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Farmers' Experiences with GNSS-Based Tractor Auto Guidance in Adana Province of Turkey

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Abstract: Auto Guidance (AG) systems offer many advantages for farmers including more accuracy, more efficiency and agricultural input savings. The adoption of AG systems is increasing in many countries. Also, their adoption rate is rising in Adana province and in other regions of Turkey. The aim of this study was to assess the experiences and satisfactions of 55 out of about 110 farmers who used AG systems in Adana using face-to-face interviews. A large portion of the farmers (34.5%) had a land area of 200-300 ha followed by 50-100 ha (23.6%). The most common (49.1%) GNSS signal correction method was RTK + CORS + GSM which requires annual subscription fee. Participant farmers used the AG system mostly in tillage (98.2%) followed by planting (47.3%) and fertilization (29.1%). Most of the problems (83.3%) they faced were related to hardware. The biggest benefits provided by the system were creating straight soil ridges (98.2%), flexible working hours (92.7%), time-savings (80.0%), fuel savings (80.0%) and labor savings (50.9%). The majority of the users were "Very satisfied" (81.8%) and "Satisfied" (16.4%) with the system. However, 96.4% of them did not use other Precision Agriculture (PA) technologies and the greatest reason (54.5%) was that they did not have any knowledge about them; thus, farmers need training on other PA technologies.

Keywords: Auto guidance, precision agriculture, survey, Adana, Turkey

Adana İlinde Çiftçilerin Uydu-Esaslı Traktör Otomatik Dümenleme Sistemi Deneyimleri

Öz: Otomatik Dümenleme (OD) sistemleri tarımsal işlemlerde çiftçilere yüksek hassassiyet, yüksek verim ve daha az tarımsal girdi kullanımı gibi birçok yarar sağlamaktadır. OD sistemlerinin kullanımı birçok ülkede artmaktadır. Türkiye'de Adana ilinde ve diğer bölgelerde kullanımı da artmaktadır. Bu çalışmanın amacı, Adana'da OD sistemleri kullanan yaklaşık 110 çiftçiden 55'i ile yüz yüze görüşerek çiftçilerin deneyim ve memnuniyet düzeylerini değerlendirmekti. Çiftçilerin büyük bir kısmının (%34.5) 200-300 ha ve 50-100 ha (%23.6) araziye sahip olduğu tespit edilmiştir. En yaygın (%49.1) GNSS sinyal düzeltme yöntemi yıllık abonelik ücreti gerektiren RTK + CORS + GSM sistemidir. Çiftçiler, OD sistemini en fazla toprak işleme (%98.2), ekim (%47.3) ve gübreleme (%29.1) işlemlerinde kullanmaktadır. Karşılaştıkları sorunların çoğunlukla (%83.3) donanımla ilgili olduğu belirlenmiştir. Sistemin sağladığı en önemli yararların, düz toprak sırtı oluşturma (%98.2), esnek çalışma saatleri (%92.7), zamandan tasarruf (%80.0), yakıt tasarrufu (%80.0) ve işgücü tasarrufu (%50.9) olduğu tespit edilmiştir. Kullanıcıların çoğunluğu sistemden "Çok memnun" (%81.8) ve "Memnun" (%16.4) olduğunu bildirmiştir. Bununla birlikte, katılımcı çiftçilerin %96.4'ü diğer Hassas Tarım (HT) teknolojilerini kullanmamaktadır ve bunun en büyük nedeninin (% 54.5) bu sistemler hakkında bilgi sahibi olmamalarıdır. Bu sebeple, çiftçilerin diğer HT teknolojileri üzerine eğitim almaları gerekli görülmektedir.

Anahtar Kelimeler: Otomatik dümenleme, hassas tarım, anket, Adana, Türkiye

1. Introduction

Technological improvements in agriculture result in better management applications leading to more precision in farm operations from planting to harvesting to reduce inputs, increase profits and protect the environment (Ess and Morgan 2003; Keskin and Görücü Keskin 2012; Keskin et al. 2017). Precision Agriculture (PA) comprises improved technologies such as soil sensing and mapping, yield mapping, global navigation satellite systems (GNSS), remote sensing, geographical information systems (GIS), variable rate application and auto steering (Ess and Morgan 2003).

Automatic Steering or Automatic Guidance (AG) of farm tractors and machinery dates back to the beginning of the twentieth century. One of the first methods of auto steering depended on the mechanical steering attachments (Willrodt 1924). The other methods developed later included electrical, geomagnetic, vision, mechanical, ultrasound and GNSS-based methods (Reid 2000) (Table 1).

Table 1. Automatic guidance methods for farm tractors and machinery
Çizelge 1. *Tarım traktörleri ve makineleri için otomatik dümenleme yöntemleri*

Method	Principle	Source
Mechanical	Sensing a tramline, hill, marker track or wheel track using a mechanical attachment	Willrodt, 1924
Electrical	Sensing a magnetic field around a buried wire by an antenna	Schafer & Young, 1979
Geomagnetic	Sensing the earth's magnetic field by a magnetometer	Reid 2000
Vision	Sensing the crop rows by a camera system	Fehr & Gerrish 1995
Ultrasonic	Sensing a tramline, crop row, hill, marker track or wheel track by an ultrasound sensor	Reichhardt, 2012
GNSS	Using a precise GNSS receiver to find the route	Reichhardt, 2012

Some researchers used electrical methods comprising antennas mounted near the front wheel of the tractor that sense the location of a buried wire excited by a low-current and low-frequency signal (Schafer and Young 1979). The geomagnetic method employs a geomagnetic direction sensor (GDS) which is a magnetometer that senses the earth's magnetic field and uses it as a heading sensor similar to an electronic compass (Reid 2000). The vision-based systems include a camera system that senses the crop rows and steers the tractor accordingly (Fehr and Gerrish 1995). The ultrasonic guidance works by utilizing an ultrasound sensor measuring distance from a tramline, row, hill, marker track or wheel track (Reichhardt 2012). However, the most common guidance method is the GNSS-based method that uses a GPS or GNSS receiver to steer the tractor or a self-propelled farm machinery such as combine harvesters. It is also possible to use two or more methods together in the frame of sensor fusion to increase the guidance accuracy (Reid 2000). The more advanced form of tractor guidance is the driverless tractors. Currently, prototype driverless tractors named field robots are under development and testing. This looks promising and one report estimates that driverless tractor market revenue would reach about $31 billion by 2024 (Kanicki 2016).

GNSS-based AG systems offer many advantages for farmers including more accuracy, higher operation speeds, easy operation, working at night, less affected by bad weather, reduced operator fatigue, low setup time, reduced overlapping, reduced skips, working without foam markers, and reduced inputs (fertilizer, pesticides, seeds, etc.) (Grisso et al. 2009).

Adoption of PA technologies are affected by many factors including personality and family structure of the farmer, education level, characteristics of the farms, farm size, affordability and profitability of equipment, characteristics of the technologies (complexity and compatibility), legal affairs, social interaction (fairs, exhibition and field days) and properties of the institutions offering support on these technologies (Keskin 2013; Say et al. 2017). Recent studies have shown

that the adoption of PA is in an increasing trend in developed countries while farmers in developing countries also started to adopt PA technologies in recent years (Say et al. 2017).

There have been some studies on the adoption rate of the AG systems. Norwood and Fulton (2009) stated that most common PA technologies were yield monitoring and automatic steering (32%) in the US. Leonard (2014) reported that 80% of the grain growers in Australia used AG. Erickson and Widmar (2015) reported that one of the most popular PA technologies was GPS guidance with auto control/steer (83%) in the US. Based on a survey study in the US, 74% of the participants used auto-steer on tractors, sprayers or combines (The Hale Group 2014). According to the reports by the USDA, over 40% of peanut farms and about 55% of rice farms used AG systems in the US in 2013 (USDA 2015a; USDA 2015b). In China, tractor AG was the most accepted technology in Heilongjiang Province (Verma 2015). Silva et al. (2011) reported that the first two most preferred PA technologies as satellite imaging (76%) and AG (39%) by the sugar and ethanol companies in the Sao Paulo state of Brasil. Say et al. (2017) reported that, in both developed and developing countries, AG is the most adopted in the last decade while yield monitoring and variable rate application was more dominant earlier.

In Turkey, cultivated area is large (24.5 million ha); however, the average farm size is only 5.9 ha which is much lower than EU and US averages (17.4 and 18.0 ha respectively) (Berk 2013). Although the use of technology increases in agriculture, the average size of farms is limited. In order to cope with the land fragmentation problem which hinders the productivity in agriculture, legal arrangements were made and projects are under way for land consolidation. In recent years, parallel to the rapid development of agricultural technologies, the adoption of GNSS-based AG systems is increasing in Adana province and in the other regions of Turkey. It was estimated that about 110 farmers used these systems in only Adana province as of the end of 2016. However, no study was reported on the satisfaction level of farmers on the AG systems in Turkey before. Therefore, the objective of this study was to assess the experiences and satisfaction level of farmers with the use of AG systems in the Adana province of Turkey using a face-to-face survey.

2. Methodology

The study was conducted in the Adana province of Turkey based on face-to-face interview questionnaire. Adana is one of the 81 provinces and located on the mid-south of Turkey (Fig 1). This province is one of the important agricultural areas in Turkey having a population of about 2.2 million people and a total agricultural land area of 498 705 ha that accounts for about 2% of the total cultivation area of Turkey (GTHB 2014). Most important crops include cereals (mainly wheat), cotton, corn, soybean, peanut, sunflower, olives, citrus, watermelons, vegetables, fruits and medicinal and aromatic plants. The region has a typical Mediterranean climate with warm and rainy winters and hot, humid and dry summers. Farmers in this region tend to use new agricultural practices including farm machinery technologies in their production.

Figure 1. The location of study area in Turkey
Şekil 1. *Çalışma alanının Türkiye'deki yeri*

The information provided by the face-to-face survey method from the farmers using the AG system in Adana province constituted the major data of this research. At the first stage of the study, a suitable questionnaire was developed. The questionnaire was mainly composed of questions that would determine the satisfaction level of the adopter farmers about the system. A questionnaire

with multiple choice questions was structured in six main sections:

1) Personal information (age, gender, education level, work experience, etc.)

2) General information (farm and job-related questions)

3) Questions on AG I (make, model, usage, problems, etc.)

4) Questions on AG II (economy, renting, subsidies, ROI, etc.)

5) Questions on utilization of other PA technologies

6) Questions on training for PA technologies.

After completing the first four sections, an informative 5-10 minute short introduction about PA technologies was made with the participants before the fifth and sixth section. To determine the satisfaction levels of farmers with AG system, respondents were asked the question "What is your satisfaction level about the system?" The farmers' response according to five-point Lickert scale ranged from "Very dissatisfied (1)" to "Very satisfied (5)".

The questionnaire study was carried out by cluster sampling method and conducted with 55 out of 110 adopter farmers (50% inclusion). The participants were selected from farmers using one of three different AG brands (Topcon, Trimble, John Deere) (the total number of farmers using the system in Adana was around 110 by the end of 2016). Then the research data were classified and evaluated. The frequency and descriptive analysis of the data and the calculations between the variables were carried out by using MS Excel and SPSS 22 programs.

3. Results and Discussion

The study was conducted with 55 participants using face-to-face survey method. The participants were AG adopter farmers. Table 2 shows the demographic profile and descriptive statistics of the target group. Majority of the farmers were in the age group of 21-30 (%34.5) followed by 31-40 (%21.9). All of the participants were male. It was observed that majority of the farmers had high school education (%40.0). The results regarding the work experience and cultivating crop type indicated that the majority of the farmers had 21-25 years (%23.6) experience and cultivating field crops (%65.5).

In the following sections of the survey, four general questions were asked to the participants in an attempt to determine their orientation toward new technologies (Table 3).

Table 2. Personal characteristics of the survey participants (n=55)
Çizelge 2. *Anket katılımcılarının kişisel özellikleri (n=55)*

Characteristic	Value	*f*	%
Age (years)	21-30	19	34.5%
	31-40	16	29.1%
	41-50	12	21.8%
	51-60	8	14.5%
		55	**100%**
Gender	Male	55	100.0%
	Female	0	0.0%
		55	**100%**
Education level	Primary school	13	23.6%
	Secondary school	12	21.8%
	High school	22	40.0%
	University degree	8	14.6%
		55	**100%**
Work experience (years)	<10	8	14.5%
	11-15	12	21.8%
	16-20	6	10.9%
	21-25	13	23.6%
	26-30	6	10.9%
	>31	10	18.2%
		55	**100%**
Cultivating Crop type	No cultivation (Renting only)	3	5.5%
	Field crops	36	65.5%
	Horticultural crops	1	1.8%
	Both field and horticultural crops	15	27.3%
		55	**100%**

Primarily, the participants were asked if they follow new trends in agriculture. All the participants (100%) gave positive answer. The current competitive environment in the region could be a major factor that forces farmers to keep up with innovations to increase the productivity, efficiency and profit. The first three most widely preferred sources for following new technologies were agricultural fairs (94.5%), internet (87.3%) and TV (63.6%). All participants stated that they attend national agricultural fairs while 27.3% of them visit international agricultural fairs as well (Table 3). A large portion of the farmers (34.5%) had a land area of 200-300 ha followed by 50-100

ha (23.6%). Farmers who do not have agricultural land (3.6%) consist of people who bought the system and provided renting services to other farmers for mainly soil tillage and preparation.

In addition, approximately half of the users (47.3%) had 6 or more farm tractors (Table 4). Farmers use the auto guidance systems on relatively larger tractors with a power of more than 90 HP (66 kW) since they use these systems mainly for soil tillage and this work requires tractors with higher power ratings. 23.6% of the participant farmers had self-propelled machinery (53.8% cotton picker, 15.4% combine harvester and 15.4% peanut thresher).

Table 3. Farmers' orientation towards new agricultural trends and technologies
Çizelge 3. *Çiftçilerin tarımdaki yeni konu ve teknolojilere yönelimi*

Question	Answer	*f*	%
Do you follow new trends in agriculture?	Yes	55	100.0%
	No	0	0.0%
		55	**100%**
Which sources do you use? (Multiple answers allowed)	Agricultural Fairs	52	94.5%
	Internet	48	87.3%
	TV	35	63.6%
	Other farmers	28	50.9%
	Other	10	18.1%
Do you attend national ag fairs?	Yes	55	100.0%
	No	0	0.0%
		55	**100%**
Do you attend international ag fairs?	Yes	15	27.3%
	No	40	72.7%
		55	**100%**

Around two-thirds of the users (63.6%) stated that they used the system for about a year while 83.6% farmers had only one system (Table 5). A significant part of the farmers (70.9%) stated that they obtained the information about the AG system from other farmers who already used the system. Currently, farmers use three different GNSS signal augmentation methods in the province (Fig 2).

The most common (49.1%) method was RTK + CORS + GSM method which requires an annual subscription fee (100-300 USD depending on the quality and service provider) (Table 5).

The second common method (29.1%) was Satellite Based Augmentation System (SBAS) which also requires annual subscription (250-800 USD depending on the quality and service provider). The least used method (21.8%) was Real Time Kinematic (RTK) method which requires an additional GNSS receiver which is setup near the field and sends correction signals. The pass-to-pass accuracy of these methods are 2-30 cm for RTK + CORS + GSM and 10-30 cm SBAS and 2 cm for RTK systems (Topcon 2016).

Concerning the purpose of AG system usage, all participants stated that they used the AG system in tillage (98.2%) (Fig 3) followed by planting (47.3%), fertilization (29.1%) and spraying (21.8%). It was observed that the purpose of AG usage changed before and after purchase (from 30.9% to 47.3% in planting, 16.4% to 29.1% in fertilization and 10.9% to 21.8% in spraying) (Fig 3).

Table 4. Farm characteristics of the participant farmers
Çizelge 4. *Ankete katılan çiftçilerin çiftliklerine ait özellikler*

Characteristic/ Question	Value	*f*	%
Total field size (ha)	0*	2	3.6%
	10.1-50.0	9	16.3%
	50.1-100.0	13	23.6%
	100.1-200.0	10	18.2%
	200.1-300.0	19	34.5%
	>300.0	2	3.6%
		55	**100%**
Number of Tractors	1	1	1.8%
	2	4	7.3%
	3	12	21.8%
	4	5	9.1%
	5	7	12.7%
	>5	26	47.3%
		55	**100%**

* Purchased the AG system for renting only

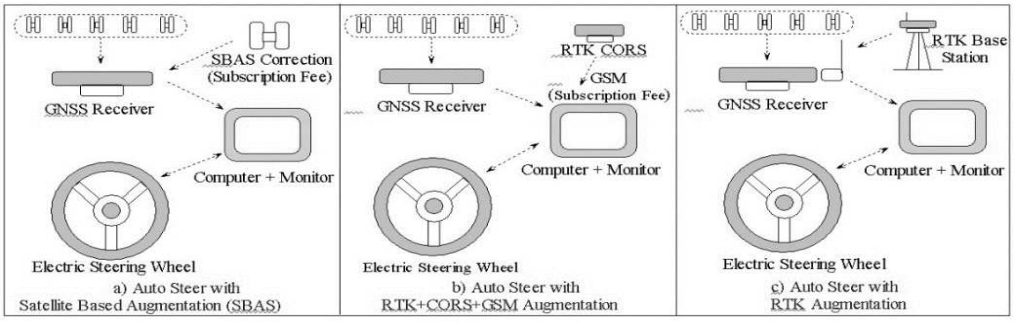

Figure 2. Different GNSS augmentation systems used in the Automatic Guidance (AG) systems
Şekil 2. *Otomatik Dümenleme (OD) sistemlerinde kullanılan farklı sinyal düzeltme yöntemleri*

This means that some farmers figured out that the system was more useful in planting, fertilization and spraying after they purchased system. The vast majority (98.2%) of the farmers stated that the dealer provided training for the system after installation. Most of the farmers (25.5%) had a training of about three hours.

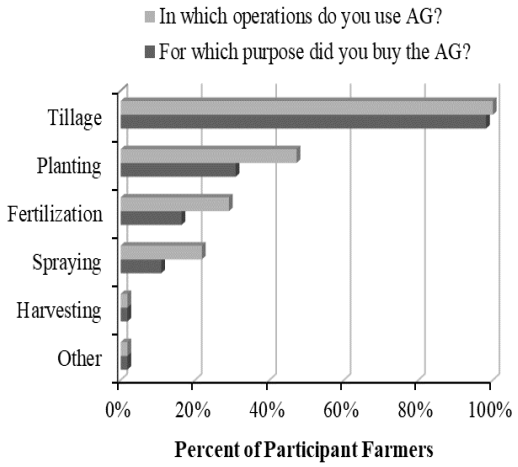

Figure 3. Difference between buying purpose and current usage purpose of AG system
Şekil 3. *OD sistemlerinin alım amacı ve mevcut kullanım amacı arasındaki farklılık*

Regarding the problems that farmers faced during the AG operation, 43.6% of the users stated that they had problems with the system at least once. It was determined that the most common problem was hardware problem (83.3%) as the software problem rate was 12.5%. One of the most frequent problems was the GSM interruption problem that was reported by the farmers who used RTK + CORS + GSM augmentation method. However, the majority (98.2%) stated that they reached the technical services when they needed and that they were satisfied with the provided technical service (96.4%). In addition, more than half of the respondents (54.5%) told that they have a suggestion to make the system more useful. The majority of the participants (66.7%) stated that it would be more user-friendly if the system automatically makes end of row turns itself. Also, nearly one-third (33.3%) of the farmers who made suggestions wanted the interruption problem of the GNSS augmentation signal supplied by GSM connection to be solved (Table 6).

Table 5. Statistical data related to AG system ownership
Çizelge 5. *OD sistemi sahipliği ile ilgili istatistiksel veril*er

Characteristic/ Question	Value	*f*	%
Number of Units	1	46	83.6%
	2	6	10.9%
	≥3	3	5.4%
		55	**100%**
How long do you use AG?	< 1 year	35	63.6%
	2 years	8	14.5%
	3 years	5	9.1%
	≥ 4 years	7	12.7%
		55	**100%**
From what source did you get info on AGs? (Multiple answers allowed)	Other farmers	39	70.9%
	Ag fairs	24	43.6%
	Internet	23	41.8%
	Company	23	41.8%
	Other	7	12.8%
		55	**100%**
Which GNSS signal augmentation method do you use?	RTK+CORS+GSM	27	49.1%
	SBAS (Subscription)	16	29.1%
	RTK	12	21.8%
		55	**100%**

The average costs of the AG systems used in the region varied according to GNSS augmentation method. Average system costs were determined to be around 15 500 USD for SBAS, 20 500 USD for RTK + CORS + GSM and 30 400 USD for RTK respectively.

Despite the high investment cost of the system compared to the economic conditions of the country, a large part of the users (36.1% + 36.1%) predicted that the system will pay itself off in 2 or 3 years due to its benefits. Also, more than half of the users (56.4%) serve the other farmers by means of renting the AG system mainly for ridge tillage operations (Table 7). As to the question 'Does the Ministry of Food, Agriculture and Livestock offer grants and/or subsidy for this system?', 61.8% of all participants gave a negative answer or they did not have any knowledge on this matter. 94.5% of respondents think that the Ministry should offer grant or subsidy for AG systems due to its high investment cost (82.7%), yield increase advantage (13.5%) and labor saving advantage (7.7%). In the further sections of the questionnaire, two more questions related to the benefits of the AG system were directed to the participants.

A large part of the users indicated that the biggest benefits provided by the system were creating straight soil ridges (98.2%) followed by flexible working hours (92.7%), time-savings (80.0%), fuel savings (80.0%) and labor savings (50.9%).

Table 6. Farmers' recommendations about the AG system

Çizelge 6. *Çiftçilerin OD sistemi ile ilgili önerileri*

Question	Answers	*f*	%
Any Suggestions? (Multiple answers possible)	It should make the turns itself	20	66.7%
	GSM interruption problem should be solved	10	33.3%
	Software interface should be more easier	3	10.0%
	RTK setup and battery charge problem be solved	1	3.3%
	Field image appear as an aerial view on screen	1	3.3%

It was found out that the most significant benefit of the AG system was straight ridges for field crops (corn and cotton) and orchards (mainly for citrus trees) (Fig 4).

Table 7. Statistical data related to AG system economy

Çizelge 7. *OD sisteminin ekonomisi ile ilgili istatistiksel veriler*

Question	Answer	*f*	%
How long will it take to pay the AG system off?	<1 year	2	5.6%
	2 years	13	36.1%
	3 years	13	36.1%
	≥4 years	8	22.2%
		36	**100%**
Have you ever rented the AS to other farmers?	Yes	31	56.4%
	No	24	43.6%
		55	**100%**

Moreover, all users think that the system would be beneficial for Turkish agriculture if the purchase costs were lower and more farmers could use the system. Participants stated that the benefits of the AG system would be straight ridges (50.9%), yield increase (49.1%), agricultural input savings (27.3), fuel savings (23.6%), time savings (18.2%) and labor savings (12.7%). Similar advantages were reported by other researches in the US including more accuracy, higher operation speeds, easy operation, working at night, reduced overlaps, skips and inputs (fertilizer, pesticides, seeds, etc.) (Grisso et al. 2009; Groover and Grisso 2008).

Regarding the satisfaction levels of the users, a large proportion of the users stated that they were "Very satisfied" (81.8%) and "Satisfied" (16.4%) regarding the system (Fig 5). Parallel to this result, all users (100%) stated that they recommend this system to other farmers. In the subsequent part of the questionnaire, after a short informative conversation on other PA technologies, a number of questions were asked on other PA technologies.

In regards to farmers' answers, high majority of them (96.4%) did not use any other PA technologies. It was determined that the greatest reason (54.5%) for them not to use these technologies was that they did not have any knowledge about them (Fig 6). This shows the need for a training program on PA technologies for farmers.

Figure 4. Straight ridges for field crops (left) and orchards (right)
Şekil 4. *Tarla bitkileri (solda) ve meyve bahçeleri (sağda) için düz toprak sırtları*

Also, the participants were asked if they wanted to use other PA technologies and 69.1% of them were positive. Farmers who answered 'No' for this question (30.9%) told that high investment cost, detailed knowledge about the PA systems and "no need" were important barriers preventing the adoption of the PA technologies.

When asked 'Which technology would you like to use, if possible?' to the farmers, 86.8% of participants answered that variable rate fertilization followed by variable rate spraying. Farmers wanted to reduce the amount of fertilizers due to their high cost.

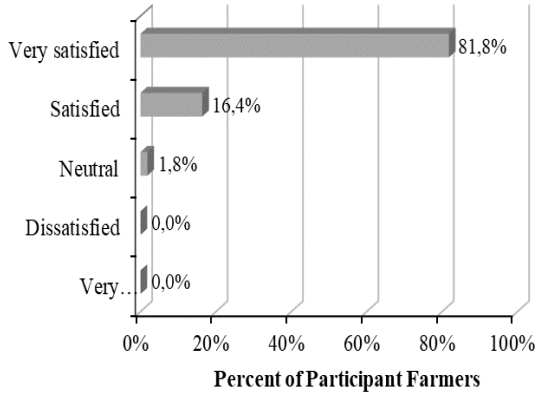

Figure 5. Satisfaction level of the farmers about AG system
Şekil 5. *Çiftçilerin OD sistemi ile ilgili memnuniyet düzeyleri*

It was also found that only 9.1% of the farmers who used AG systems got general training on PA technologies. On the other hand, almost all of the participants (98.2%) who followed the new trends and technologies wanted to get more detailed training about PA for both themselves and their staff.

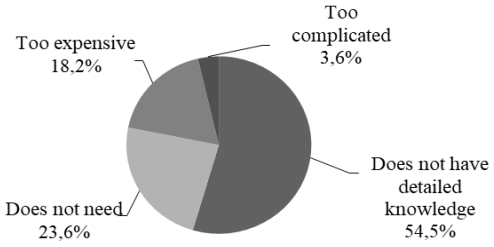

Figure 6. Distribution of reasons that hinder the use of PA technologies
Şekil 6. *Hassas Tarım Teknolojilerinin kullanımına engel olan sebeplerin dağılımı*

In another survey study in Cukurova region of Turkey which includes Adana province, Keskin and Sekerli (2016) reported that 51.8% of all participants (n=164) indicated that they did not hear the term 'PA' before and only 29.3% of the participants who heard the term 'PA' knew its concept. This means that farmers need training on all general PA technologies. The governmental agencies and universities have main role for the training tasks.

The data were also statistically studied using correlation analysis. No significant relationships were found between the farmers' satisfaction level and farmers' characteristics (age, education level, work experience, cultivated crop type, field size) ($P>0.05$). A substantial association was obtained between the numbers of AG systems and the field sizes ($P<0.05$), the participation in the international agricultural fairs ($P<0.05$) and having training on PA technologies ($P<0.01$). This means that the farmers who had bigger fields, participated in the fairs abroad and had training on PA systems had

more than one AG systems mainly due to earning more income. Also, a notable association was available between having training on PA technologies and the usage of other PA technologies ($P<0.05$). Furthermore, a significant relation was found between field sizes and participation in the international agricultural fairs ($P<0.01$).

4. Conclusions

This study was carried out to investigate the famers' satisfaction levels and experiences on the Auto Guidance (AG) system usage in the Adana province of Turkey. 55 of about 110 farmers (50%) who used AG system by the end of 2016 were included in a face-to-face survey study. The summarized findings and conclusions were as follow:

Majority of the participant farmers were in the age group of 21-30 (%34.5) followed by 31-40 (%21.9). A significant part of the farmers (70.9%) stated that they obtained the information about the AG system from other farmers who already used the system. A large portion of the farmers (34.5%) had a land area of 200-300 ha and followed by 50-100 ha (23.6%).

The three GNSS augmentation methods used in the region were RTK, subscription-based SBAS and subscription-based RTK + CORS + GSM. The most common (49.1%) GNSS signal correction method was RTK + CORS + GSM method which requires an annual subscription fee.

All of the participants stated that they used the AG system in tillage (98.2%) followed by planting (47.3%) and fertilization (29.1%). Most common problem was hardware problem (83.3%) followed by software problem (12.5%).

94.5% of respondent farmers think that the Ministry of Agriculture should offer grant or subsidy for AG systems due to its high investment cost (82.7%), yield increase advantage (13.5%) and labor saving advantage (7.7%).

Participants used the AG system mostly in tillage (98.2%) followed by planting (47.3%), fertilization (29.1%) and spraying (21.8%). They indicated that the biggest benefits provided by the system were creating straight soil ridges (98.2%) followed by flexible working hours (92.7%), time-savings (80.0%), fuel savings (80.0%) and labor savings (50.9%).

It was found that a large proportion of the users were "Very satisfied" (81.8%) and "Satisfied" (16.4%) regarding the system. However, 96.4% of them did not use any other PA technologies. It was determined that the greatest reason (54.5%) for farmers not to use these technologies is that they did not have any knowledge about them. Therefore, training programs on PA technologies are needed for the farmers.

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