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The Possibility of Using Unmanned Aerial Vehicles in Agricultural Activities in Turkey

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IN THIS study, the perceptions and attitudes of farmers towards drone use and the variables that affect their intention to use drones in two provinces in the Southeastern Anatolia region of Turkey were investigated. The main purpose of this study is to determine the hidden variables that may affect the intention to use unmanned aerial vehicles, which have been used in agricultural activities by some farmers in the region in the last few years and are expected to become widespread rapidly. For this purpose, the Technology Acceptance Model (TAM) was used as the primary reference to predict adoption intention. A proportional sample size was used to determine the number of surveys, and the survey was conducted with 249 producers.The study was conducted between September 2022 and January 2023 in Mardin and Şanlıurfa provinces located between 37°50›–41°54› east longitude and 36°40›–38°12› north latitude in the Southeastern Anatolia Region of Turkey.A structural equation model (SEM) was used for basic data analysis. As a result of the results obtained, it was determined that the perceived usefulness and perceived economic benefit had significant effects on the intention to use the drone, on the contrary, the perceived ease of use and trust attitude did not affect the intention to use. Furthermore, the possibility of reducing workload, enhancing productivity, and lowering expenses appeared to be the most significant factors influencing drone adoption intention. The results showed that spraying and fertilization activities using drones are more beneficial in terms of crop productivity and labor force reduction compared to traditional methods. As a result, it has been suggested that legal arrangements should be made to include drones in machinery and equipment support given by the state to encourage the use of drones and to expand the use of unmanned aerial vehicles in agricultural activities.

Keywords: Drones,perceived usefulness, structural equation model, sustainability, technology acceptance model

Introduction

Precision farming practices, which can assist farmers in making better decisions, have advanced greatly in recent years, with the global industry expected to reach $43.4 billion by 2025 (Pinquet, 2021). Precision Agriculture is a form of production consisting of strategies and technologies that provide resource use efficiency by analyzing temporal, spatial, and individual data, reducing externalities arising from production, and implementing environmentally friendly practices (Bozdoğan et al., 2016; Michels et al., 2021). One of the precision agriculture technologies used in agricultural production today is unmanned aerial vehicles known as drones. Drone technologies are an important innovation with the potential to transform traditional manual activities in agricultural operations. Drones with simple technical structure and easy use; offers farmers the opportunity to plan agricultural activities by creating three-dimensional images with images captured in high resolution with the sensors and camera placed on them (Türker et al., 2020). In addition, thanks to the variable rate application, it can fertilize, spray, and plant

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in the amount of field-specific need, and it has the opportunity to perform the operations as desired during the applications thanks to the developed sensor and control systems (Özgüven, 2018).

Although the use of aircraft for agricultural activities began in 1921 with the US Department of Agriculture's use of aircraft to deliver pesticides in collaboration with the US Army Combat Corps' research station in Ohio, it concerned uncontrolled aircraft from the ground. It has been reported that the rapid spread of unmanned aerial vehicles in agricultural production started in 2011 (Frankelius et al., 2019). Studies have shown that drones can be used for many purposes in agricultural activities. With the help of drones, site-specific information can be collected and predictions can be made about plant growth and yield. In addition, information can be collected on topics such as disease and weed detection, soil health, water stress, and animal movements (Candiago et al., 2015; Rani et al., 2019; Daponte et al., 2019; Pathak et al., 2020). Despite all these advantages, the disadvantages of drones used in agricultural activities are that they cannot be used in case of rain and strong winds, their battery life is insufficient and they are adversely affected by signal cutters in areas close to military areas.

The adoption of new technologies in agriculture can help businesses succeed financially and expand, but producers' perspectives on innovation can vary. For this reason, it is very important to understand the reasons for the behavior shown for acceptance or resistance to change. Innovations with obvious economic benefits for manufacturers adequately explain the manufacturer's behavior towards adoption, as they are easy to adopt without other intervening considerations (Sinden and King, 1990). However, since farmers' adoption of new technology is not entirely dependent on measurable objective factors (Diederen et al., 2003), the most important factor affecting the adoption process is their perceived benefit for innovation. Therefore, understanding the perceptions and beliefs of farmers helps more to determine their perspectives towards technology.

This article aims to determine the perceptions and attitudes of farmers towards the use of drones and the factors affecting the adoption process in the Southeastern Anatolia region, which is one of the important agricultural production centers of Turkey. For this purpose, Davis (1989)'s Technology Acceptance Model (TAM), which is one of the most frequently used models in studies on the use of information and technology systems, was used. TAM is made up of the latent variables of perceived usefulness and perceived usability, which are anticipated to affect people's intentions to utilize new technology or applications and, eventually, their actual adoption choice. TAM is superior to other models because it has higher generality in technological acceptance, as well as the existence of crucial psychological aspects in shaping behavior in this theory (Jimenez et al., 2021). Many researchers have focused on explaining and predicting people's behavior to accept new technology and information using TAM. For example, Cakirli Akyüz and Theuvsen (2020) presented an overview of farmers' perceptions by comparing the behavioral intentions of traditional and organic grape producers in Turkey. Combining the basic elements of the Planned Behavior Theory and the technology acceptance model, it was concluded that organic agriculture was perceived as a beneficial, low-cost innovation by traditional farmers. Ronaghi and Ronaghi (2021), using the TAM model, investigated the factors affecting the adoption of augmented reality technology in the Iranian agricultural sector, and the results showed that the variables of public participation and education have a significant effect on the acceptance of augmented reality technology among farmers at all levels. In the study conducted by Verma and Sinha (2018) in the northern states of India to determine the important factors affecting the adoption of mobile-based agricultural extension services based on the technology acceptance model; The causal link between perceived utility, perceived usability, social effect, attitude, perceived economic well-being, and behavioral intention was empirically tested using structural equation modeling. The results showed that social influence affects attitude, ease of use, perceived economic well-being, and perceived usefulness, but not behavioral intention. Zuo et al., (2021), in their study examining the adoption of drone technology by irrigators in the Murray-Darling Basin in southern Australia, found that one-third of irrigation farmers plan to use drones in the next five years and that the adoption of drone technologies when irrigation can achieve tangible benefits such as labor and water savings. He said it was more likely. In the study by Caffaro et al., (2020) in Italy, the factors driving the intention to adopt smart farming technologies were evaluated in a group of farmers. The results of this study showed that perceived benefit affects farmers' intention to adopt smart farming technologies. In a study conducted in Colombia, Valencia-Arias et al. (2022) investigated the factors associated with the adoption of drone delivery of products during the covid-19 outbreak, and the results of the study using the TAM model showed that performance risk, compatibility, personal innovation, and environmental friendliness had the greatest impact on the intention to use drone delivery.

By evaluating the characteristics influencing farmers' adoption of drones for agricultural applications, this study provides recommendations for both enterprises and future academic investigations. Due to the scarcity of studies on the subject in Turkey, it is hoped that the findings will serve as a model for policymakers to use in agricultural extension studies, providing detailed information about farmers' drone adoption, and can also be used as a resource in academic studies.

Theoretical framework and hypothesis

TAM served as the main source of information for this study's construction and empirical assessment of a model intended to forecast farmers' intentions to use drone technology. TAM theorizes that perceived usefulness (Pu) and perceived ease of use (Peou) are key determinants of users' intention to use any new technology or innovation (Davis, 1989). Pu can be expressed as the degree to which an individual believes that implementing a particular technology will improve their job performance, while Peou is the degree to which an individual believes a particular technology will be effortless and easy to use. The hypotheses for drone use intention and actual adoption in the research are presented below (Figure 1).

H1: Confident attitude towards drone use (Pca) is effective on perceived ease of use (Peo).

H2: Drones' perceived ease of use (Peou) influences their perceived usefulness (Pu).

H3: The perceived usefulness (Pu) of drones influences the perceived economic benefit (Peb).

H4: The perceived economic benefit (Peb) of drones influences intention to use them in agricultural (Iou).

H5: Drones' perceived usefulness (Pu) affects their intended use in agriculture (Iou).

H6: The perceived ease of use (Peou) of drones influences the intention to use in agriculture (Iou).

H7: Confident attitude toward drone use (Pca), influences intention to use drones in agriculture (Iou).

H8: The intention to use drones in agriculture (Iou) has a beneficial impact on their practical adoption.

Materials and methods

Materials

The main material used in the study consists of data obtained through questionnaires from producers producing field crops in the provinces of Mardin and Şanlıurfa, two important agricultural production centers in Turkey's Southeastern Anatolia Region (Figure 2). The proportional

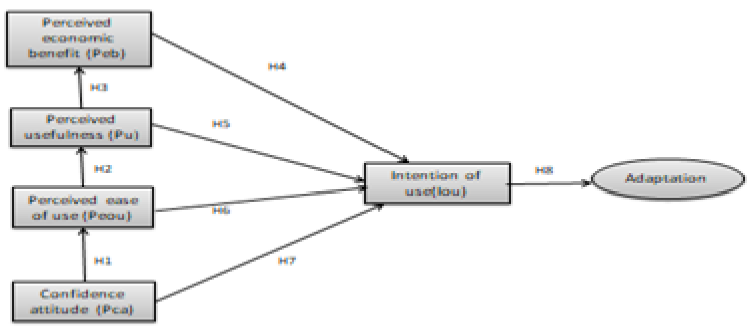

Fig. 1. Research model and hypothesis.

sample size was used to determine the number of surveys. The sample volume for a finite population based on the known or expected proportion of persons with a given trait is as follows. The P-value is the number of parts of the population that have a particular trait. P=0.5 should be taken to reach the maximum sample volume. Values of P less than or higher than 0.5 reduce the sample volume. For this reason, P=0.5 should be taken as working with the maximum sample volume

$$n = \frac{N * p(1-p)}{(N-1)\sigma_p^2 + p * (1-p)}$$

will reduce the possible error in cases where P is unknown (Aksoy and Yavuz, 2012).

In the formula; n= sample size, N= population size, p= proportion of manufacturers using drones (for 0.5 maximum sample size), σp2 = variance of ratio (with 95% confidence interval and 5% margin of error). As a result of the calculation, the sample size was determined as 249. The distribution of the survey numbers to the provinces was determined proportionally based on the number of producers in each province.

Methods

The questionnaire form used in the research was derived from Michels et al., (2021), but some sections were redesigned considering that the producers in the research area would not understand some expressions. From September 2022 until January 2023, the surveys were sent to the producers online through social media groups, leading farmers, and farmers' unions in the provinces. In the same period, face-to-face surveys were conducted in the provinces mentioned by the researcher. The questionnaire form consists of two parts, and in the first part, it consisted of 16 items about the use of drones by farmers, and a 5-point Likert scale was used to measure the level of participation in each item. In this section, '1' means the least agreeing with the given statement, and '5' means agreeing at the highest level. The second part consisted of open and closed-ended questions to obtain information about the demographic characteristics of the farmers and their businesses.

Data analysis

The structural equation model (SEM) was used for the basic data analysis of the research. SEM is a method that combines factor analysis and multiple regression analysis. Measurement reliability and validity were evaluated with Cronbach's α, average variance extracted (AVE), composite reliability (CR), and confirmatory factor analysis. Cronbach's alpha values above 0.7

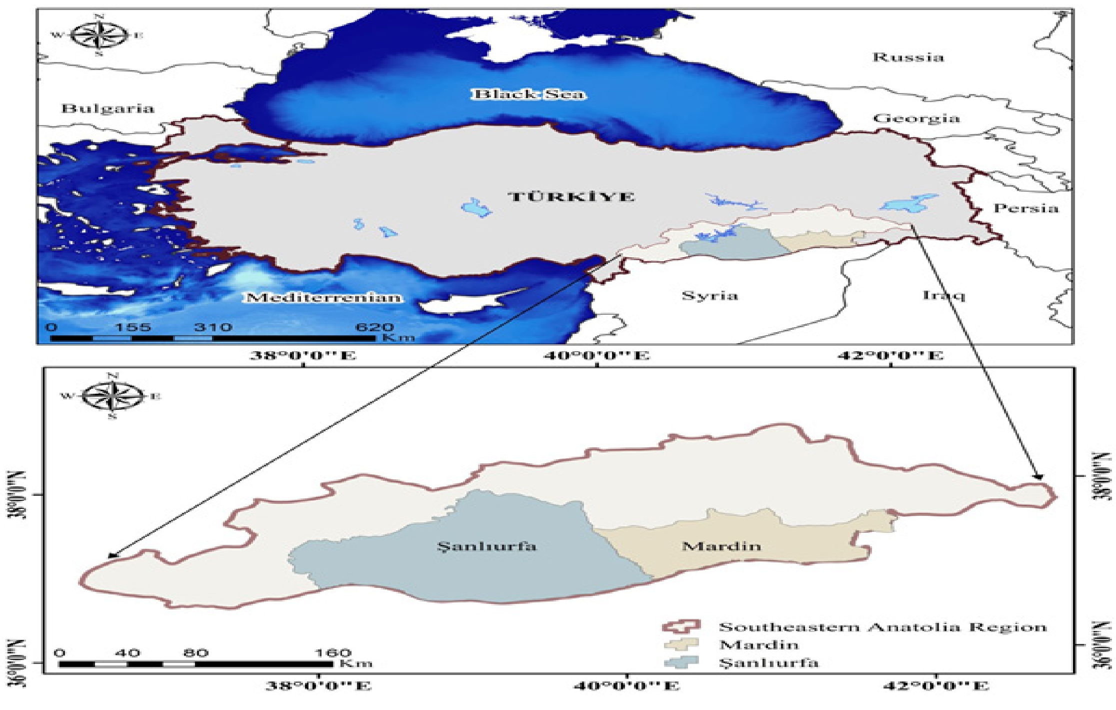

Fig. 2. Location of the study area.

are generally considered satisfactory, but values between 0.7 and 0.6 are also acceptable (Gliem and Gliem, 2003). Data analyzes were performed using statistical software packages SPSS and AMOS. The data was described using frequency, percentage, mean, and standard deviation. R^2, path coefficients, and their significance levels were also examined in the evaluation of the theoretical models.

In the evaluation of the model goodness of fit, the ratio of chi-square to degrees of freedom (X^2/DF), root mean square approximation error (RMSEA), comparative index of fit (CFI), incremental fit index (IFI), the goodness of fit index (GFI), normed fit index (NFI), non-normed fit index (TLI), and adjusted goodness-of-fit index (AGFI) were used. Hu and Bentler (1999) suggested that the CFI value should be greater than 0.95 and the other criteria should be greater than 0.90. Schumacker and Lomax (2004) suggest that values between 1-5 for X^2/DF and values approaching 0.95 for GFI and NFI will provide a good fit. The data analysis results showed that the model goodness of fit was achieved (Table 1).

Results

Descriptive analysis

In the first part of the study, the demographic characteristics of the producers, which are known to affect their acceptance of new information and technologies, were examined and the descriptive analysis results are given below (Table 2). 91.2% of the producers in the sample are male and 8.8% are female. It is estimated that the rate of female farmers remains very low as agricultural activities are carried out mostly by men due to the patriarchal structure in the research area and the lands are generally shared among men. The average age of the producers is 41.1, the producer with the highest age is 78 and the lowest is 20 years old. 27.7% of the surveyed producers stated that they used unmanned aerial vehicles for agricultural purposes in the previous production season. It is known that the educational status of the producers is effective in the adoption of new applications and technologies, and people with a high level of education adopt innovations earlier (Rogers, 1995; Kaynak and Boz, 2015). It was determined that 43.4% of the producers in the sample were high school graduates, primary school graduates were determined 28.1%, university graduates 20.5%, and secondary school graduates 8.0%. As a result of the chi-square analysis, it was determined that there was a significant difference between the use of unmanned aerial vehicles for agricultural purposes and the level of education (p=0.000), and the level of drone use increased as the level of education increased. While the average farm size in Turkey is 5.9 hectares (Ertunç and Janus, 2021), the average land size in the examined businesses is 26.4 hectares. The average land size in the Southeastern Anatolia Region, which is the research area, has been reported as 10.4 hectares (Malaslı et al., 2015). The land size of the enterprises in the sample is above the average of both Turkey and the region, since almost all of the examined enterprises produce field crops in the plains, and the lands in these regions are less fragmented and large-scale than the enterprises producing horticultural crops. All of the enterprises produce field crops (wheat, barley, corn, lentils, etc.) and it was determined that some producers (11.2%) also cultivate peanuts and grapes. While the average agricultural experience of the farmers was 19.5 years, 52.2% of those with social security and 36.9% of those with non-agricultural income were determined. While 73.9% of the producers used social media applications, 55.8% reported that they were members of at least one of the agricultural groups in social media.Pictures of drones with a capacity

TABLE 1. Results of model fitness test.

Goodness-of-fit index	**X^2/DF**	**RMSEA**	**CFI**	**IFI**	**GFI**	**NFI**	**TLI**	**AGFI**	**SRMR**
Criteria	<5	<0.10	>0.95	>0.90	>0.95	>0.95	>0.90	>0.80	<0.080
Analysis results	1.896	0.060	0.982	0.982	0.917	0.963	0.978	0.884	0. 023

TABLE 2. Results of descriptive analysis (n=249).

Variable	Mean	SD	Min.	Max
Gender (1: Male, 0: Female)	0,91		0	1
Age	41,1	12,8	20	78
Education level (1: primary school, 2: middle school, 3: high school, 4: university)	2,6		1	4
Land size (hectare)	26,4	23,2	1	250
Agricultural experience (years)	19,5	12,9	2	60
Having social security (0: no, 1: yes)	0,52	0,5	0	1
Having non-agricultural income (0: no, 1: yes)	0,37	0,48	0	1
Social media use case (0: no, 1: yes)	0,74	0,44	0	1
Membership in agricultural groups on social media (0: no, 1: yes)	0,56	0,49	0	1
Use of drones in agricultural activities (0: no, 1: yes)	0,28	0,45	0	1

SD: Standart deviation.

Fig. 3. Pictures of drones with a capacity of 30 litres used in the research area.

of 30 litres used in the research area are shown in Figure 3.

Reliability and validity analysis

The reliability and validity of the measurement model were performed by factor analysis, Cronbach's α, average variance extracted (AVE), and composite reliability (CR) (Table 3). Cronbach's α value was greater than 0.7 for all latent variables. The lowest AVE value was determined as 0.592 for perceived ease of use (Peou), but higher values were obtained for all latent variables than the critical value (0.5), which is the convergent validity required for structural equation. This means that the latent variable captures more than 50% of the variance of the indicators. Since the indicator loads are above 0.7 for all indicators in the model, the latent variable can explain the average of more than half of the variance of the indicators (Purwanto&Sudargini, 2021). The CR value was also above the critical value of 0.7 for all latent variables, and the lowest CR value was measured as 0.836 for Peou.

Structural equation model analysis

When the research model and analysis results are examined (Table 4 and Figure 4), the attitude of trust has a statistically significant β: -0.951; p<0.01; R^2: 0.704) effect on perceived ease of use. Therefore, the H1 hypothesis is accepted and it can be stated that people with a high self-confidence attitude towards the use of unmanned aerial vehicles have a high perception of using them. The H2 hypothesis shows that perceived ease of use has a positive effect on perceived usefulness (β: 0.929; p<0.01; R^2: 0.664), and farmers can accept that their usefulness will be higher if they perceive drones as easy-to-use tools. As a result of the results obtained for the H3 hypothesis examining the effect of perceived

TABLE 3. Reliability and validity analysis results for the prediction model.

Latent variables	Mean	Standard deviation	Loading	Cronbach's α	CR	AVE
Perceived economic benefit (Peb)				0.949	0.971	0.816
Drones increase crop productivity (Peb1)	3.534	1.171	0.941***			
The cost of work done using drones can be reduced (Peb2)	3.426	1.098	0.905***			
Drones can increase profit (Peb3)	3.438	1.069	0.884***			
I think drones are cost-effective (Peb4)	3.590	1.286	0.884***			
Perceived usefulness (Pu)				0.971	0.986	0.879
Applications with drones give better results than other systems (Pu1)	3.534	1.307	0.914***			
Drones make the job easier (Pu2)	3.598	1.125	0.940***			
I can do jobs in my field faster using drone (Pu3)	3.554	1.173	0.957***			
Using drones can improve my work performance(Pu4)	3.554	1.124	0.941***			
I can diversify my work on the farm using a drone (Pu5)	3.566	1.065	0.936***			
Perceived ease of use (Peou)				0.741	0.836	0.592
I think drones are easy-to-use tools(Peo1)	3.317	1.128	0.809***			
It will be easy for me to learn to use a drone (Peo2)	3.385	1.101	0.728***			
Perceived confidence attitude (Pca)				0.894	0.941	0.741
I think using a drone is complicated and difficult(Pca1)	2.767	1.202	0.879***			
It is difficult for me to use a drone (Pca2)	2.671	1.162	0.875***			
I think I am not a farmer who is good at working with digital tools like drones (Pca3)	2.590	1.100	0.828***			
Intention of use (Iou)				0.951	0.973	0.905
I'm considering using drones in the near future (Iou1)	3.755	1.185	0.957***			
I want to use drone in my agricultural activities (Iou2)	3.731	1.152	0.946***			

***p <0.001, Criteria: Loading > 0.7, CR > 0.7, AVE > 0.5

On a 5-point likert scale (1 = strong disagreement; 5 = strong agreement)

TABLE 4. SEM analysis results.

Hypothesis			□	S.E.	C.R.	R^2	P	Hypothesis result
(H1) Peou	<---	Pca	-0,951	0,059	-11,914	0,704	***	Accept
(H2) Pu	<---	Peou	0,929	0,116	12,191	0,664	***	Accept
(H3) Peb	<---	Pu	0,974	0,036	24,977	0,749	***	Accept
(H4) Iou	<---	Peb	0,532	0,163	3,287	0,653	***	Accept
(H5) Iou	<---	Pu	0,419	0,203	1,975		**	Accept
(H6) Iou	<---	Peou	-0,073	0,47	-0,219		0,826	Reject
(H7) Iou	<---	Pca	-0,112	0,222	-0,529		0,597	Reject
(H8) Adapt.	<---	Iou	0,47	0,023	8,129	0,221	***	Accept

□: : Standard path coefficients; S.E : Standart error; ***: P<0.0.01; **: P<0.05

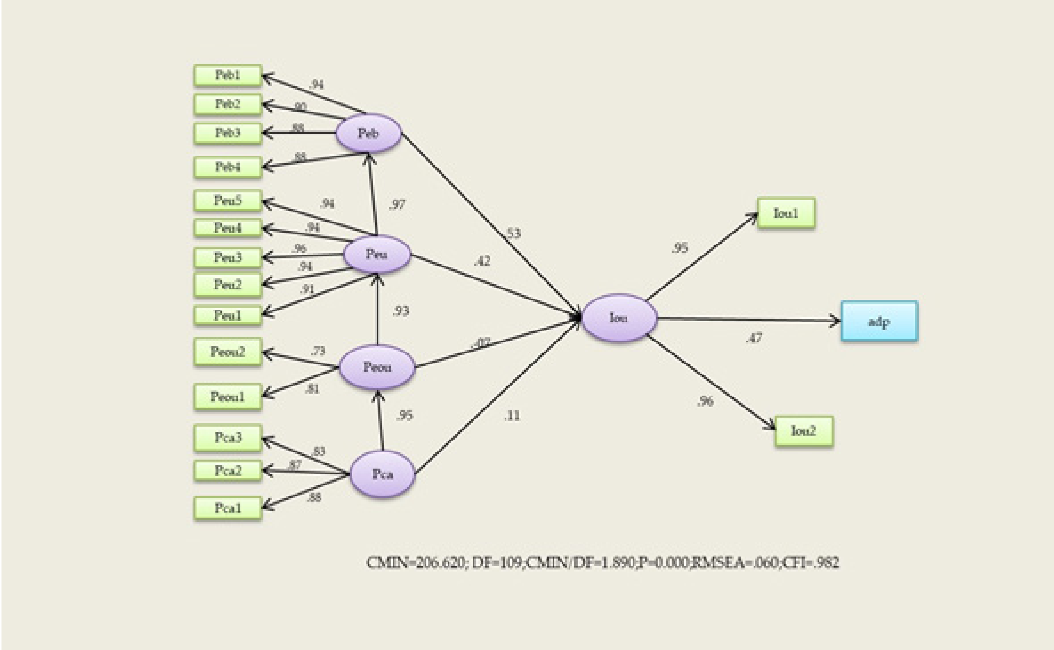

Fig. 4. Structural equation model.

usefulness on the perceived economic benefit (*β*: 0.974; p<0.01; R^2: 0.749), it was determined that the perceived usefulness of drones had a positive effect on the perceived economic benefit and the hypothesis was accepted. Hypotheses H4 and H5 examine the effect of perceived economic benefit and perceived usefulness on the intention to use drones. Path coefficients were determined as (β: 0.532; p<0.01) and (β: 0.419; p<0.05), respectively, and R^2 as 0.653.

Both hypotheses are accepted, so farmers who find the economic benefits and usefulness of drones high are more likely to use them. The H6 hypothesis examined the effect of perceived ease of use on intention to use, and the path coefficient was not statistically significant (β: -0.073 p=0.826), and the hypothesis was rejected. This result shows that although some farmers perceive drones as easy-to-use tools, they may not have the intention to use them. Likewise, the H7 hypothesis examined the effect of Perceived confidence attitude on intention to use and was rejected as statistically insignificant (β: -0.112 p=0.597). Finally, the H8 hypothesis examined the relationship between drone intention and actual use, and (β: 0.470; p<0.01; R^2: 0.221) it was determined that farmers with higher drone usage intention had higher adoption rates.

Discussion

As a result of the conclusions obtained from the study, it can be said that the latent variable with the highest average for the benefits of drones is Pu (3.561±1.10), and accordingly, it can be said that the farmers who use drones or intend to use drones consider the perceived usefulness of drones more important than their economic benefits. Among the observed variables, it was determined that the variable with the highest average is that the drones make the work easier (Pu2). Therefore, it was revealed that the level of usefulness of drone use in the activities performed was high for the farmers in the sample. Likewise, in terms of the economic benefit variable, the high average (3.497±1.07) revealed that factors such as the possibility of reducing workload, increasing productivity, and reducing costs were the most relevant issues affecting drone adoption intentions. The results obtained are in agreement with the results obtained from the studies of Pierpaoli et al., (2013) and Caffaro et al., (2020). The Pca → Peou result shows that farmers with high perceived confidence in drone use will perceive drones as easy tools. Michels et al., (2021), in their study on the use of drones by farmers in Germany, also revealed that there is a significant relationship between the attitude of trust and the perceived ease of use. However, although the same study found a correlation between perceived ease of use and intention to use, in our current study, it was determined that there was no significant relationship between Peou → Iou. This result can be interpreted that although some farmers perceive unmanned aerial vehicles as easy-to-use tools, they do not want to give up on traditional methods, or they do not want to use technology due to factors such as the lack of widespread use of it. Likewise, the lack of statistical significance between Pca → Iou showed that the farmers' trust attitudes towards drone use in the sample were not related to their intention to use.

Venkatesh and Davis (2000) stated that the less laborious the use of technology, the more work performance will be achieved by using it. The significant effect on Peou → Pu also shows that farmers who see drone use as less troublesome may see them as more useful tools, which is in line with the results of Rezaei et al., (2020) in their study in Iran. The relationship between Pu → Peb shows that farmers, who think that they can do their work on the farm faster and easier by using drones, believe that the economic benefit will increase. The variables that affect drone usage intention were Pu and Peb. Pu → Iou shows that perceived usefulness has an impact on intention to use, and the perception of drones as tools with high functionality and utility has a significant impact on their application. Ducey and Coovert (2016) reached a similar conclusion in their study. The Peb → Iou relationship shows that perceiving unmanned aerial vehicles as economic tools or believing that they will reduce costs or increase profits will have a positive effect on the intention to utilize them.

The producers included in the research stated that if they use their own unmanned aerial vehicles, the spraying and fertilisation activities carried out using drone technology compared to traditional agriculture save time and have a reducing effect on costs because they are carried out using less labor and the battery charging cost is very low compared to the fuel cost, and that the spraying activities using drone technology have positive effects on the yield. However, it was established that nearly 90% of the manufacturers employing drones in the research region do not own their own unmanned aerial vehicles, therefore the majority of them rent drones.

Conclusions

In a period when technological innovations and applications in agriculture spread rapidly, the variables affecting the intention to use drones in agricultural activities and the actual adoption in the Southeastern Anatolia Region, which is one of the important agricultural regions of Turkey, were examined. As a result of the study, it was determined that Peb and Pu had a positive effect on drone usage intention. Also, as expected, drone usage intention has a positive effect on actual adoption. It is estimated that the ease of use and the lack of confidence in Iou are due to the fact that the drones are not used by the farmers themselves in the research area. Because it is estimated that a significant part of the existing applications are made by companies that rent drones. To explain the economic and business benefits of unmanned aerial vehicles to farmers and to encourage the use of drones, it would be beneficial to add drones to machinery and equipment support. It has been determined that legal procedures regarding the use of drones, security problems in the research area, and signal cutters, especially near the Syrian border, restrict the use of drones. For this reason, it is necessary to make legal arrangements to popularize the utilization of drones in agricultural activities.

Ethics Approval

Ethics committee approval for the study was obtained with the approval of Mardin Artuklu University on 19.01.2023/81703.

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