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Development of an Iot Based Tractor Tracking Device to Be Used as a Precision Agriculture Tool for Turkey's Agricultural Tractors

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Abstract **Original Research Article**

Precision agriculture (PA) is one of the most trending topics of today's agriculture. This subject covers wide range of technologies like sensors, microcontroller-based devices, machine to machine communication technologies, global positioning systems, drones, satellite images, and big data and so on. Using these technologies on agricultural machinery will enable farmers to use less in inputs that reduces expenses versus produce higher quantity which means high income. Besides these technologies, internet of things (IoT) technology is a new PA era that agricultural production will be the one area mostly affected by it. IoT covers hardware like sensors, machine to machine and long-range connection technologies, and software like decision support systems, stand-alone and web-based software. IoT enables almost anything on the planet to be connected to internet to gather data. This technology's most advantageous point is that it can be integrated to anything for a very cheap price. This advantage enables countries which lacks in use of precision agricultural techniques. Turkey is one of the countries that have barriers to adopt in PA. For that reason, in this paper benefits of using IoT technologies in Turkey's agriculture, available solutions in Turkey were discussed and a developed IoT based tractor tracking device's potential use in farms were investigated.

Keywords: Agricultural tractors, precision agriculture, internet of things.

INTRODUCTION

World's rising population has arisen higher need for food. When population rise from 7.5 billion from now to 9 billion with a rise of 20% in 2050 [1] considered, it is calculated that the raw material should be as 70% more to feed that much people. This calculation results in with a restriction making agricultural production with less and gain more.

PA comes out as a critical solution for this crucial need as Pierce and Nowak [2] defined it as a tool to do the right thing in right time, right place in the right way. PA covers different technologies and techniques to use less input versus gain more. This is achieved by using variable and data-oriented applications through field, crop, machinery, tractor and even also farmer. Sensing, geospatial, actuator and data driven computer and software technologies are used to get most from PA [3].

Agricultural situation and technological development vary country by country. The average farm areas based on countries are 800 hectares in Australia, 180 hectares in United States, 17 in Europe and 0.8 hectares in Africa. Average machine width and tractor power size differ based on these values. In small farm areas machines with small width and small tractor sizes are used whereas in big areas higher width machines with higher tractor power size are used. In countries where small tractor power size and small machine width is used due to the small farm area, it would be a dream for expecting precision agriculture technologies to be used. However, barriers for the use of PA not only caused by agricultural development but also by some of the issues related to PA's nature like, political dimensions, research issues, environmental damage costs and training issues [4].

Nevertheless, PA has a crucial effect for the future of agriculture to feed that much people and it should be available for everyone. Since the development of PA term, the technology has developed fast. However, PA was just based on variable rate application and global positioning systems at the beginning, today it covers new sensor technologies and networks, machine to machine communications (M2M), internet connected devices and data driven algorithms and software. Because these technologies' use widespread, purchase costs are becoming less day by day. However, when the literature is investigated the adoption of PA has not been so fast in the farms [4]. So, there seems to be a chance for accelerating small farmers to adopt PA technology to be use in their farms.

Internet of things (IoT) could be the one that make sense for farmers to invest in devices that are using this technology. This term was firstly pronounced by Kevin Ashton in 1999 [5] to tell about a new idea to place RFIDs' (radio-frequency identification) on to the products to know about the stock situation. After 20 years appearance of this term, today I may define IoT as anything in the universe with internet connection that capable of transmit at least one specification of data to the internet. So, what makes this technology can be used easily is not only that the enabling internet connection in everywhere but also developments in sensor and microprocessor technologies cheaper with mass production. As Evans reported, there will be 50 billion things are expected to be connected to the internet according in 2020. When the technological developments, rocket and satellite technologies considered such as Elon Musk's new internet connection satellite technology called Starlink which is expected to be finished in 2027 [6], IoT technology will penetrate almost everywhere and on anything on the earth.

Turkey's agricultural situation and tractor park analysis for decision on development of the device

By the end of 2018, Turkey has 82 million of population with 14.66% increase in the last decade [7]. Agricultural farm area continues to decrease which has reached 23.2 million hectares (Figure 1) [8]. Turkey has smaller average farm area with 6.4 hectares on contrary to Europe and United States with 17 and 180 hectares, respectively.

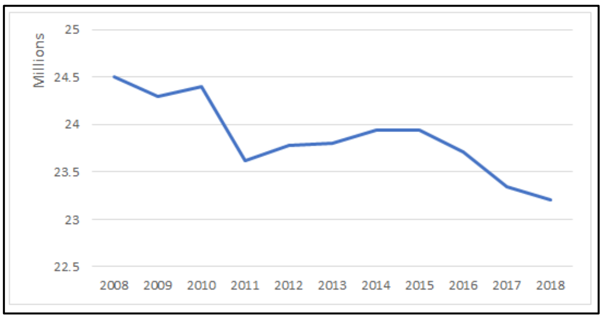

Fig-1: Change of total farm area in Turkey based on years [8]

Nearly 60% of total farm areas are divided into 3 parts and 65% of them are less than 5 hectares which crate barrier to use high width agricultural machinery with high power tractors (Figure 2) [9]. There are 1.885 million of tractors are used in the farms by the end of 2018 [10] and 92% of them are owned by farmers not collectively used [9].

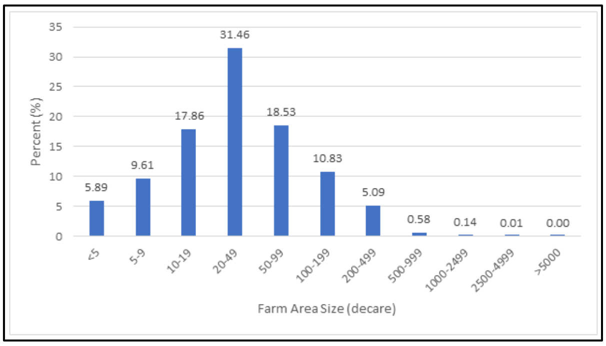

Fig-2: Rate of number of farms by farm area size [11]

When literature has investigated, no evidence could be found according to statistics of the use of precision agriculture devices or sensors. There were some studies found based on digitalization and adaptation of Turkey's farm to precision agriculture.

In a recent study to determine farmers aim to use auto guidance systems in Adana region, it was found out that %96.4 of the farmers did not use PA technologies, since they did not know about this technology [12]. In another research that was done again in Çukurova region, however 35.9% of the farmers did not know about PA, 92.3% of them reported that they had followed new trends in agriculture, yet 61.5% of them were interested in satellite positioning systems contrary to be not interested in automatic steering or variable rate application system by 38.5% and 28.2%, respectively [13]. In another survey that was done under a study about adaptation of Turkey's agriculture to globalization and Agriculture 4.0, it was revealed that however most of the participated farmers were using computer and smart phones, none of them had unmanned vehicles whereas, 3 out of 422 farmers were using sensor equipped machinery [14].

According to some unofficial information gathered from some tractor companies in Turkey, mainly there are 3 companies that serve PA devices, mostly satellite guidance systems, which have different specifications and capabilities. These devices are mostly used on high power tractors with precision from ±15 cm to ±4 cm. For the highest precision, it is required to use base station to correct the signal however; these are too expensive for the farmers. When the literature was investigated to know about the use or purchase statistics of these devices, there could be no information was found.

For the prove of the use PA devices usage in whether in big farms or big tractors, there was a survey done with the 7 big farmers in Adana region. The results gathered from this survey were as follows;

- The smallest farm area was 20 hectares whereas the biggest one 1000 hectares,
- There were at least 3 tractors and at most 6 tractors,

- The smallest tractor power was 55 kW whereas the highest one was 121 kW
- Average tractor power size at least 66 kW and at most 132 kW,
- There were no PA devices were used on these tractors,
- There were no records based on tractors use, downtime, maintenance, duration of operation and fuel consumption.

According to the surveys held, farmers wanted a high-tech and easily affordable device for tracking of the tractor besides auto-steering systems and know about the position, performance and geolocation of the tractor. For making this device available, a study was conducted to develop an IoT based tractor tracking device and gather tractor performance data and show it on web-based software.

Developed IoT Device for Tractor Tracking

The developed system was designed as two modules; hardware and software. The hardware designed to gather performance data from tractor like fuel flow and power consumption using available sensors on the tractor and get geolocation data using GPS module on it (Figure 3). For making this a PCB (printed circuit board) designed with several analogue and digital communication ports to connect to the sensors on the tractor and get data. A 16-bit main microprocessor soldered on to the PCB to process gathered data from the tractor. Also, a LoRaWAN based data transmission module which uses LPWAN (low-power wide area network) communication technology embedded on to the developed PCB which allows main microprocessor to send processed data to the internet using this module. Soldered LoRaWAN module transmits data using 868 MHz frequency (Figure 3). A multiplexer integrated circuit was also embedded on to the PCB whether to send data over LoRaWAN transmission module or to switch and send to a GSM compatible module which uses MODBUS protocol if LoRaWAN connection not available.

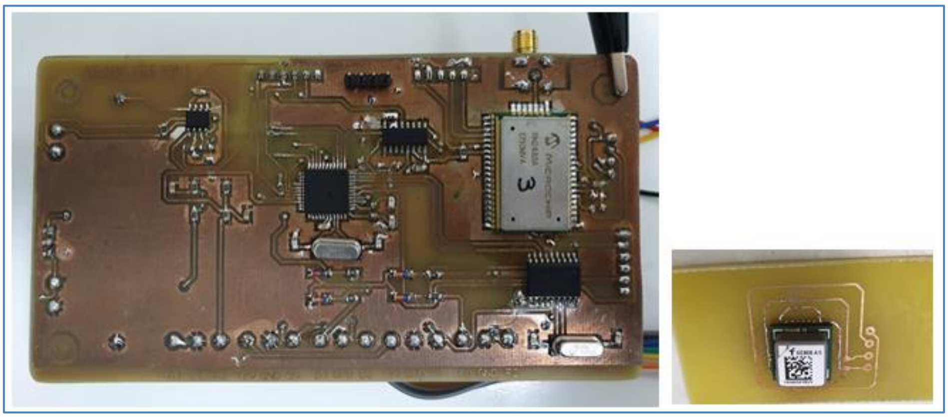

Fig-3: Developed hardware and GPS module (Courtesy of AGRISENS Ltd)

The main microprocessor's embedded software was written using CCS C compiler software and then it was programmed using Microchip Pickit3 circuit debugger (Figure 4). After microprocessor was programmed, it was put under debugging test circle to find and correct software errors using MPLAB software using circuit debugger.

Fig-4: Pickit3 circuit debugger

The other part of the system which is web-based software was developed using HTML (hypertext mark-up language) and PHP (hypertext pre-processor) programming languages. A MYSQL database was also developed to record sent data by the hardware. To record sent data to the database, an algorithm was developed using JSON (java script object notation) in a PHP file (Figure 5). When a data packet was sent by the hardware, this PHP file was triggered, and the sent data was recorded into the database. The developed software allows users to create user accounts and add used tractors in their farms. After user ads used tractors, a unique identifier was assigned based on the implemented hardware on to the tractor. With this unique identifier, user can reach each tractor's performance data like fuel consumption, time of use, power use and geographical position of the tractor on the map (Figure 6 and Figure 7).

```
query='SELECT * FROM data ORDER BY id DESC';
$result=mysql_query($query,$db) or die(mysql_error($db));
echo '<p><table>
<tr>
<td">td></tr>
<tr>
<th>Latitude</th>
<th>Longitude</th>
<th>Speed</th>
<th>Slip</th>
<th>Fuel Consumption</th>
<th>Pulling Power</th>
<th>PTO Power</th>
</tr><tr>';

while($row=mysql_fetch_array($result))
{
$data=$row['data'];
$dataarray=array(substr($data,0,6),substr($data,6,6),substr($data,12,3),sub
str($data,15,2),substr($data,17,3),substr($data,20,4),substr($data,24,4));

$data0=(hexdec($dataarray[0]));
if($data0>=(pow(2,24))/2)
{
   $veri0=((pow(2,24)-$data0+1)/93206.7);
   echo '<td>'.$veri0.'S</td>';
}
else
{
   $veri0=($data0/93206.7);
   echo'<td>'.$veri0.'N</td>';
}

$data1=(hexdec($dataarray[1]));
if($data1>=pow(2,24)/2)
{
   $veri1=((pow(2,24)-$data1+1)/46603.4);
   echo'<td>'.$veri1.'W</td>';
}
else
{
   $veri1=($data1/46603.4);
   echo'<td>'.$veri1.'E</td>';
}

echo '<td>'.((hexdec($dataarray[2]))/10).'</td>';
echo '<td>'.(hexdec($dataarray[3]).'</td>';
echo '<td>'.((hexdec($dataarray[4]))/10.'</td>';
echo '<td>'.((hexdec($dataarray[5]))/10).'</td>';
echo '<td>'.((hexdec($dataarray[6]))/10).'</td>';
echo '</tr>';
}
echo '</table></p>';
```

Fig-5: Developed data transfer algorithm

Fig-6: Developed PHP code to show tractor performance data on the web

AGRiSENS

Date	EUI	Temperature (C)	Humidity (%)	Lux	Pressure	LON	LAT	Speed (km/h)	Torque (Nm)	Revolution	Power (kW)	Fuel Consumption (L/h)
2018-05-11 13:35:58	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.38017898660159	37.0339400936249	3.1300	114.6130	450.5690	5.4100	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3802143033490700	37.0339733622635800	0.7300	26.7760	452.5030	1.2700	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3802936355921300	37.0340480878807700	3.6900	135.2200	451.7810	6.4000	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3803464217200300	37.0340978126449700	-0.1500	-5.3490	444.3950	-0.2500	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3803991278397500	37.0341474612389900	2.9500	108.0480	454.5770	5.1400	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3804254543910700	37.0341722643516200	0.1600	5.8950	449.3630	0.2800	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3805043415130000	37.0342466236715800	1.8800	68.6890	451.4420	3.2500	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3806093734203900	37.0343457822708300	-0.0400	-1.5050	446.4390	-0.0700	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3807053412623300	37.0344363830520800	2.5000	91.4050	451.4480	4.3200	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3808369037815400	37.0345442918182400	1.3100	47.8670	452.6280	2.2700	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3808974956543500	37.0346013718246200	0.7400	27.2240	450.3900	1.2800	0.0000
2017-10-17 10:32:10	01-AC-1A-6A	26.400	67.4000	0.0000	1010.4000	35.3809838659392400	37.0346827488100000	0.8600	31.3790	448.7540	1.4700	0.0000

Fig-7: Developed web-based software

CONCLUSIONS

In this study, situation of the use of PA tools and the potential of the use of IoT technology as a precision agriculture tool on tractors in Turkey was investigated. It was revealed that the rate of the use of PA technology is very low due to the high investment costs and very few of the farmers were using auto-steering systems on tractors. Conducted survey revealed that average tractor power size was very low even in the big farms and the farmers were willing to use PA tools but, they were complaining about the investment costs. Since the results of the conversations with the farmers showed that they would invest in low-cost PA devices, a low-cost IoT based tractor tracking device with GPS capability was developed in this study. The developed system was based on a module and web-based software. The module had the capability to send tractor performance parameters like geolocation data, speed, fuel consumption and power use to the cloud whereas the web-based software allows farmers to see and analyse these results on the web. Since farmers expecting this device commercially and it is expected that this IoT based device will be widely used on Turkey's tractors so, the studies are continuing for better development for this system.

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