness positively has indirect effect on intention to adopt precision agriculture through perceived net benefit. But this variable has not direct effect on intention to use (Adrian *et al*., 2005).

Fig. 3 shows that attitude to use has the highest effect on intention to use (β= 0.44, p<0.01) of precision agriculture technologies. This is consistent with H140. Lee *et al*. (2007) showed that attitude is an important determinate to use of technology.

The variables attitude of confidence, individual innovativeness, perceived usefulness and perceived ease of use accounted for 27 percent of changes in on attitude of use of precision agriculture (SMC=0.27). Totally, the variables attitude of confidence, individual innovativeness, perceived usefulness, perceived ease of use and attitude of use accounted for 42 percent of changes in intention of use of precision agriculture (SMC=0.42).



*: significant in p<0.05 **: significant in p<0.01

Fig. 3. SEM analysis for PAT

Conclusion

Sustainable agriculture not only manages the use of sources for human food provision but also preserves the quality of environment and increases natural resources reservoirs. It confirms that the nature should not be neglected and agriculture products must be increased with regard to the environment so that the production process will continue in to the future. Among modern and useful technologies, application of precision agriculture technology is precise management of farming based on information and internal knowledge and production inputs. It only considers use of inputs when required and based on site specific management.

This study applied the TAM as a basis to investigate the attitude and intention to use of precision agriculture technologies by Iranian agricultural specialists. We integrated the variable of individual innovativeness in addition attitude of confidence to this model. General findings of this study indicated that our model accounted for major part of the variance in intention to use of precision agriculture technologies.

Attitude to use is the most determinant of intention to use of precision agriculture technologies. Various studies have shown that an antecedent to use or decision to adoption is suitable attitude toward new technology. Perceived ease of use and perceived usefulness of technology are important to change users' attitude. Also, we showed that experts who indicated confidence about using and learning precision agriculture technologies have greater intention to use these technologies.

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This study developed a technology acceptance model adding individual innovativeness and attitude of confidence to the technology acceptance model. Thus, a more comprehensive study is suggested using this model, and future studies to evaluate the completed variables.

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