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Monitor The Soil Moisture with IoT System To Improve Urban Farming Productivity and Enhance Food Security

Mukhamad Kasendra[1] ✉, Dendy K Pramudito[2], Dedi Afandi[3]

[1,2,3]Universitas Pelita Bangsa, Indonesia

k4s.endra@gmail.com

Abstract

Farming or planting is part of human efforts to meet food needs, but along the time agricultural land is decreasing where one of the causes is due to infrastructure development, such as road construction, office buildings and others, so that the threat of a food crisis has arisen. A new agricultural method or technique emerged by utilizing existing land such as home yards as a substitute for rice fields called urban farming or urban agriculture, where this agriculture technique is not only conducted in rural areas but also can be implemented in urban areas. Of course it is a good initiative, as one of the actions in dealing with the threat of a food crisis due to reduced agricultural land. However, during implementation, urban farmers find technical obstacles such as monitoring or controlling soil conditions and with time limitations. With the improvement or innovation of technology and the availability of the internet, this should be able to solve the problem, considering that these two things have not yet utilized properly in terms of agricultural activities, such as the use of the internet by farmers which is generally used for communicating. One technology that can be used and solved that problem is the Internet of Things (IoT). IoT can be utilized in monitoring the humidity of the soil via smartphones in real time. So, the obstacles that arise can be resolved by utilizing IoT and of course for the future this technology can be developed according to the needs.

Keywords: *Farming, Urban Farming, Internet of Things, Technology, Innovation.*

1. Introduction

The needs for food have become the primary needs in human life. It has been explained in Article 27 Section 2 UUD 45, which explains that people have the same rights to get a proper life, including in terms of food as one of the main needs[1]. Now around the world we are facing the "Food Crisis" phenomenon, that brings an impact on the increasing number of starving people. Currently the food crisis and the threat of starvation is becoming a global problem[2]. Currently approximately 2.37 billion people or nearly 30% of world population are facing food crisis or security, which means they do not have adequate access to food to meet their nutritional needs and prevent malnutrition[3]. Starvation due to the food crisis is occurring in Indonesia too. The first reason why the food crisis happens in Indonesia is because the agricultural land is getting smaller and turning into an infrastructure and industrial needs and second is decreasing soil quality that impacts the decreased food productivity[2]. From this situation especially due to the reduction of agricultural land due to field conversion. Then arise a new concept or phenomenon that can help or reduce the emergence of a food crisis and improve the food security by utilizing existing land namely "Urban Farming".

Urban farming is the activity of cultivating plants or farming and also livestock around urban areas that have the main purpose to get the food[4]. Urban farming has many benefits that can be felt by people. The general impact is we are contributing to dealing with the food crisis issue. Urban farming has many benefits, such as being a solution for the problems that occur in urban areas by creating green open spaces, improving food security and also increasing the value of mutual cooperation[5]. Its application in Indonesia still has some challenges, such as the awareness and knowledge of people who want to start it[6]. There are many factors that make everyone unsuccessful when implementing it, especially because of time limitation to monitor the condition and other technical factors including lack of utilization of technology including the internet, such as to monitor soil moisture, where the positive impact of technologies improve the economy and productivity [7]. There are a few farmers who are not yet connected to the internet and utilizing the technology and currently the internet is available, although it is not yet evenly distributed, but mostly farmers use it for communication but not been used or utilized for technology that support their activities [8].

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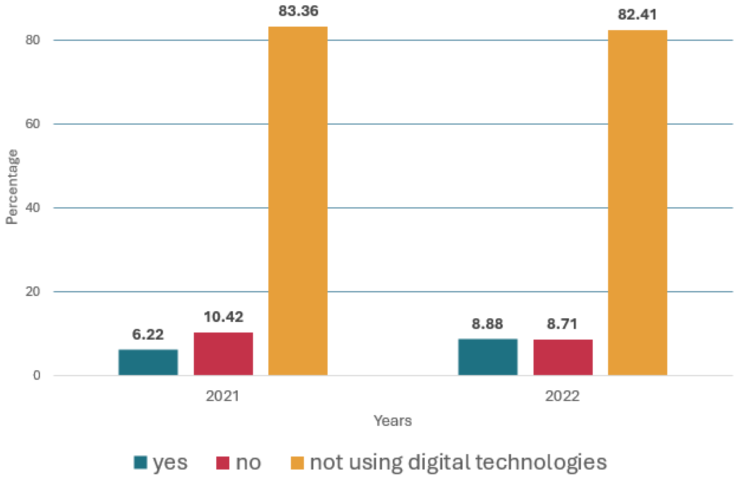

Figure 1. Internet Usage Among Farmers in 2021 and 2022 [8]

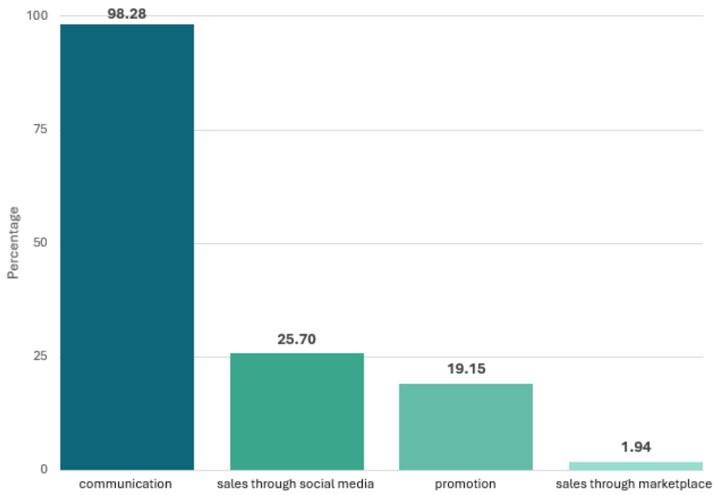

Figure 2. Percentage of Farmers Using the Internet [8]

Based on Figure 2 there is technology that is suitable for urban farmers who utilize the internet and technology to support their activities to solve the problem such as monitoring soil moisture as we know soil condition is an important part, it is called Internet of Things (IoT) to become smart planting or farming, where it is utilizing an IoT to conduct automatic monitoring and control farming areas[9]. IoT is a technology that has a concept by utilizing an internet connection to connect with other objects with goal is to support the activities become easier[10] and IoT works according to the interactions between existing and connected components automatically and unlimited distance [11] so IoT can help the urban farmer still have the full control of their vegetable that can be accessed remotely via smartphone and IoT can be a support system for urban farmer to support them to ensure their get the desired result with the limitation, this is like the definition of the system itself, which is a combination of the elements to carry out certain activities to achieve certain goals [12]. So with this implementation system smartphones can be utilized more and almost all people have it, because smartphones are becoming a primary need[13].

2. Research Methods

There are several stages in implementing an IoT system to ensure the system runs as expectation, starting from problem, problem analysis, data source, method, testing and testing result.

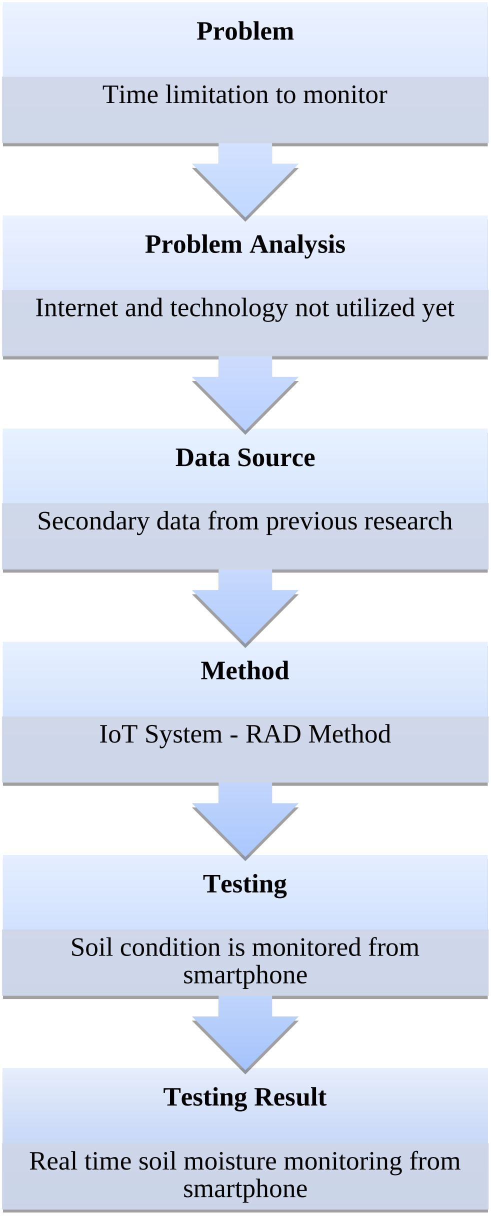

Figure 3. Research Stages

2.1. Problem and Problem Analysis

Urban farmers are not the main job for the urban society, so they have a problem to monitor the soil condition due to time limitations. As we all know soil is an important aspect of agriculture that needs to be maintained and controlled to ensure the result of the vegetable is in accordance with their expectation. And if we see the Figure 2 when the internet is not utilizing yet to assist their activities, this is a great opportunity to implement IoT technology that can be applied to accommodate their activities. So with utilization of IoT, it can be a support system for farmers in carrying out or monitoring agricultural activities in real time using a smartphone without interrupting other activities.

Herewith SWOT analysis that compares agriculture with and without technology or IoT. SWOT analysis is used to conduct a comprehensive analysis[14].

Table 1. SWOT Analysis

Agriculture Without IoT	
Strengths	**Weakness**
1. Urban Farmers can monitor soil moisture conditions directly, without needing additional devices. 2. Low operation cost.	1. Observation of soil moisture conditions is not accurate and real time. 2. Actions or responses taken are slower, as they depend on direct monitoring or observation.
Agriculture With IoT	
Opportunities	**Threats**
1. Urban farmers can monitor soil moisture conditions in real time 2. Automation systems when performing action, such as automatic watering.	1. Potentially this development has not been accepted by farmers. 2. Additional operational costs.

2.2. Data Source

The focus of data source is to get the value as information for IoT implementation. The information collection method that is used in this research is using secondary data derived from previous research or information that is relevant with the IoT system to be developed. The data source needed in this research is about the recommended data ranges of soil moisture that are used in agriculture. Based on the secondary data that has been obtained from websites and articles. The range data will be used as references in determining the ideal value of soil moisture is 41% – 80%, it is based in the research that has been done, for optimal results soil moisture should be maintained at around 80% of field capacity, with 40% being the maximum level of water stress on plants or vegetables[15].

2.3. Method

The design process uses the RAD (Rapid Application Development) method which has the stages of requirement planning, design workshop, instruction phase and implementation[16]. RAD is an object based software development model designed to accelerate the development process. This method aims to reduce the time usually required in development, making it more efficient, effective[17] and to ensure the feasibility of a system, where the purpose of it is to evaluate and develop the system[18].

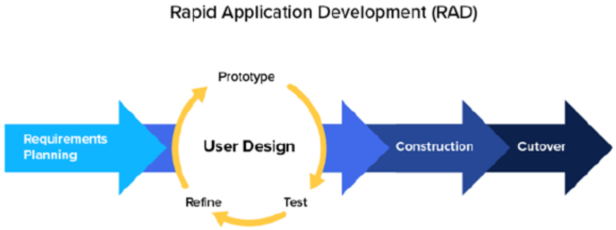

Figure 4. RAD Method [17]

a. Requirement Planning

   The initial stage of system development focuses on problem identification and data sources. In this context of an IoT system for soil moisture monitoring system, it is important to understand the needs of farmers or users in terms of real time monitoring information. The goal is to understand the proposed system as well as users' needs. And the expected user needs from this IoT systems are:

   1. Urban farmers can monitor soil moisture conditions in real time.
   2. Automation systems when performing action to conduct automatic watering.

b. Design Worksop / Design System
At this phase, user participation is very important to achieve the desired goals. The design system is carried out iteratively to find any gaps between the design and user needs. In this case the design of the soil moisture monitoring system must consider the component that will be used and how data is transmitted through to the IoT network and then visualized. The result of this phase is the suitability of hardware and software components that will be used and proper with this system.

1. Flow process

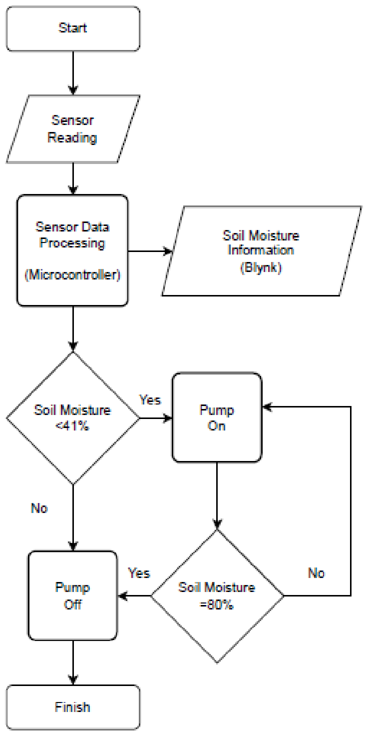

Figure 5. Flow Chart System

The flow process above is the proposed system that will be developed. From this proposed system flow process is already accommodated the condition refers to their or user expectation, such as this system will conduct the automatic watering when the soil moisture value is less than 41% and the automatic watering will be stopped if soil moisture value equal than 80%. The soil moisture data range that is used for this system is following the reference that described in **2.2. Data Source**.

2. Design System

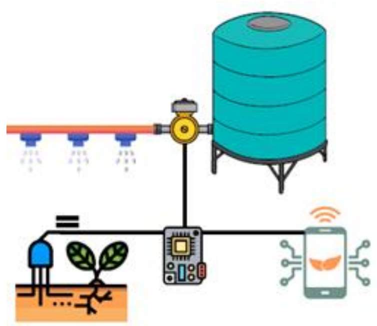

Figure 6. Design System

This system is an Internet of Things (IoT) utilizing sensor and microcontroller ESP32 that has an internet connection feature. The picture above explains the design of this system which functions to monitor or control the condition of soil as the main part of agriculture. Where sensors receive or collect data from the surrounding environment then it will be used as a reference for describing soil conditions and also for pump control. Furthermore the data will be sent from sensor to microcontroller to be processed becoming a request to the actuator (relay) to operate the pump and also sending information to the smartphone which will be displayed or visualized through to the blynk application.

3. Components

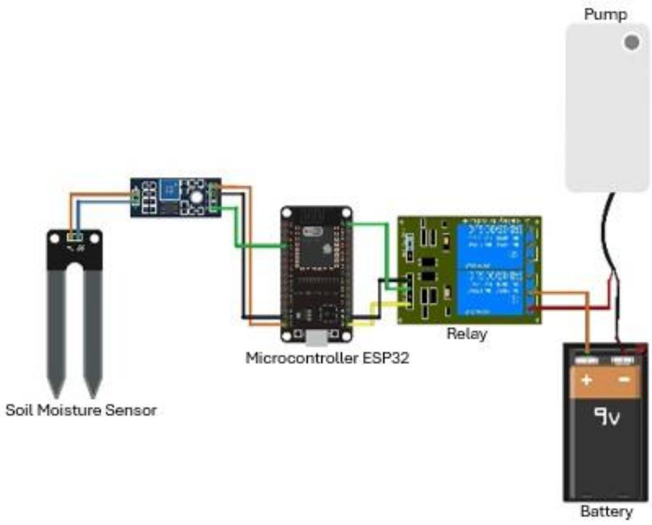

Figure 7. Components Interaction

This section describes the interactions between the software and hardware that will be developed. There are three parts or interaction that will be explained:

a. Software
   1. Arduino IDE, it is a text editor that functions to create, edit and also compile the code and then sent it to a compatible microcontroller[19].
   2. Blynk application, is one of the popular application in the IoT system because it offers ease of creation without need to write program code and this application can be accessed through website and smartphones, so there are many user utilize it to developed IoT application[20].
b. Hardware
   1. Microcontroller ESP32, it is a special microcontroller because it already has a WiFi module integrated directly on the circuit board, so it can connect to WiFi without adding additional WiFi module devices[21].
   2. Soil Moisture Sensor
   3. Relay
   4. Pump
   5. Battery
c. Component Interaction
   1. Sensor Soil Moisture with Microcontroller ESP32

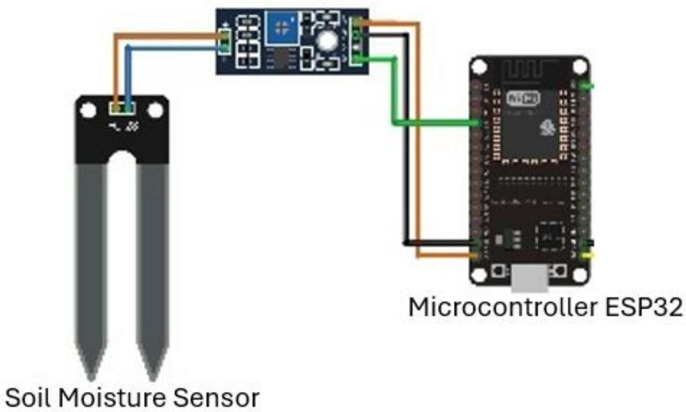

Figure 8. Interaction between Sensor Soil Moisture with Microcontroller ESP32

Table 2. Interaction between Sensor Soil Moisture with Microcontroller ESP32

Pin Sensor	Pin ESP32	Explanation
VCC	3V3/VIN	Provides power to the sensor.
GND	GND	Connect ground sensor to microcontroller.
A0	ADC	Analog to Diagram Converter, To read the analog signal from sensor to determine the moisture level.

2. Microcontroller ESP32 with Relay

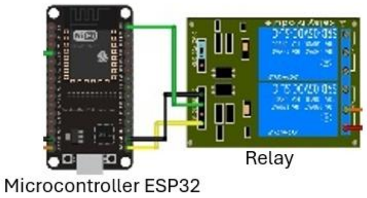

Figure 9. Interaction between Microcontroller ESP32 and Relay

Table 3. Interaction between Microcontroller ESP32 and Relay

Pin Relay	Pin ESP32	Explanation
VCC	3V3/VIN	Provides power to the sensor.
GND	GND	Connect ground relay to microcontroller.
IN1	GPIO	Pin for setting the Relay status (On/Off).

3. Relay with Pump and Battery

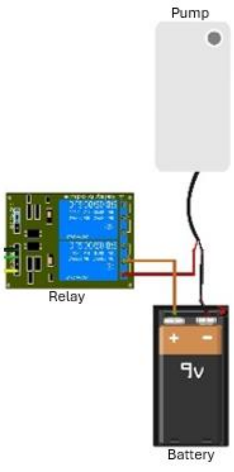

Figure 10. Interaction between Relay with Pump and Battery

Table 4. Interaction between Relay and Pump

Pin Relay	Pump	Explanation
NO (Normal Output)	One of the pump input	Pump will start when needed or according to the set conditions.

Table 5. Interaction between Relay and Battery

Pin Relay	Battery	Explanation
Com	Positive (+) part of the battery	To control power from the battery.

d. Mockup

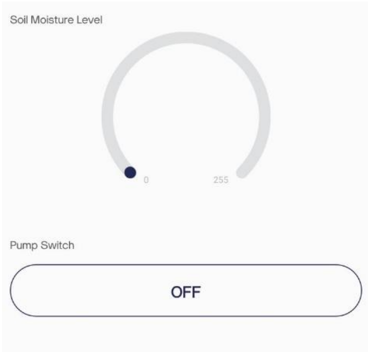

Figure 11. Visualization mockup from Blynk Apps

This is visualization mockup from blynk apps to visualize the result of sensor readings that will be developed. On the display there is a gauge widget that has a function to display soil moisture level and then there is a button or switch to turn on and off the pump manually.

c. Instruction / Development Phase

In this phase is the execution of the design, such as purchasing the suitable component, UI and programming with Arduino IDE in accordance with the design that have been determined at the design system phase and in this phase the system testing is carried out to ensure the gap that found in design system is fixed.

d. Implementation

Implementation phase is the final phase to implement the IoT system.

3. Results and Discussion

3.1. Results

Herewith the final result of implementation of IoT soil moisture monitoring system.

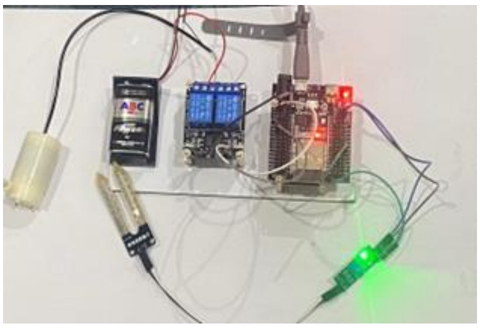

Figure 12. Component Circuit

Figure 13. Implementation IoT System

The results of testing the soil moisture monitoring system that has been carried out, where there are two aspects in this test that need to be considered as describe in point 2.3 Method and Requirement Planning section to ensure this system can run according to these requirements, there are:

1. Urban farmers can monitor soil moisture conditions in real time.
2. Automation systems when performing action to conduct automatic watering.

Table 6. IoT Reading Result

Time	Sensor Reading	Remark
21:01:39.764	83	Wet Soil Condition, Pump Off
21:01:40.745	82	Wet Soil Condition, Pump Off
21:01:41.747	83	Wet Soil Condition, Pump Off
21:01:42.747	58	Normal Soil Condition
21:01:43.745	49	Normal Soil Condition
21:01:44.746	54	Normal Soil Condition
21:01:45.746	54	Normal Soil Condition
21:01:46.754	53	Normal Soil Condition
21:01:47.746	53	Normal Soil Condition
21:01:48.736	54	Normal Soil Condition
21:01:49.747	54	Normal Soil Condition
21:01:50.779	54	Normal Soil Condition
21:01:51.763	53	Normal Soil Condition
21:01:52.762	55	Normal Soil Condition
21:01:53.746	53	Normal Soil Condition
21:01:54.744	65	Normal Soil Condition
21:01:55.746	53	Normal Soil Condition
21:01:56.763	51	Normal Soil Condition
21:01:57.763	37	Dry Soil Condition, Pump On
21:01:58.765	40	Dry Soil Condition, Pump On

In table 6. IoT Reading Result that appear on serial when running program in Arduino IDE, it will explain the soil moisture value and also a description of action taken according to the value, with following explanation results:

1. When reading equals or exceeds 80% the pump will stop and the serialized information “Wet Soil Condition, Pump Off”.
2. When reading is within the data range of 41% - 80% the serial shows the information “Normal Soil Condition”.
3. When reading is less than 41%, the serial will show “Dry Soil Condition, Pump On”.

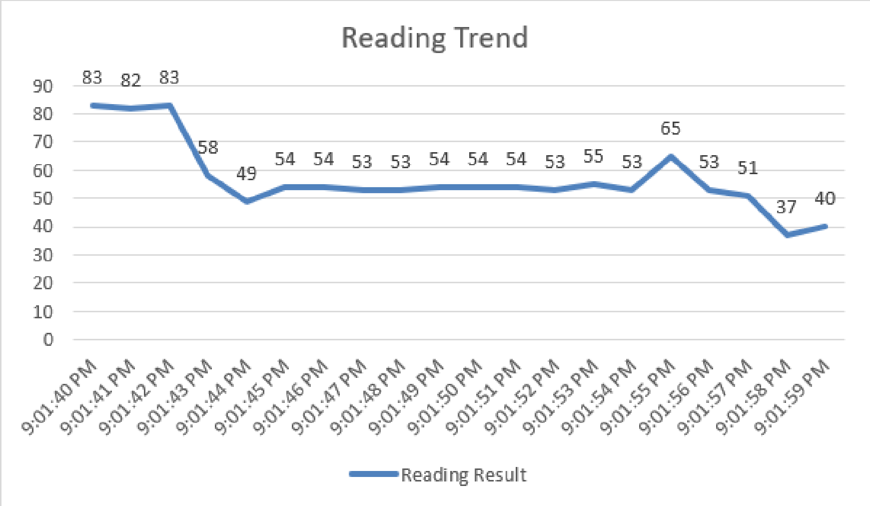

Figure 14. Trend Reading Result

And if observed through figure 14. Trend Reading Result and table 6. IoT Reading Result based on the time information obtained this IoT system can detect or respond quickly to any changes that occur in soil condition. **So this has fulfilled requirement No.1**.

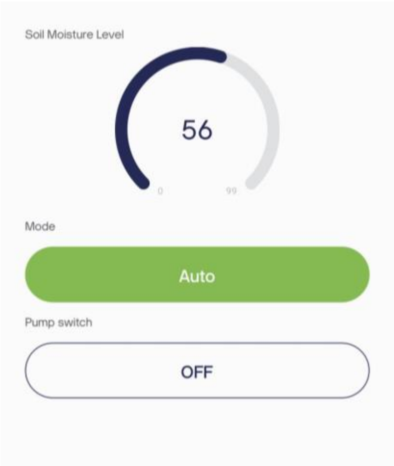

Figure 15. Visualization Soil Moisture Level

In figure 15 it explains this system is successful in visualizing soil moisture value from a blynk application that can be accessed from a smartphone and refer to table 6 when the value is less than 41% then pump is automatically on, so that both conditions have **fulfilled requirement No.2**.
In the final result shown in figure 14 there is an additional feature that was developed that is “feature mode”. This feature gives the user flexibility to determine the desired mode of watering, such as if there is an automatic watering that does not work and also if the user has their own moisture references based on the type of vegetable.

Table 7. Requirement Fulfillment

No	Requirement	Requirement Type	Result
1	Real time monitoring	Mandatory	Pass
2	Watering Automation	Mandatory	Pass
3	Visualization	Mandatory	Pass
4	Feature Mode	Improvement - Optional	Pass

3.2. Discussion

After number of phases of the system design and implementation process, it was found that the device can function or running properly in accordance with requirement, this system can read the soil moisture value and visualize it through to blynk application in real time and also can perform watering automatically and even this system was developed by providing the mode or type of watering desired by the user, with automatic and manual watering options.

a. Utilize Internet and Technology for Agriculture
   Based on the processes that have been carried out and if refer to table 7 a result is derived where IoT can be a support system for urban farmers in carrying out their activities without disturbing others activities. With the massive expansion of the internet, it hopes that farmers will not only utilize the internet for communication only, but also how to utilize internet and technology such as IoT to support and help farmers to be able carry out agricultural activities without disturbing other activities.
b. IoT as Support System
   The success of this IoT system to read and visualize the value of soil moisture value in real time, shown in figure 14, makes it important information for urban farmers which is unable to be performed every time and certainly can help to ensure the expected agricultural results. The utilization of IoT is also considered very important in carrying out activities so that work carried out is much more efficient.
c. Implementation RAD Method
   Soil as a planting medium is an important aspect for agriculture, so it must be controlled well to ensure it is always in a good condition, such as soil moisture value that is used for vegetables. This system also designed to be adjusted in accordance with the requirement that is watering, so by designing this system with RAD method is the right decision because RAD has a phase to developing system as in the figure no 4, especially for design system. This method on the design system phase is ensuring the prototyping is fulfilling the requirement, so when this phase is already finished this system is ready to utilize. It is evidenced by the system needing to meet the soil moisture value in range 41% - 80% and the pump turning on and off when it meets the condition automatically.
d. Comparison
   Refer to table 1 about SWOT analysis, when comparing agriculture with IoT and without IoT, and there are found some opportunities when farmers utilize IoT like real time monitoring and automation watering. And it's proven by the result that was already mentioned before and summarized in table 7.

4. Conclusion

Based on the results of the design and implementation IoT soil monitoring system, it can be concluded as follows:

a. **The application of IoT soil moisture monitoring system, allows users to monitor soil condition** in real time through a smartphone by utilizing an internet connection. Of course these results help urban farmers in ensuring the condition of the soil moisture is always in a good condition.
b. **Using ESP32 that already supports WiFi as a microcontroller that is used in this system is running well** to carry out its duties in receiving, processing and sending data that is received from sensor to blynk application.
c. **The applied automatic watering system is running well**, the pump will respond to the following condition that is already determined. The meaning of the condition is about pump response, such as pump will start watering when the soil moisture level is less than 41% and pump will stop watering when the soil moisture level is above 80%.
d. **Manual watering feature as one of the contingency plans** if the automatic watering system is not functioning properly. This feature is part of the system development/improvement and it is running well.

And based on the design and implementation this system that has been carried out, there are several suggestions which are expected to be used for further development, including:

a. **Additional features are** possible to do in this system, such as using sliders on the blynk application so this system can be used for all kinds of plants and vegetables according to the wishes of the user.
b. **System development**, with many aspects in the world of agriculture, this IoT system is very possible to be developed in supporting the needs in agricultural activities, such as notification and addition of sensors according to needs and also related to the data storage.

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