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The Development of Mobile-based Farmland Mapping System with Drones and Wireless Devices

Case Study: Gilangharjo Village, Bantul District, Indonesia

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ABSTRACT

Farmland is one of the strategic resources in agricultural management. Thus, this resource must be recorded and utilized correctly. One of the ways to track the utilization of farmlands is by using a farmland mapping information system. Despite so, the use of the website is considered inefficient and difficult to implement as it lacks flexibility and requires a vast space to use it. A mobile-based farmland mapping system equipped with Unmanned Aerial Vehicles (UAV) is added to “Dutatani” integrated farming system, the brainchild of the previous research. This research utilizes GPS u-Blox and Arduino module to generate the land boundaries’ coordinates automatically. This wireless device is connected to the Android app integrated with the online database. The coordinates captured by the wireless device will be received by the mobile app and then turned into an online map taken from the Google Maps API satellite image. The farmland mapping results will be integrated into the Dutatani database, connecting them to the previous farmland mapping information system. Two tests are performed: (1) The accuracy testing on the farmland mapping data with Time to First Fix (TTFF) parameter; (2) Functionality testing to detect the average success rate. Based on the testing results, we conclude that the data collection process takes longer to complete (12 minutes with an average of 5.4 minutes) than the TTFF standard of the GPS u-Blox (2 minutes). The system testing success rate is 82% of the total functionality testing average we performed. Thus, this system is successfully developed, albeit its limitation in the utilization duration.

Key words : Web Mapping, Mobile Mapping, Drone, GPS, Arduino, Precision Farming.

1. INTRODUCTION

Indonesia is an agrarian country, with the majority of its population working in the agriculture sector. As one of the main agriculture business resources, farmland becomes the government’s one among many focuses on agriculture development agenda. The Indonesian government shows its support to the improvement and advancement of its agriculture sector by distributing the land concession rights in the form of land certificates to farmers across the country so that they have legal rights. The government is also open to developing agricultural technology to improve agricultural products’ quality and streamline the farmland management process. The existence of an agricultural information system further supports this fact.

Dutatani is one of the agricultural information systems developed continuously by the developer team of Universitas Kristen Duta Wacana Information Technology Faculty since 2016 (http://dutatani.id) [1]. The Integrated Agricultural Information System (IAIS) focuses on developing a precise farmland mapping system by utilizing the farmlands’ satellite coordinates. This web-based system is connected to Google Maps API services to retrieve the longitude and latitude coordinates and form them into each farmland’s spatial information [2]. The research team encountered several issues when using the website to map the farmlands. These included the lack of human resources needed to map the farmland, inefficient access, lack of accuracy regarding the farmland input process, and the difficulty accessing invisible areas.

This research aims to develop a method to collect land boundaries’ coordinates by utilizing drones equipped with GPS u-Blox [3], as shown in Figure 1, and Arduino wireless prototype to go over the farmlands’ boundaries. The decision to use the GPS uBlox module device is due to its beneficial features, such as batteries, data backup storage devices, electronic compass, and ceramic antenna that can help capture the signal [3]. This research will use the GPS u-Blox by default, so the *AssistNow Autonomous* feature is yet to be activated [3].

Figure 1: GPS u-Blox Module

The use of Android, drone, and GPS u-Blox module adds additional features to the farmland mapping system. This technology aims to solve issues that occur in the field and improve the farmland mapping process' efficiency and effectiveness. This research will try to answer the following questions: (1) How is the implementation and development process of the farmland mapping mobile system? (2) What is the accuracy and precision level produced by the mobile mapping, drone, and GPS u-Blox in assisting the farmland mapping process?

To answer both questions, the research team uses the Rapid Application Development (RAD) software to develop the farmland mapping system. RAD has also been used to create the web mapping system [2] and the Dutatani farming portal [1]. Additionally, this research will perform testing against the functionality and accuracy level of the device we develop.

This research aims to develop a method to collect land boundaries' coordinates by utilizing an Android-based mobile technology. It seeks to integrate the data and features within the system. The practical contribution of this research is an IoT and GPS-based integrated farmland mapping system and its testing. This testing involves Tani Harjo and Tani Rahayu farmer group as a case study, both of which operate in the Gilangharjo Village, Yogyakarta. This research gives a new perspective on the improvement of the farmland mapping process by integrating web and mobile-based systems, drones, and wireless devices. Furthermore, this research provides a theoretical contribution to software testing by weighing the accuracy of the geolocation data retrieved by the device.

2. . LITERATURE REVIEW

2.1. Information System and Farmland Mapping Technology

A mapping system is one of the information systems that store existing locations' geospatial data. The Geographical Information System (SIG) is a unique software used to map farmlands [4]. Several Database Management System (DBMS) supports geospatial data, such as PostgresSQL that supports PostGIS Extensions, Openstreet Maps, and MapBox mobile cloud computing mapping services [5], and Google Maps [6].

Farmland mapping information system is an agriculture-based technology implementation for farmers, of which its development has a close relation to the precision farming concept using the needed spatial data. The said system also relates to the result of daring map illustration procedures for regional identification, shown in a structured manner according to the needs [2].

Researches related to the farmland mapping information system include those performed in Indonesia, particularly in Lumajang, East Java [6]. The system being developed is a web-based farmland mapping system that operates on a database and local server. It utilizes Google Maps Online services to display a daring map. That said, the system being developed has yet to integrate mobile device utilization to perform the farmland mapping process. The use of Google Maps to support digital farmland data collection is done using the available services [2], [7]. Google Maps provides a polygon feature [8] to help visualize the current geospatial data [2].

A device that can real-time record farmland mapping data is highly needed. The use of a device that operates in the Android platform helps provide the latest data by prioritizing a user-friendly application and providing more effective solutions [5]. The use of GIS in the farmland mapping process also helps display complex data, aiding the decision-making process regarding the agriculture products' management [9]. Thus, production and operational costs can be monitored [10].

The Farmland mapping information system benefits the decision-makers [11] to support unused farmlands management [12]. The technology used in the farmland mapping information system utilizes Landsat imagery with a segmentation approach to the existing resolutions.

Another mobile device used to support the farmland mapping process is the Unmanned Aerial System (UAS) or a drone [13] [14], [15]. A drone application connected to the mobile app can ease the mapping and data collection process in remote areas [14]. The drone complements the website, as accessing the desktop computer requires internet connection [13].

The use of drones as one among many agriculture innovations encounters several issues. Firstly, drone technology has a rather steep implementation cost [16]. The farmland area will determine the amount of investment needed to implement said technology in the agriculture sector. Furthermore, a drone lacks flexibility and data operability as each drone has different geospatial data [15]. Therefore, a technology with high flexibility and low implementation costs is needed.

This research tries to fill the gap regarding the use of cheaper and more flexible drone technology. The research team uses Arduino, GPS u-Blox, and data transmitter with a radio frequency between 2.4 GHz and 2.5 GHz. This technology aims to help develop a low-cost farmland mapping technology. Meanwhile, GPS u-Blox is one of the low-cost single-frequency devices that effectively collect geospatial data [17].

2.2. GPS and Performance Measurement

According to Chang [18], geographic coordinates are a reference to determine an area above the earth's surface based on the longitude and latitude coordinates. The longitude coordinate determines the measurement of the east or west angle to the prime meridian (an imaginary line that connects the north pole and the south pole) while the latitude coordinate determines the measurement of the north or south angle to the equator (an imaginary line drawn between both poles and parallel to the axis of the planet's rotation). The longitude coordinate (point X) is the west corner (a) of the prime meridian, and the latitude coordinate (point Y) is the north corner of the equator, as shown in Figure 2. The use of GPS also encounters issues as it signal availability, thus disrupting the real-time data retrieval [17].

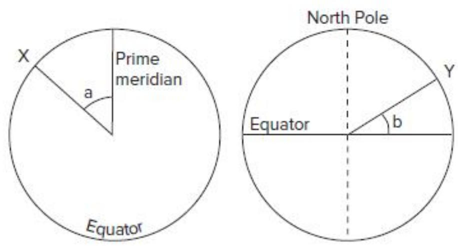

Figure 2: Longitude and Latitude Coordinates

One of the parameters used to measure the level of accuracy is Time To First Fix (TTFF), which is a parameter that defines the GPS module's speed in accessing the almanac and empirical data from the satellite [15]. As each device has a GPS component, it can access the almanac and empirical data from the available satellite [17]. The accuracy testing is required to know whether the geospatial data taken from the mobile device and UAV can be verified. That said, u-Blox is needed to confirm the obtained coordinates' accuracy when developing an Arduino device with the GPS mobile.

2.3. Rapid Application Development (RAD)

According to Naz & Khan [19], Rapid Application Development (RAD) or Rapid Prototyping is a software development method with minimum planning to streamline the prototyping process. The RAD cycle can be seen in Figure 3.

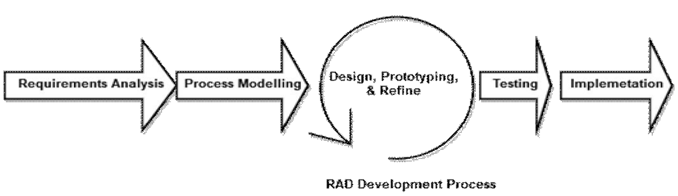

Figure 3: RAD Development Process

The software development with RAD has a cyclical approach and occurs repeatedly [20]. The system is constructed in the early stage of development using the iterative method to determine user requirements. The approach used in this RAD method adopts several structured software development methods, such as the waterfall model, with a shorter time [19]. Additionally, the implementation of RAD in software development emphasizes reusing the components of the existing software and is expected to reduce development and maintenance costs [21]. In its implementation, RAD emphasizes on a brief planning process by focusing on the software development process comprised of development, testing, and user feedback.

3. RESEARCH METHOD

3.1. The Development of Farmland Mapping Software

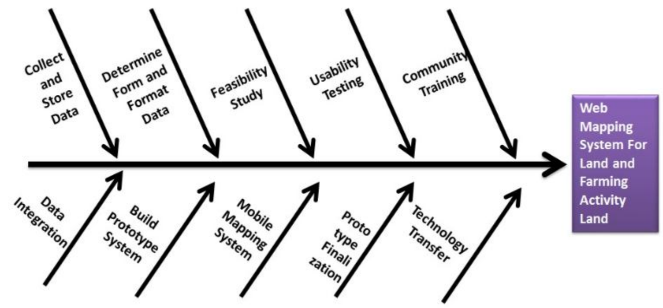

Figure 4. The Development Stages of Web & Mobile Farmland Mapping System

The entirety of this research has been conducted since 2019 with the stages as follow:

1) **Data collection and requirements analysis**
   The data collection process and requirements analysis were done early by farmers using the Focus Group Discussion (FGD) method for the web mapping development [22] with the representatives of Tani Harjo and Tani Rahayu farmer group. To get the potential users' profile, particularly regarding the user's ability to operate a digital device, the research team conducted interviews and tested the use of computers and smartphones among farmers.
2) **Determination of Form and Data Format**
   After interviewing the farmer groups' representatives, the research team collaborated with one of the organizations that operate in the organic agriculture sector and determined the required data. In the early stage, the research team created printed forms and surveyed the farmland ownership, the need for agricultural production facilities and infrastructures, and types of plants ideal to be planted in said area.
3) **Agricultural Data Integration**
   The agricultural data integration was done so that the data gathered during the farmland mapping process can be integrated with the previously developed Dutatani portal [1]. Figure 5 shows the architecture design of the farmland mapping system and its integration with the Dutatani.

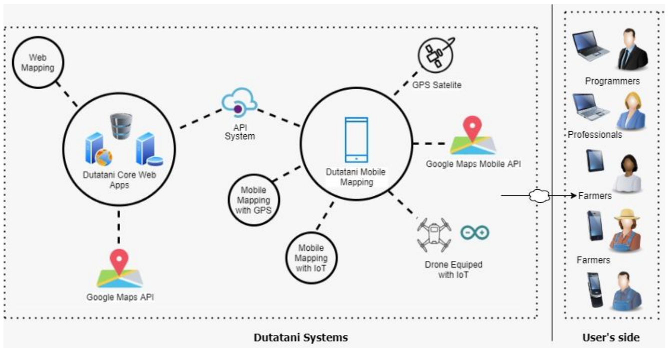

Figure 5: Farmland Mapping System Architecture Design and Integration with Dutatani

4) **Development of Farmland Web Mapping System**
The system was developed using the RAD method [2] [23].
5) **Feasibility Test of Farmland Web Mapping System**
The feasibility test of the farmland web mapping system was done using the TELOS method and obtained an 8.4 score, indicating that the system is worthy of development and use [24]. The research team also conducted a case study on the web mapping study and analysis [25].
6) **Development of Farmland Mobile Mapping System**
The development of the farmland mobile mapping system was ported from its web version, which used the RAD method. The Android-based system is built with a Flutter framework. The IoT system implementation on the farmland mobile mapping system started by analyzing the previous mobile mapping data, system integration, and prototype design.
7) **Feasibility Test of Web and Mobile-based Farmland Mapping System**
The web and mobile-based farmland mapping system testing will be done to examine their usability and the accuracy of coordinates processed and computed by the system. The testing aims to investigate the functionality of the current farmland mapping system. This stage will propose recommendations for the system's future improvements.
8) **Prototype Finalization**
The prototype tested in the seventh stage will be finalized. This stage aims to fix the current content, validate, and verify the data recorded in the current farmland mapping database.
9) **Community Training**
The training will involve potential users of the system. It will mark the beginning of the technology transfer process to Tani Harjo and Tani Rahayu.
10) **Technology Transfer**
The last stage consists of technology transfer to Tani Harjo and Tani Rahayu farmer group so that they can use the system and update the data independently.

3.2. Input Data Analysis

The data used in this research come from Dutatani.id main database, comprising of farmer, farmland, farmland details, farmland status, user, and user category data. The data provided is structured already, several farmer groups inputted most of the filled ones to the dashboard of the web-based farmland mapping information system. This research is a development of the dashboard-based farmland mapping information system that focuses on the GPS, Google Maps API, and IoT-based automatic farmland coordinates documentation technique.

The farmer and farmland data were retrieved from Tani Harjo and Tani Rahayu farmer group's respective regions in Gilangharjo Village. The data can be inputted directly to the Dutatani.id main database through the dashboard-based farmland mapping information system or using this mobile application. The retrieval of farmlands' coordinates and their details utilizes an Arduino prototype transmitter pinned on the drone. The drone is piloted by the farmer group's caretaker to identify farmlands and verify and cross-check them with the map of the mobile app connected to the prototype receiver to receive the longitude and latitude coordinates. The coordinates are then inputted to the Dutatani.id main database using the mobile app.

The results of this research's data input will be connected to the Dutatani.id main database. Therefore, each data will be integrated directly into the dashboard-based farmland mapping information system.

3.3. System Architecture Design

The system architecture design explains the design of the prototype and mobile interface built within the system. The prototype device and mobile app will communicate with each other to retrieve the longitude and latitude coordinates of the farmlands documented in the Dutatani.id server database.

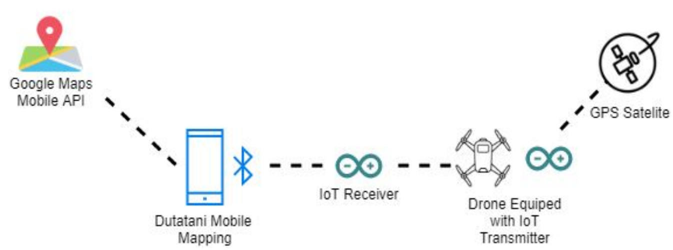

Figure 6: The architecture of Mobile-based Farmland Mapping System and UAV

Two types of prototype devices will be built: transmitter and receiver. The transmitter captures GPS signal and turns it into longitude and latitude coordinates when hovering over a land boundary. It then sends the coordinates to the receiver to be inputted to the mobile application, as seen in Figure 6.

This research will conduct a drone utilization testing for land boundaries data documentation to identify its height limit and long radius when performing the data collection process, position error in GPS, and the strengths and weaknesses of the system.

3.4. Prototype Transmitter Design

The prototype transmitter comprises several hardware devices as follows: 1). Arduino Nano, 2). u-Blox Neo-6M GPS Module, 3). nRF24L01 Socket Adapter Board, 4). Transceiver nRF24L01 2.4GHz, and 5). Flexible jumper cable as shown in Figure 7.

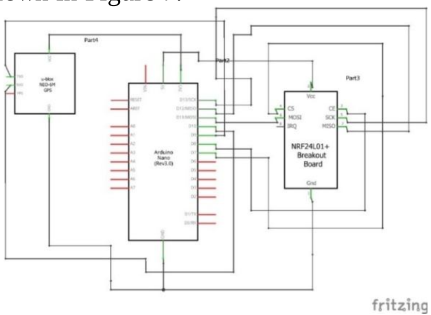

Figure 7: Prototype Transmitter Design Scheme

The transceiver nRF24L01 is connected to the socket adapter board to stabilize the voltage reception so that the data can be transmitted. The prototype transmitter will receive the GPS signal, turn it into longitude and latitude coordinates, and then send them to the prototype receiver through radio frequency (RF).

3.5. Prototype Receiver Design

The prototype receiver comprises several hardware devices as follows 1). Arduino Nano, 2). HC-05 Bluetooth Module, 3). nRF24L01 Socket Adapter Board, 4). Transceiver nRF24L01 2.4GHz, and 5). Flexible jumper cable as shown in Figure 8.

These hardware devices are assembled using the Fritzing application. The prototype receiver will receive the data transmitted by the prototype transmitter through a radio frequency signal. The longitude and latitude coordinates will then be communicated to the mobile application via Bluetooth.

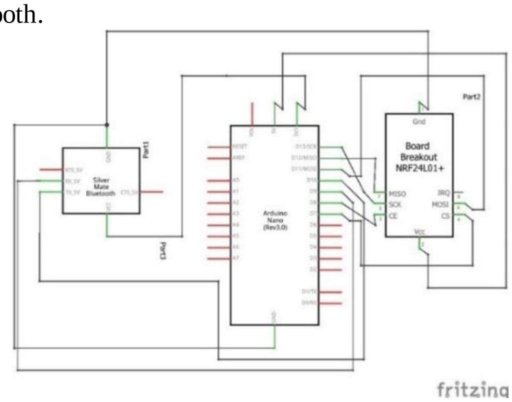

Figure 8: Prototype Receiver Design Scheme

4. RESULT AND DISCUSSION

The product of this research is a Flutter framework-based mobile farmland mapping system for Android ported from the current web version [2]. This system has simplified features with additional ones, such as add GPS-based and drone-based coordinates data. Figure 9 showcases the Dutatani mobile mapping system that has been built.

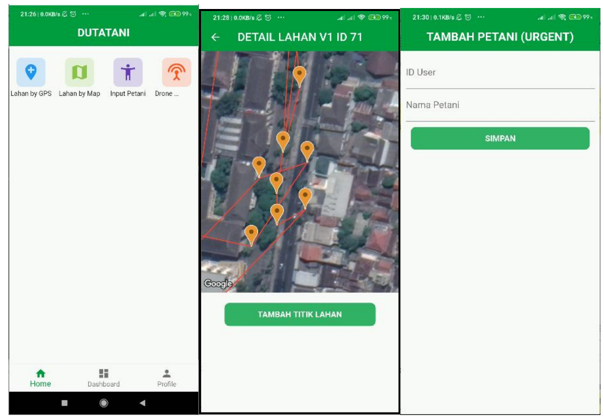

Figure 9: Android-based Mobile Mapping System

The research team conducted testing on a drone equipped with a wireless prototype for farmland mapping and the system's main features. The testing was done in the field of Tani Harjo and Tani Rahayu farmer group at sunny noon. The testing used Drone FIMI A3 weighed 560 grams and was equipped with a GPS, HD 1080P camera, and a 2-axis camera gimbal. While it can be controlled, the drone can only carry 120-gram additional weight, receive at least 10 GPS satellite signals to fly, and has 8 minutes signal wait time. The implementation of the drone can be seen in Figure 10.

Figure 10: Drone Implementation with Prototype Transmitter

The 60-gram prototype transmitter was attached to the drone using a suspension device to stick to the drone's body without hindering the propeller. The prototype receiver was put on the ground with its antenna pointed diagonally to the drone.

4.1. Long Radius and Height Limit of Farmland Documentation

The long radius testing was conducted by flying the drone and an active prototype transmitter with a height of 2 meters from the ground as far away as possible and in a line of sight state (no obstruction between the prototype transmitter and the prototype receiver for barrier-free signal transmission). The first and last coordinates identified by the mobile application when the prototype receiver no longer received coordinates and the mobile app no longer displayed new coordinates were then monitored.

Figure 11: First and Last Coordinates of Ranging Testing

Figure 11 showcases the first coordinates and the longest coordinates of the five testing trials done within a 207-meter long radius before the prototype receiver stopped receiving RF signal from the prototype transmitter during the ranging testing. The maximum height to which it could see the land boundaries correctly was between 1.5 meters and 2 meters, as seen in Figure 12.

Figure 12: Maximum Land Height of 2 Meters

4.2. Time to First Fix Testing (TTFF)

The TTFF GPS prototype testing was done by placing the GPS module in the rice field area. There was a GPS module to receive the longitude and latitude coordinates in the prototype transmitter. Table I showcases 30 rice field coordinates documentation accuracy testing using the GPS uBlox NEO-6M module.

Table I: GPS Module Accuracy Testing

Test	TTFF (seconds)	Test	TTFF (seconds)
1	302	16	720
2	156	17	344
3	293	18	610
4	123	19	434
5	512	20	20
6	242	21	42
7	632	22	242
8	362	23	321
9	449	24	436
10	251	25	285
11	645	26	342
12	170	27	460
13	63	28	197
14	184	29	112
15	659	30	146
		Average	325.133

The TTFF average of the 30 testing trials is 325.13 seconds or 5.4 minutes. The longest TTFF duration is 720 seconds or 12 minutes, while the fastest TTFF duration is 20 seconds or 0.3 minutes. There is quite a difference between the TTFF testing results due to inactive AssistNow Autonomous mode.

4.3. Functionality Testing

The functionality of the mobile mapping application has been tested using a test case scenario. The 22 test case scenarios are divided into ten categories, as seen in the Table II Requirement Traceability Matrix (RTM).

Table II: Requirement Traceability Matrix

Req No	Req Desc	Test Case ID	Test Case Scenario
1	Login	TA01 TA02	Open Dutatani application Log into the system with admin username and password
2	Select Location Mapping Menu with IoT	TB01	Select the mapping menu with IoT
3	Select List of Farmers	TC01 TC02	View list of farmers Select a farmer by the name of “AMBARNUR."
4	Search farmer name	TD01	Search for a farmer named “AMBARNUR."
	Access add farmland menu	TE01 TE02	Select add farmland by clicking on the (+) button at the bottom right of the screen Connect cellphone with "MyIoT 02" IoT device
6	Add farmland	TF01 TF02 TF03	Wait for a GPS signal to pinpoint the location on the map. Fill the required information on the farmland (e.g., farmland name, area, and village) Save farmland data by selecting the save button
7	View farmland	TG01	View farmland with the name inputted in

Req No	Req Desc	Test Case ID	Test Case Scenario
			TF02
		TG02	Access farmland coordinates the details menu by selecting a farmland's name.
		TG03	Access farmland coordinates by selecting the farmland coordinate details menu
8	Complete farmland coordinates data	TH01	Connect cellphone with "MyIoT 02" IoT device
		TH02	Wait for GPS signal to pinpoint the location on the map
		TH03	Add coordinates by pressing add coordinates button
9	Delete farmland	TI01	View the farmland with the name inputted in TF02
		TI02	Access farmland coordinates the details menu by selecting a farmland's name.
		TI03	Delete farmland by selecting delete farmland data menu
10	Logout	TJ01	Select the profile tab
		TJ02	Press the logout button

Based on the 30 users' testing, the functionality of the application has an 82% average success rate, making it deemed useful. Table III and Figure 13 showcase the results.

Table III: Testing Results

Test Case	Test Case Scenario	Number Pass	Percentage %
TA01	Open Dutatani application	30	100%
TA02	Log into the system with admin username and password	28	93%
TB01	Select the mapping menu with IoT	28	93%
TC01	View list of farmers	25	83%
TC02	Select a farmer by the name of "AMBARNUR."	25	83%
TD01	Search for a farmer named "AMBARNUR."	26	87%
TE01	Select add farmland by clicking on the (+) button at the bottom right of the screen	20	67%
TE02	Connect cellphone with "MyIoT 02" IoT device	20	67%
TF01	Wait for GPS signal to pinpoint the location on the map	22	73%
TF02	Fill the required information on the farmland (e.g., farmland name, area, and village)	28	93%
TF03	Save farmland data by selecting the save button	26	87%
TG01	View farmland with the name inputted in TF02	29	97%
TG02	Access farmland coordinates details menu by selecting a farmland's name	20	67%
TG03	Access farmland coordinates by selecting the farmland coordinate details menu	22	73%
TH01	Connect cellphone with "MyIoT 02" IoT device	20	67%
TH02	Wait for GPS signal to pinpoint the location on the map	20	67%
TH03	Add coordinates by pressing add coordinates button	28	93%
TI01	View the farmland with the name inputted in TF02	21	70%
TI02	Access farmland coordinates details menu by selecting a farmland's name	20	67%
TI03	Delete farmland by selecting delete farmland data menu	27	90%
TJ01	Select the profile tab	26	87%
TJ02	Press the logout button	30	100%

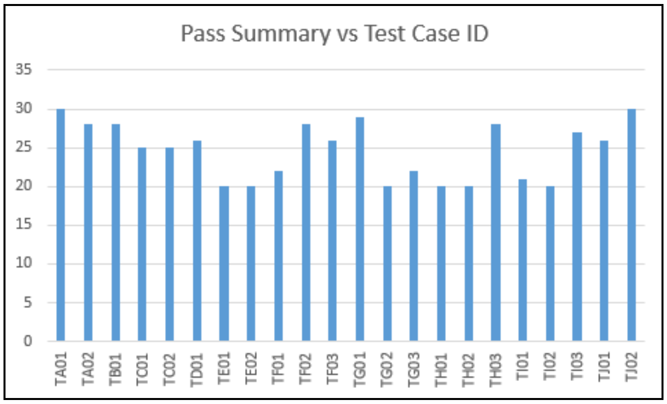

Figure 13: Graphic of Testing Scenario Result

In this test case scenario, the logging in and out of the application scenarios get the highest score. Meanwhile, adding farmland and waiting for GPS signals from the IoT devices has the lowest score. This result correlates with the TTFF testing result, which took 12 minutes and an average of 5.4. Compared to GPS uBlox 2-minute standard, this testing has a relatively longer time than the TTFF standard.

5. CONCLUSION

Based on the research results and system implementation, it can be concluded that the mobile farmland mapping system has been successfully developed. The research successfully uses drones to record land boundaries' coordinates in a barrier-free location. The system being built has a 12-minute wait time to access a stable GPS signal. The wireless prototype being built can send the data from a maximum distance of 207 meters. The system can be integrated with the old mapping system by adding new menus. The accuracy error level of drone utilization reaches an average of 86.66 cm (high accuracy). For the future development of the system, it is recommended to improve the drone's accuracy using a combination of measurements taken from the satellite image and area prediction based on the satellite image information.

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