E-precision agriculture for small scale cash crops in Tobasa regency

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Abstract. Cash crop is a promising sector in Tobasa regency; however, the trend showed a negative change of the cash crop production. This research aims to develop an application which is based on Arduino for watering and fertilizing corn land. The result of using e-precision agriculture based on embedded system is 100% higher than the conventional one and the risk of harvesting failure using the embedded system decreased to 50%. Embedded system in this study acquired critical environment measurements which at last affected the yield raising and risk reduction. As the result, the use of e-precision agriculture provided a framework to be used by different stakeholders to implement e-agriculture platform that supports marketing of agricultural production since the system is proven to save the material and time which finally reduces the risk of harvesting failure and increases the yield. In other words, the system is able to economize the use of water and fertilizer on a small corn land. The system will be developed for more efficiency in material loss and the mobile-based application development to reach sustainable rural development particularly for cash-crop farmers.

1. Introduction
Agriculture is a never-ending effort since human needs food for living every day; however, human population trend shows that the number of people in Indonesia is getting increased. This becomes a big opportunity for everyone interested in cultivating agriculture land particularly cash crops. Cash crop, as is called, is the income resource for farmers since it has a direct relation with the market and the product can earn “cash” for them [1]. Cash crop is an agricultural sector that is potentially developed in Indonesia. Fertile land, tropical climate, high rainfall, and abundant sunlight are positive factors for the country which is 252 million populated. From the human resource point of view, Indonesia is now entering the phase of demographical bonus which is related to higher productive age compared to the non-productive one. North Sumatera Province is the part of Indonesia which has the potential for cash crop such as corn, cassava, soya beans, and peanuts; ironically, the total production of corn and peanuts decreased dramatically from 2012-2014. Corn production fell from 1.35 million tons to 1.15 million tons in only two years period while peanuts experienced 1.5 tons production reduction at the same time [2]. This is caused by the declination of the harvested land for human residence. Toba Samosir (Tobasa) is a regency located in the northern part of North Sumatera, is known as a center of paddy and corn supplier for North Sumatera. Other
cash crops such as cassava, green nuts, and peanuts also grow in this area. Almost all districts in Tobasa grow cash crops as the alternative crops after wetland paddy. Despite its capacity to produce those crops, Tobasa also experienced the depletion of corn production for the last three years in which the production decreased sharply from 24,957 tons in 2011 to 14,247 tons in 2013 [3]. This situation is in line with a census carried out by Statistic Bureau of Indonesia which showed the negative trend of the number of cash crops farmers in Indonesia. In 2013, there were 10.5 million of them left compared to 16.5 million in 2003 [4]. These farmers tend to change their activities to other occupation since the number of harvested land was not promising anymore. One the problem faced by the farmers is about technological issue where all activities are still carried out manually such as in Tobasa regency. For example, with a farmer, it needs more than two hours for spreading water and fertilizer on a 2.500 m² corn land. In this paper, a technological solution is introduced to cash crop farmers in order to stimulate the land in order to increase corn production. The technology is a smart application based on Arduino for watering and fertilizing corn land. This application gives an effective solution for farmers since they do not have to visit their land all the time for monitoring [5]. The objective of this study is to create an application which helps the farmers use embedded system for their agricultural activities to actualize precision agriculture in Tobasa regency. The significance of this study gives benefit to the farmers for monitoring their corn land and implemented the basis of precision agriculture which finally influences the farmers’ economy for sustainable rural livelihood.

2. Method
2.1 System design
This application uses Arduino open-source microcontroller which is compatible with any platform and it can be connected via Universal Serial Bus (USB) [6]. Arduino is then connected with ESP8266, a wifi module functions as an extra microcontroller to create TCP/IP. This module needs 3.3v and has three wifi modes such as station, access point and both. It is also equipped with processor, memory, and GPIO. pH sensor is deployed to provide the accuracy for reading the soil acidity and it has serial asynchronous interface connection. Water level sensor is an instrument used to give a signal that water is reaching a certain level. It sends dry contact signal (NO/NC) to the panel. This detector gives alert to stimulate other automatic items to move [7]. Other materials used for this application are water valve, water pipes, and water pump. Software which is the main focus of this research is built with a framework. Programming of a communication between the information system and automatic watering and fertilizing involves wifi module which is placed in Arduino. When the information system sends a message or commands carried out by Arduino and the message will be executed. After execution, Arduino will send back the message to the information system stating that the message has been completely executed.

Figure 1 illustrates the system design where the application is connected to Arduino. When a user accesses information system and sends “watering” command, Arduino receives the command and processes it. After that, Arduino sends the command to servo and servo sends the command to open the water valve and conducts the watering. In this web-based application, the user can see the soil’s pH and is able to see the need of the crop based on the data stored in database. When the crop is in need of water or fertilizer, user can automatically monitor, control, and carry out watering or fertilizing. When the water in the tank gets lower, water level sensor will detect the water volume and sends the command to relay to refill the water and fertilizer.
2.2 System flowchart

The flowchart of the system is illustrated in Figure 2. When the system is accessed, a user is able to check whether the crop needs watering based on pH sensor. If the crop needs watering,
the user can click “water button” in the application. Then, a command is sent to Arduino and Arduino sends the command to servo while carrying out watering. Water level sensor also works simultaneously to check the water availability in the tank. When soil’s pH meets the standard, watering and fertilizing is stopped and the user can execute other feature such as selling and crops management which are displayed by the application.

2.3 Graphical User Interface
The graphical user interface is designed to be user friendly so that the novice user can easily use it without any complicated training.

![Figure 3. GUI of general control system](image1)

![Figure 4. GUI of crop control system](image2)

Figure 3 displays the crops available in the land and when a specific crop is clicked, it displays the new page containing important information of the crop and carries out watering or fertilizing. For example in Figure 4, “corn” option is clicked and then the interface shows the family of the crop, growth information, and maintenance. There are two buttons below the
data, “water button” and “back button”. Watering and fertilizing are carried out after reading
the necessity data of the crop e.g. if the pH is 6 or 7 based on the data, watering or fertilizing
is not executed.

3. Result and discussion
The experiment was carried out on a 500 m² manual and e-precision corn land respectively.
The comparison of both methods yield is shown in Table 1.

Table 1. Monitoring result on corn land (per 500 m²)

| Evaluation aspect | Manual         | E-precision agriculture |
|-------------------|---------------|-------------------------|
| Watering time     | 24 minutes    | 5 minutes               |
| Fertilizing time  | 30 minutes    | 10 minutes              |
| Water loss        | 2-2.25 l      | 0.5 l                   |
| Fertilizer loss   | 1.2 -1.5 kg   | 0.2 kg                  |
| Yield             | 1 ton         | 2 tons                  |
| Harvest fail risk | 10%           | 5%                      |

Table 1 shows the result of monitoring in six aspects using conventional method compared to
e-precision agriculture on a corn land with 500 m² wide. With manual method, the loss of
time for watering was five times higher and fertilizing time was three times higher than e-
precision agriculture. The manual method required the farmers to carry water buckets and the
watering was carried out based on the preferences of the farmer. This result indicates the
increasing yield of e-agriculture using distributed system for monitoring temperature,
moisture, and light intensity in the greenhouse using Arduino Uno. This system consisted of
two sensor-actuator nodes and a controller node connected to internet using Ethernet Shield
board. The system’s ability to monitor indoor environment of greenhouse, and environment
data access via web enabled the monitoring and plant management to be performed automatically [8]. Moisture on soil content is determined by the water content where the
proper amount of water in the soil in this study was considered standard to grow the crop
properly. The similar issue took place when fertilizing the crops where the farmers spread the
fertilizer using the backpack-tank. With the help of the application, the pipes spread the water
and fertilizer based on the sensor working on the soil and the time for executing the
instruction. This means that the application implemented in this study is suitable for
agriculture environment [9] since the result that is gained is more efficient and user-friendly.
This also indicates the success of a design of a complete application with an electronic device
that can help landlord agriculture to start out a dependable quality product in the marketplace.
In terms of material loss using manual method, the amount of water that lost was four times
higher and the fertilizer loss was six times higher. Since there was no standard of watering
and fertilizing of the manual method, water fell out from the bucket during the period of
bringing it from the water source to the land and the farmers had to carry the buckets many
time. In addition, fertilizing process did not have the same standard from one to another corn.
Smart agriculture irrigation control using wireless sensor networks can monitor and control
the irrigation automatically with the information from the web server node [10]. These
material and time loss indeed influences the result of harvesting where the result of using e-
precision agriculture was 100% higher than the conventional one. The risk of harvest fail
using the embedded system decreased to 50% since the precision in watering and fertilizing
made the growth of the crop in good condition where all corn seed have the same nutrition
from watering and fertilizing. Embedded system in this study acquired critical environment measurements which at last affected the yield raising and risk reduction [11]. In summary, the use of e-precision agriculture provided a framework to be used by different stakeholders to implement e-agriculture platform that supports marketing of agricultural production [12] since the system is proven to save the material and time which finally reduces the risk of harvesting failure and increases the yield.

4. Conclusion
The implementation of e-precision agriculture in this study gave evidence that time, material, and risk had been reduced effectively. The accuracy of the system was proven in the term of the harvesting yield which increased up to two folds. In other words, the system was able to economize the use of water and fertilizer on a small corn land. For future work, the system will be developed for more efficiency in material loss since there was still found little loss during the implementation. The system will also be implemented for other cash crops such as peanuts and cassava. Other parameter aspects such as temperature, light intensity, and pests will be included for the next development for each kind of cash crop. The data collection and analysis for each crop will be used for developing large-scale cash crop in Tobasa regency. Finally, the mobile-based application development is highly recommended for better result so as to raise the awareness of the farmers to work again on their land and to reach sustainable rural development for the people around.

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