© by PSP Volume 29 – No. 07A/2020 pages 5689-5695 Fresenius Environmental Bulletin

EVALUATION OF INTERNET OF THINGS (IoT) TECHNOLOGY TO BE USED AS A PRECISION AGRICULTURE SOLUTION FOR TURKEY'S AGRICULTURE

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ABSTRACT

Internet of things, big data, data mining and digitalization which are today's most popular terms of global technology, which are expected to have the highest effect on agriculture in its 10th years of time. Using these technologies in agriculture covers a wide angle from precision farming applications to decision support systems and connected agricultural machinery to web-based decision support systems. The digitalization of agriculture is getting wider all around the world despite having some differences between continentals and countries. Despite having some problems like small and multi-part agricultural areas, there have been significant steps in digitalization of agriculture in Turkey. In this paper, readiness of Turkey's agriculture to digitalization and IoT devices to be used on, characteristics and barriers for adaptation, benefits of digitalization for Turkey's agriculture and available solutions in Turkey with an example of a survey conducted with 7 big farmers on the basis of using tractor tracking devices were explained.

KEYWORDS:
Internet of things, tractor tracking systems, precision farming, LPWAN

INTRODUCTION

Words like digitalization, communication, big data, internet of things and block chain are the most popular topics of today's information technology and science. Besides today's world industry is more complicated, the terms information and data mining are becoming more important than ever before. At the beginning of 90's with the availability of internet and having had a huge spread at the beginning of 2000's, the speed of communication and data transfer rates have reached higher speeds. Although human being has had a long way in automotive, health and space, and taking in consideration of today's 7.5 billion world population [1], that would be a wrong consideration to except agriculture from these technological developments. Although world wheat production is 3.75 tons per hectare, this value should be as much as 6.25 tons per hectare in 2050 when the world population is expected to reach 9 billion [2]. This situation concludes that the raw material to feed that much of people should be increased by 70% higher than produced today.

Conventional agricultural production techniques should be supported with different technological solutions for making agricultural production higher in yield, less in time consuming and grain loss and in the end heading to solve hunger problem globally. The emergence of the problem for agricultural production areas is more crucial than ever before. However average farm area is 800 hectares in Australia, 180 hectares in United States of America, it is not enough to produce high quality and quantity agricultural products in continents like Europe with 17 hectares and Africa with 0.8 hectares of average farm sizes.

One of the solutions to make agricultural production higher not only in quality but also in quantity is to use "Agriculture 4.0" techniques which could be mentioned under the term of "Industry 4.0" that has been an evolutionary term had a huge development in core industry.

Digitalization in agriculture and agriculture 4.0. Agriculture 4.0 is a common term which is expected to penetrate all areas of agriculture soon and covers precision farming techniques and devices, machine to machine (M2M) connected devices and agricultural devices and machines capable of internet connection (IoT), agricultural software and decision support systems (DSS).

Since developments in agricultural production has begun at the beginning of the 19th century as Agriculture 1.0, the developments had very low productivity capabilities at that time. Effective pesticides and seeds were developed, and high productive machines were built with the Agriculture 2.0 which was started in 1950's. With the development of Agriculture 3.0, availability of differential global positioning systems (DGPS) signal to be used not only for

army forces but also for civilians has made it possible to use auto steering systems on tractors and combine harvesters. Farm areas were able to be tracked using satellite systems and visual analyses have enabled variable rate applications, too. Also, telematics solutions were developed for tracking agricultural machinery and logistics.

Agriculture 4.0 has started a century in which high technology and cheaper sensors, low-frequency and cost-free connection technologies, cloud based intelligent agricultural software and decision support systems with big data analyse solutions are used. With these technologies, decrease in production loses, savings in agricultural inputs and optimization in agricultural production are being expected.

According to a study where savings in agricultural inputs and increase in yield were compared; it was determined that 5% increase in savings is equal to 1% increase in yield. When agricultural risks are considered, it was expressed that using Agriculture 4.0 techniques are not only risk free but also have a huge impact on yield increase, also it was determined that Agriculture 4.0 technology has a 2 month return of investment time with a respect to yield increase.

Readiness of Turkey's Agriculture for Digitalization and Adaptation to IoT in Agriculture. Agricultural mass production has been started with the establishment of Republic of Turkey and after the 2nd World War there has been a huge development with the increase of agricultural machines. Parallel to the developments in industry, not only in agricultural production and machinery sector had been a development but also in agricultural production rates, technology use on agricultural machines, too.

In the last decade the population of Turkey has reached to 80.7 million [3] with a 11% of increase, agricultural farm area has reduced to 23.6 million hectares with a 10.5% decrease (Figure 1) [4]. Whereas mean farm area is 17 hectares in Europe and 180 hectares in United States of America, Turkey's average farm area is far less than these countries with 6.4 hectares.

64.8% of Turkey's farms have less than 5 hectares of farm area and 59.9% of total farm areas are divided into 3 parts so that makes a huge barrier for investment of precision agricultural technologies to Turkey's farm since these technologies are effective to use in large areas (Table 1) [5]. European Agricultural Machinery Industry Association (CEMA) has informed that the farmers who own more than 50 hectares of farm area have a big potential to invest on precision agricultural technology such as internet of things in agriculture, web, mobile and cloud software [6]. Ongoing situation about Turkey's farms and agricultural areas could be turned into an advantage for Turkey's farmers to by the use of IoT technology since the purchasing prices are very low.

When Turkey's tractor and machinery park is investigated, it is found out that 92% of total 1.7 million tractors [7] and 79% of total 17 thousand combine harvesters are owned by the farmer [8] (Table 2). So that auto-tracking systems especially used on tractors and precision farming technologies like DGPS' are all imported, this situation makes it very difficult for Turkey's farmers to pay for that kind of technological equipment to be used in agricultural production.

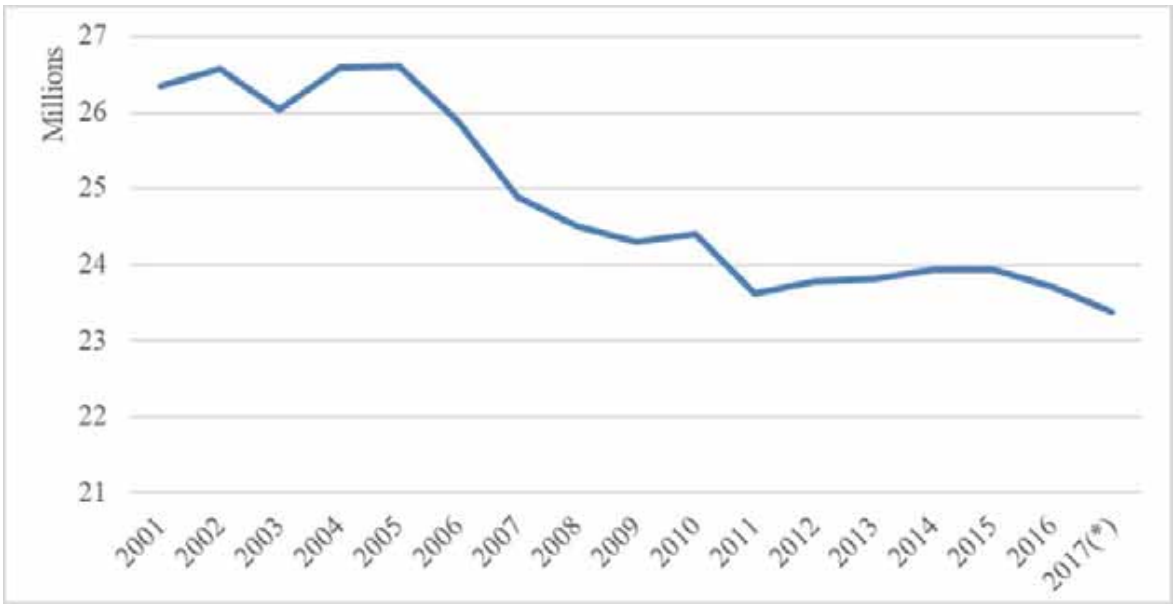


FIGURE 1
Change of Total Farm Area in Turkey Based on Years

TABLE 1
Average Farm Area Size in Turkey [4]

Farm Size (hectares)	Number of Farms	%
Total	3022127	100
<0.5	178006	5.89
0.5-0.9	290461	9.61
1.0-1.9	539816	17.86
2.0-4.9	950840	31.46
5.0-9.9	560049	18.53
10-19.9	327363	10.83
20-49.9	153685	5.09
50-99.9	17429	0.58
100-249.9	4199	0.14
250-499.9	222	0.01
>500	57	0.00

MATERIALS AND METHODS

Turkey has 3.7 millions of farms and 28.8% of which is 880 thousands of them have 914 thousand tractors. That number of tractors covers 72% of total tractor numbers except junk tractors number. Totally 77 thousands of farms which is 2% of total farm number are using 6% of total tractors on shared basis.

For this research there have been seven meetings done with the big farmers around Adana region, where there are lots of big farms, which produces cotton, corn, wheat, soy bean and citrus fruits and have a potential for using future's agricultural technologies like using IoT based tractor tracking technologies were investigated (Figure 2).

RESULTS AND DISCUSSION

It was found out from the surveys that the smallest farm area was 20 hectares and the biggest one was 1000 hectares (Table 3). There were at least 3 tractors whereas at most 6 tractors on these farms and it was revealed that the number of the tractors in the farm were higher with the total farm area. The smallest tractor power was 55 kW whereas the highest one was 121 kW and the average tractor power was between 66 to 132 kW for each farm (Table 4). Tractor operators were hired people for these farms which have less than 20 hectares of farm area. Also, it was figured out that neither technological solution nor tractor tracking systems were used on the tractors in these farms and the machines that were used were conventional ones with no technological device equipped. It was found out that there was no evidence for the record for downtime, maintenance, duration of the operation and fuel consumption of tractors. The farmers explained that there wasn't any solution for tractor tracking systems on the market and the only technological development which is mostly

TABLE 2
Tractor and Combine Harvester Park in Turkey Based on Ownership

Tractor		Combine Harvester	
Owned (%)	Shared (%)	Owned (%)	Shared (%)
92	8	79	21

TABLE 3
The Production Size of Different Crops of the Farms Joined to the Survey

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7
Corn	1000 ha	30 ha	20 ha	400 ha	10 ha	60 ha	330 ha
Cotton	-	80 ha	50 ha	-	150 ha	-	-
Wheat	-	90 ha		-	-	-	-
Sunflower	-	25 ha		-	-	-	-
Soybean	-	-		-	40 ha	100 ha	-

TABLE 4
Tractor Numbers and Power Size of the Farms Joined to the Survey

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7
Tractor 1	112	81	101.5	84	69	110	195
Tractor 2	77	64	58.8	55	78.2	77	121.7
Tractor 3	74	70.8	62.4	70.6	92	70	81.8
Tractor 4	67	51.5	60.3	-	77.5	61	-
Tractor 5	-	70.8	37.3	-	58	-	-
Tractor 6	-	-	57.4	-	-	-	-
Average Power	66	67.6	75.5	69.9	74.9	79.5	132.6

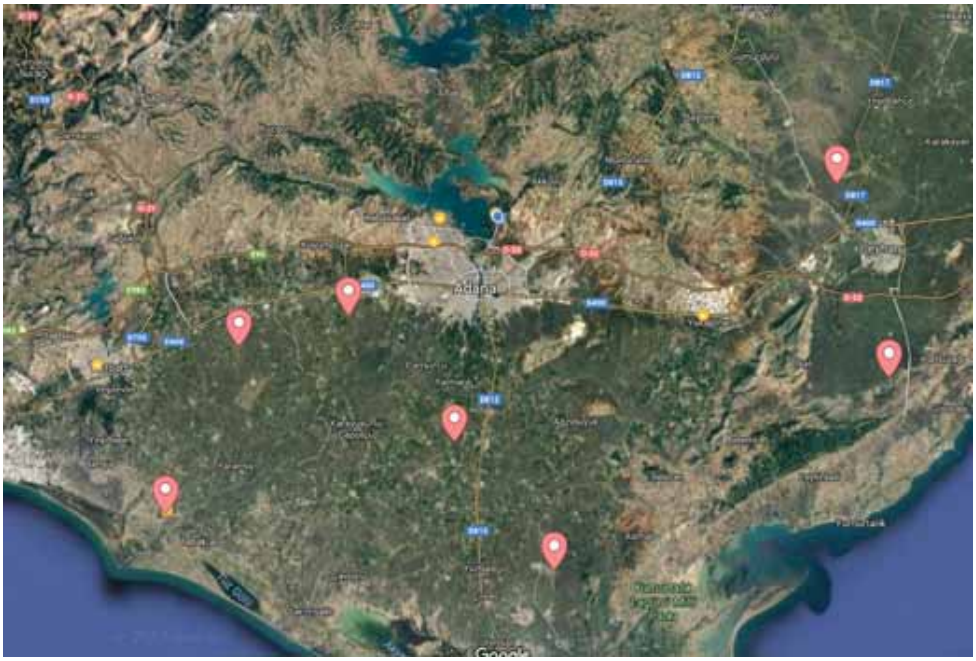


FIGURE 2
Distribution of the Farms That Surveys were Carried Out

found was auto-steering systems. Only one of these farms that the surveys carried out had auto-tracking system and the owner of the tractor was unhappy with the price of this technology. The measurement of the duration of the farm operation was impossible especially for the farms which have more than four tractors and the farmers reported for the need of that kind of a measurement system.

To define out of the situation that the surveyed farms, Turkey's tractor park, tractor companies and technological solutions were investigated. It was determined that the distribution of Turkey's tractor size mostly depends on two brands which are Turk Tractor with 48% and Massey Ferguson with 25% of Turkey's tractor number (Figure 3) [9, 10]. On the other side, it was found out that the 54% of total tractors age is 20 and over [9, 11] (Figure 4). This analyse defines out two different situations about use of IoT technology on tractors which are;

- Turkey's tractor park and the end-user technologies served by the brands which are active in Turkey are not compatible with the Turkey's old tractor park so that, most of the tractors should be renewed.
- The end-user technological solutions' prices which are sold by tractor companies are so high that, this situation makes the potential use of IoT technology on tractors high since they are cheap based on investment and operational costs.

TABLE 5
Comparison of Available Tractor Tracking Solutions Based on Technical Specifications and Usability

	Tractor Company A Product A	**Tractor Company B Product B**	**Internet of Things (IoT) (AGRISENS, 2019) Product C**
Product type	By-product	By-product	Main product
Communication base	GSM	GSM	LoRaWAN
Compatibility	ISOBUS	ISOBUS	ISOBUS + Old Tractors
Measurement points	Sensors already on tractor	Only fuel consumption	Selectable sensors
Battery	No battery (uses vehicle power supply)	No battery (uses vehicle power supply)	10 years battery life

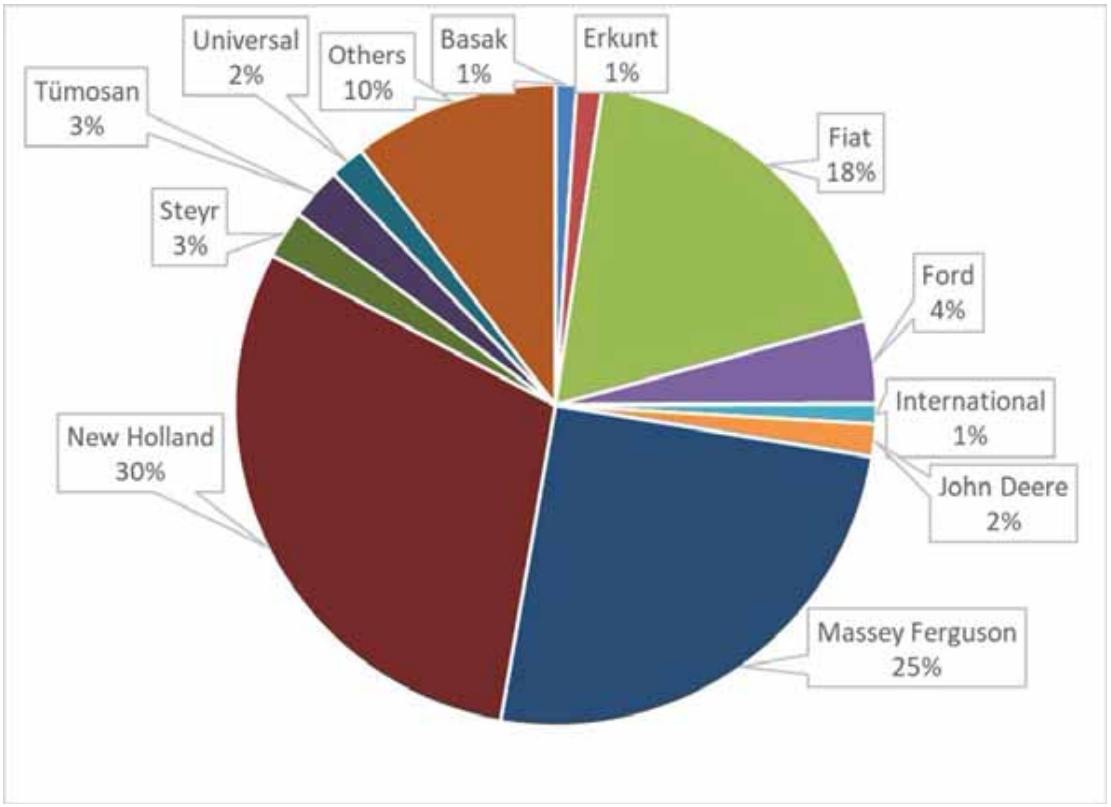


FIGURE 3
Tractor Brands in Turkey's Agriculture [10]

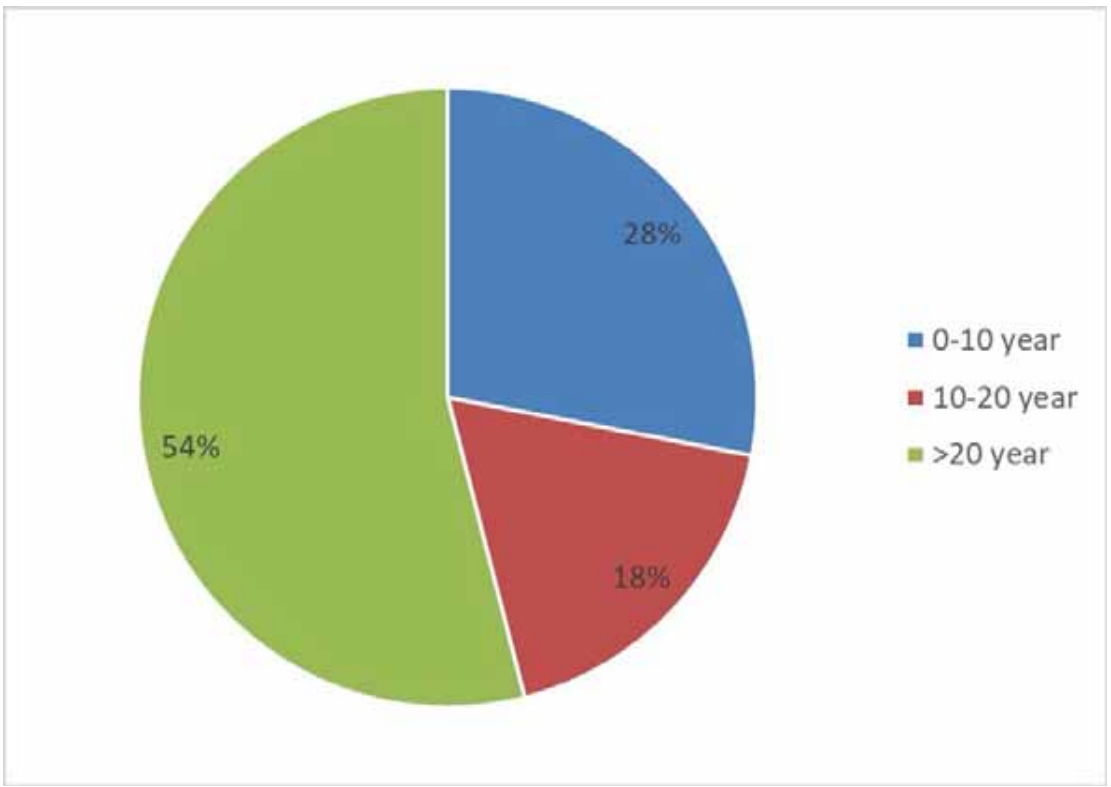


FIGURE 4
Average Age of Tractors in Turkey

One of the comparisons of two different tractor companies' tractor tracking and data acquisition systems shown in Table 5. When these systems were analyzed it was found out that, these systems are sold as a support product based on sold tractors. On the other side, it was investigated that tractor companies tracking systems use GSM (global system for mobile communications) technology which sets apart IoT technology. GSM technologies are widely used in urban areas whereas tractors are used in rural areas which becomes a constraint for GSM based technologies. Setting up a GSM base station is not only expensive but also there needs to be have an approval for being set up from local government whereas IoT-based systems uses communication protocols like LoRaWAN which uses a low-power wide area network (LPWAN) technology for which there is no need for approval to set up of a gateway. That kind of protocols uses sub-GHz frequencies which is free for use and no need for permission. On the other side, the solutions given by tractor companies are compatible with CANBUS systems however not compatible with old tractors which do not have CANBUS communication ports. Despite this situation, IoT-based tractor tracking systems not only uses CANBUS protocol but also can be connected to the old tractors which makes measurement of performance data such as fuel consumption, travel speed possible. Tractor companies' systems are directly connected to the tractor power line to get worked, however IoT based ones do not need to be powered using tractors electrical system. These systems work on their own battery and since communication systems uses sub-gigahertz frequencies, so that their battery lasts up to 10 years of time [12].

CONCLUSIONS

With this study it was evaluated that Turkey's agriculture adoption to precision agriculture based on using IoT technology has a big potential due to its agricultural situation. Small and multiple part lands, situation of agricultural machines, high average age and low-tech tractors and farmers with low income are the biggest constraints against for using high-tech precision agricultural technology like path-tracking auto steering systems, variable rate application devices, autonomous tractors and so on. Since IoT is becoming very popular in every area of production and devices using this technology are cheap, this technology has a huge potential to be used in Turkish agriculture and agricultural machineries. The survey that was done for analysing the potential showed that, even in huge farms the average tractor power is low, and the tractors do not have new technology for being adopted to high-tech precision agriculture devices. Although the farmers were willing to use new technology, the budget that they can allocate from income was very low, but they still wanted to spend for using IoT devices for their machinery.

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Received: **04.04.2019**
Accepted: **23.04.2020**

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