International Journal Software Engineering and Computer Science (IJSECS)
4 (3), 2024, 1163-1172
Published Online December 2024 in IJSECS (http://www.journal.lembagakita.org/index.php/ijsecs)
P-ISSN: 2776-4869, E-ISSN: 2776-3242. DOI: https://doi.org/10.35870/ijsecs.v4i3.3225.

RESEARCH ARTICLE Open Access

Design of a Watering Control System for Chili Seedlings Using Arduino Uno

Syarifah Fitrah Ramadhani
Information Systems Program, Universitas Ichsan Gorontalo, Gorontalo City, Gorontalo Province, Indonesia.
Email: syarifahfr@stmikadhiguna.ac.id.

Mohamad Efendi Lasulika
Information Systems Program, Universitas Ichsan Gorontalo, Gorontalo City, Gorontalo Province, Indonesia.
Email: fendidsn.ui@gmail.com.

Andi Bode *
Information Systems Program, Universitas Ichsan Gorontalo, Gorontalo City, Gorontalo Province, Indonesia.
Corresponding Email: andibode22@gmail.com.

Moh. Adrian Djailani
Information Systems Program, Universitas Ichsan Gorontalo, Gorontalo City, Gorontalo Province, Indonesia.

Risky Randa Posumah
Information Systems Program, Universitas Ichsan Gorontalo, Gorontalo City, Gorontalo Province, Indonesia.

Received: September 28, 2024; Accepted: November 15, 2024; Published: December 1, 2024.

Abstract: Technology in agriculture has brought revolutionary changes in the way we view and treat food production. This research is the design of a watering control system because controlling plant watering is an important factor in healthy plant growth. With the use of technology such as Arduino Uno, designing an automatic watering control system that can monitor soil moisture, regulate watering according to plant needs, besides that, another goal is to increase agricultural productivity by optimizing watering of chili plants. The results of research and testing that have been carried out, the Arduino Uno based automatic plant irrigation tool shows success in its design and operation; this tool has been designed and made using an Arduino Uno microcontroller and YL-69 sensor, as well as other supporting devices, which function according to their purpose and function with good performance in automatic watering. This tool can work effectively when the humidity sensor sends data to the Arduino, where if the received data is below the specified limit, the relay automatically activates the water pump to perform watering. During the process, if the sensor detects soil moisture levels above the limit, the relay will turn off the pump and stop watering.

Keywords: Arduino Uno; Automatic Watering; Chili Seedlings; Control System; Intelligent System.

1. Introduction

The agricultural sector, as one of the main pillars of human civilization, continues to undergo significant transformations along with technological advances. The technological revolution in agriculture has fundamentally changed our perspective and approach to food production [1][2][3][4]. From the use of smart sensors to sophisticated data processing techniques, these innovations have opened the door to efficiency, increased productivity, and sustainability in agricultural practices. The benefits offered by these technologies provide great hope for realizing more efficient food production, better conservation of natural resources, and sustainable economic growth [5][6][7]. Technology integration becomes increasingly crucial to address the challenges faced by the modern agricultural sector. One crucial aspect in agricultural practices is water management, especially in the form of plant watering. Proper and measured watering is a determining factor for optimal plant growth and development. Chili plants, as one of the agricultural commodities with high economic value, are highly dependent on the availability of adequate water to carry out the process of photosynthesis and meet their nutritional needs [8][9]. The specific water requirements of chili plants require special attention in watering practices. Generally, farmers water manually based on a predetermined routine schedule. However, this manual watering method is often less effective because it requires a lot of time, energy, and attention [10][11][12][13]. In addition, manual watering is also prone to human error, such as uneven watering or excessive watering, which can have a negative impact on plant growth and health. Agriculture, as one of the most important economic sectors globally, continues to strive to improve efficiency and productivity through the adoption of technology. The use of technology in agriculture is no longer just an option, but a necessity to meet the increasing need for food along with the growth of the world's population [14]. Crop irrigation control, as one of the important aspects of agriculture, plays a very vital role in ensuring optimal plant growth and health. Chili plants, which are known as one of the agricultural commodities that require special attention in terms of watering, often experience obstacles in manual irrigation practices. Manual irrigation control is often inefficient and imprecise in meeting plant water needs, which can result in water waste, uneven plant growth, and even root damage due to excess water.

In facing these challenges, the development of an automatic plant watering control system is very important to improve agricultural efficiency and ensure healthy plant growth. A well-designed automatic watering system can provide a more effective and efficient solution in meeting plant water needs, while reducing dependence on human labor. This system can also help farmers optimize water use, reduce waste, and increase crop yields. The research focuses on designing a chili seedling watering control system using the Arduino Uno microcontroller platform. The main objective of this research is to develop a system that can automatically monitor soil moisture and regulate watering according to the needs of chili plants. This system is expected to help improve the efficiency of chili plant watering, reduce water waste, and increase agricultural productivity, especially in chili cultivation. Thus, this research not only provides practical solutions for farmers but also contributes to the development of sustainable agricultural technology. In addition, this research also aims to test and evaluate the performance of the designed system. Testing is carried out to ensure that the system can work effectively and efficiently in actual field conditions. The results of this test will provide valuable feedback for future system improvements and development. Thus, this research not only focuses on system design, but also on validation and evaluation of system performance in the context of real applications.

The impact of the research is expected to provide significant contributions in several aspects. First, efficient use of resources, where the automatic control system allows watering of chili plants to be adjusted to the needs of the plants, thereby reducing water and energy waste. Second, increased productivity, where the control system ensures that chili seedlings receive the right amount of water for optimal growth, which will ultimately increase yields. Third, reduced dependence on human labor, where the automatic system can reduce the workload of farmers in manually watering plants. Fourth, increased agricultural sustainability, where more efficient water use can help maintain the sustainability of natural resources. The results of the research are expected to be the basis for the development of more sophisticated and integrated automatic irrigation systems in the future. Thus, this research not only provides practical solutions for farmers, but also contributes to the development of sustainable and environmentally friendly agricultural technology. Through this research, it is hoped that a more efficient, effective, and sustainable irrigation system can be created, which will ultimately improve farmer welfare and overall food security. Through this research, it is hoped that it can provide a significant contribution to the development of more modern and efficient agricultural technology. Thus, this research is not only relevant in a local context, but also has the potential to provide a broader impact on a national and international scale.

2. Research Method

Research on the design of a chili seedling watering control system using Arduino Uno is a study that aims to develop an automatic system for watering chili seedlings using Arduino Uno microcontroller technology. The following are the steps to achieve a goal in this study, namely: The first step in this research is to conduct a literature study related to plant watering control systems, the use of Arduino Uno in agricultural applications and basic principles in designing automatic control systems. Continue to System Design: Design of a Chilean plant irrigation control system using Arduino Uno. This includes selecting the required soil moisture sensor, water pump, and other electronic components. In addition, the user interface for setting the irrigation schedule and other parameters must be designed. Once the system design is complete, the next step is hardware implementation. This involves installing the soil moisture sensor, connecting the water pump to the Arduino Uno, and setting up the other electronic components according to the system design. In addition to the hardware, this research also requires software development to manage control logic, user interface interaction, and sensor data processing. After the system is designed and implemented, trials are conducted to ensure that the Chile seedling irrigation control system works as expected. An evaluation is conducted to assess the performance of the system and make improvements as needed.

2.1 Research Flow Chart

The research may start by identifying the needs of the Chile seedling irrigation control system, such as soil moisture sensor, water pump, and irrigation time control. After that, the research will involve the system design stage, which may include steps such as soil moisture sensor reading, decision making based on sensor data, watering time setting, and water pump control. Next, the research will include the implementation of the system using an Arduino Uno. The flowchart will include the steps of programming the Arduino Uno to read the sensor data, control the water pump, and set the watering time as needed. During the experimentation and testing phase, the flowchart will also show the steps for testing the irrigation control system, including collecting data, analyzing the results, and adjusting the system if necessary. Finally, the research will include the evaluation and documentation phase, where the flowchart may include the steps of evaluating the performance of the system, documenting the research results, and making recommendations for further development. Thus, this research will involve technical steps that include hardware and software design, as well as trials to ensure the success of the chili seedling irrigation control system using Arduino Uno.

2.2 Tool Design

The prototyping process begins once all the necessary components are in place. The first step is to assemble the YL 69 soil moisture sensor device, which is used to read the soil moisture level. The data obtained from this moisture sensor will then be processed by Arduino. Arduino will process the information and make a decision to automatically turn on or off the plant watering device by using a relay. The relay acts as a link that controls the watering device based on the decisions made by Arduino.

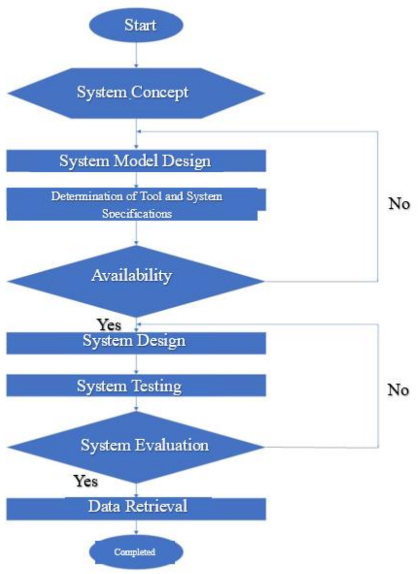

Figure 1. Flowchart of Tool and System Design

The second step is to create a program for the sensors used in the system. At this stage, the soil moisture threshold is set as a reference for the device to automatically water the plants. The program controls how the sensor reads the soil moisture level and how the data is processed by the system. When the soil moisture drops below the predetermined level, the unit triggers automatic watering according to the set program.

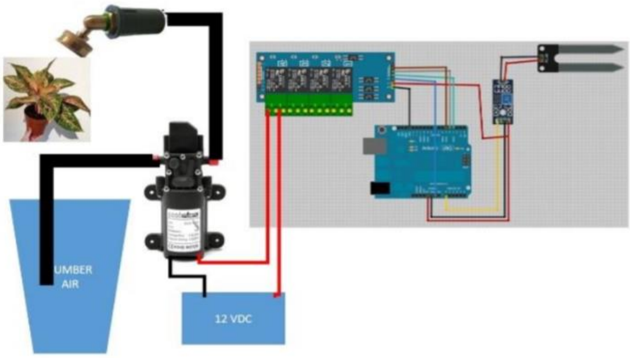

Figure 2. Tool Block Diagram

The block diagram of the automatic plant watering can prototype is designed to simplify the tool realization process. This block diagram provides a visual description of how each component of the tool is connected and works together. This diagram helps to understand the workflow of the system, starting from sensors that detect soil moisture to components that control the process of automatically watering plants. Here's how the tool works:

1) YL-69 Humidity Sensor
   This moisture sensor is designed to measure the moisture level in plant soil. The moisture data read by the sensor is sent to the Arduino Uno for further processing.
2) Arduino Uno
   Arduino Uno acts as the control center of the system. The humidity data received from the sensor is processed by Arduino. Based on the results of data processing, Arduino will determine whether to activate or deactivate the watering device using a relay.
3) Relay
   The relay acts as an automatic switch that responds to commands from the Arduino. When the Arduino decides to turn the irrigation system on or off, the relay will execute the command and turn the irrigation system on or off as needed.

2.3 System Work Design

The work design of this automatic plant watering device mainly involves reading data from the sensor module to determine whether the watering device should be activated or not. The design steps are as follows.

1) The sensor module will read the soil moisture level using the YL-69 Soil Moisture Sensor, then the data will be sent to the Arduino for processing.
2) Arduino will process the data from the sensor and determine whether the tool needs to be watered.
3) If the data from the sensor indicates that the soil is dry, the Arduino will activate a relay that automatically turns on the water pump (Water Pump ON) to water the plants.
4) Conversely, if the sensor detects that the soil is already wet, the relay will turn off the water pump (Water Pump OFF), stopping the watering process.

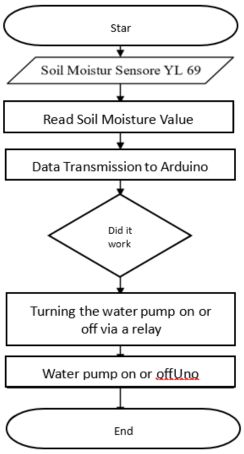

Figure 3. Tool Workflow Diagram

2.4 Testing Phase

At this stage, the researchers performed several important steps in testing the automatic irrigation system. First, the moisture sensor was placed in dry soil to test the sensor's response in low moisture conditions. Based on the readings, researchers set the moisture threshold at 500, which serves as the threshold for activating the water pump, with readings below 500 indicating dry soil conditions. Once the sensor is installed, the device begins working by sending continuous moisture data to the Arduino. If the humidity reading is below 500, the system automatically activates a relay that turns on the water pump to water the plants. The watering process continues until the sensor detects that the soil moisture level has risen above 500, at which point the Arduino turns off the pump. With this automated system, watering is done according to soil moisture needs, preventing overwatering and maintaining plant health. This test is very important to ensure that the system works efficiently according to the original design goals.

3. Result and Discussion

3.1 Results

3.1.1 Prototype Device Design Result

The design of the prototype device involves the integration of various components such as the soil moisture sensor, Arduino, relays, and water pump into a cohesive and harmonious system. The process begins with the selection and assembly of compatible components, followed by the creation of a schematic as a visual guide for connecting the components. The physical circuit is then built by installing and testing the connections on the circuit board. Once all the components are connected, the system works automatically, with the humidity sensor sending data to the Arduino, which controls the relays and the water pump. Visualization of the design results provides a clear picture of the layout and operation of the system.

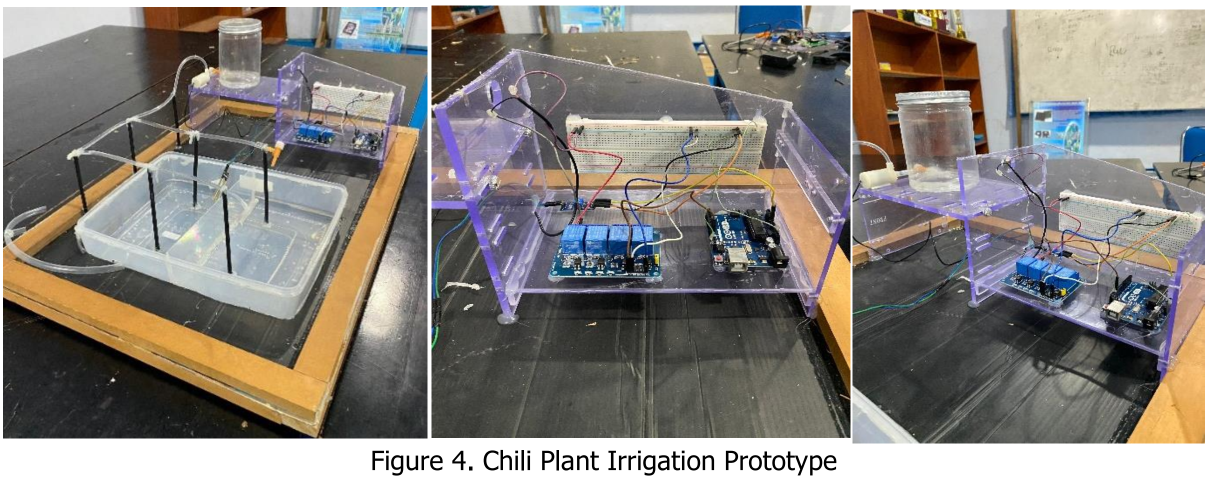

Figure 4. Chili Plant Irrigation Prototype

3.1.2 Soil Moisture Sensor Testing

The soil moisture sensor test was conducted by inserting the sensor into two soil conditions, dry soil and wet soil, to evaluate its performance in detecting moisture variations. The researchers observed the response of the sensor, which works on the principle of electrical conductivity - high moisture content gives a high reading, while low moisture content gives a low reading. The sensor's output was checked using an **Arduino Serial Monitor** to ensure accuracy and consistency. The test results were analyzed to evaluate the effectiveness of the sensor in an automatic plant watering application.

Figure 5. Dry Soil Testing

Table 1. Serial Monitor Display of Sensor Testing on Dry Soil

No	Testing on Dry Soil	Soil Moisture	Land Status	Status of Tools ON/OFF
1	10.00	700	Dry	ON
2	10.15	723	Dry	ON
3	10.20	744	Dry	ON
4	10.20	766	Dry	ON
5	10.30	784	Dry	ON
6	10.35	793	Dry	ON
7	10.40	803	Dry	ON

The test results on dry soil show that the moisture sensor works to detect moisture content and send data to the system. When the sensor reads a value below the 500 thresholds, the Arduino processes the data and automatically activates the water pump through a relay to water the plants. In this way, the system efficiently ensures that the plants get the water they need, even in dry soil conditions.

Figure 6. Testing on Wet Soil

Table 2. Serial Monitor Display of Wet Soil Sensor Test

No	Testing on Wet Soil	Soil Moisture	Land Status	Status of Tools ON/OFF
1	11.00	320	Wet	OFF
2	11.02	300	Wet	OFF
3	11.03	288	Wet	OFF
4	11.04	273	Wet	OFF

5	11.05	268	Wet	OFF
6	11.07	262	Wet	OFF
7	11.10	260	Wet	OFF

The results of testing the moisture sensor on wet soil show that if the moisture is detected below the threshold of 500, the system will automatically turn off the water pump. The sensor measures the moisture content of the soil, and if the moisture reading is low, the Arduino processes the data and sends a signal to the relay to stop the flow of electricity to the pump, thus stopping the irrigation. This process is important to prevent overwatering and ensure that the system is operating efficiently according to the soil moisture requirements.

3.1.3 Soil Moisture Sensor Test Results

The results of testing the Soil Moisture Sensor show that the sensor works well in detecting moisture levels. Tests were conducted by connecting the sensor to wet and dry soil, and the results show that the sensor can distinguish moisture levels in both conditions. The data obtained is then sent to the Arduino, allowing the system to function optimally in monitoring soil moisture and controlling automatic watering as needed.

Table 3. Soil Moisture Sensor Test Results

Soil Moisture Sensor Test Results			
Input Data	Expected	Observation	Results
Data from soil moisture sensor	Sensors can read soil moisture and send data to Arduino	Sensor plugged into wet and dry soil	Accepted

3.2 Discussion

This research has successfully designed and tested an automatic chili seedling watering control system using the Arduino Uno platform. The following discussion will outline the important findings of this research, including the design of the device prototype, testing of the soil moisture sensor, and analysis of the test results. The design of the device prototype is the core of this research. The design process involves the integration of various components, such as the YL-69 soil moisture sensor, Arduino Uno microcontroller, relay module, and water pump, into a single functional system. The design stage begins with the selection of compatible components, followed by the creation of a circuit schematic as a visual guide to connecting the components. The physical circuit is then built by installing and testing the connections on the circuit board. The integration of these components is carried out carefully to ensure that the system can work automatically. The soil moisture sensor functions as data input, which is then processed by the Arduino Uno. Based on the data received, the Arduino Uno will control the relay module to activate or deactivate the water pump. This prototype design reflects a systematic approach to hardware development, with an emphasis on functionality and efficiency. The visualization of the prototype design, as shown in Figure 4, provides a clear picture of the layout and how the system works as a whole. Soil moisture sensor testing is an important step to ensure the accuracy and consistency of the sensor in detecting variations in soil moisture. Testing is done by placing the sensor in two different soil conditions, namely dry soil and wet soil. The working principle of the sensor is based on electrical conductivity, where high water content produces high readings, and vice versa. The test results on dry soil (Figure 5 and Table 1) show that the sensor gives a high reading value, indicating dry soil conditions. In this condition, the Arduino Uno processes the data and automatically activates the water pump through a relay to carry out watering. Conversely, the test results on wet soil (Figure 3 and Table 2) show that the sensor gives a low reading value, indicating moist soil conditions. In this condition, the Arduino Uno processes the data and automatically deactivates the water pump through a relay to stop watering. This test proves that the YL-69 soil moisture sensor functions well in detecting differences in soil moisture levels. The data obtained from the sensor is then sent to the Arduino Uno to be processed and used as a basis for decision making in controlling watering. The use of the Arduino Serial Monitor in this test allows researchers to monitor the data generated by the sensor in real-time, thus ensuring the accuracy and consistency of the data obtained.

The results of the soil moisture sensor test show that the sensor works well in detecting soil moisture levels. Table 3 summarizes the test results, which show that the sensor can read soil moisture and send data to the Arduino Uno accurately. Testing was carried out in dry and wet soil conditions, and the sensor was able to distinguish the moisture levels in both conditions. The data obtained was then used by the Arduino Uno to control automatic watering according to plant needs. Data analysis shows that the system is able to respond to changes in soil moisture levels appropriately. When the sensor detects dry soil conditions (reading value above the threshold of 500), the system automatically activates the water pump to carry out watering. Conversely, when the sensor detects wet soil conditions (reading value below the threshold of 500), the system automatically deactivates the water pump to stop watering. This process ensures that chili plants get enough water without wasting or excess water. The research has made a significant contribution to the development of a microcontroller-based automatic irrigation system, proven to be effective in monitoring soil moisture and controlling watering automatically, thereby reducing dependence on manual watering. The implications of this study include efficient use of water through irrigation only when the soil is dry, increased productivity of chili plants with proper irrigation, reduced workload for farmers with irrigation automation, and application of technology in improving agricultural efficiency and sustainability. However, this study has limitations, including limited testing on a small scale and controlled conditions, the use of certain types of soil, and not considering other environmental factors such as temperature and humidity. Therefore, it is recommended for further development, including the integration of additional sensors for temperature and humidity, the development of a more interactive user interface, the use of renewable energy such as solar panels, and large-scale testing under more varied field conditions. In conclusion, this study successfully designed and tested an automatic chili seedling watering control system using Arduino Uno, which proved effective and made an important contribution to the development of more efficient and sustainable agricultural technology, with the potential for widespread application in modern agricultural practices through further development.

4. Related Work

The development of automated irrigation systems has become a significant research focus in recent years, as efforts are made to improve agricultural efficiency and reduce reliance on manual methods. Several studies have explored the use of microcontrollers, sensors, and automation technologies to achieve these goals. For example, Osanaiye *et al*. developed an IoT-based soil moisture monitoring system that demonstrated that the use of moisture sensors can significantly reduce water use, as well as reduce costs associated with agricultural labor [15]. This study highlights the importance of technology in improving water use efficiency, although it focuses more on general soil moisture monitoring and not specifically on chili plants. Another study by Kamaruddin *et al*. developed an Arduino-based irrigation management and monitoring system that uses soil moisture sensors to control a drip irrigation system [16]. The results of this study showed improvements in water use efficiency and crop yields, but did not discuss in depth the integration with relay modules and water pumps commonly used in simple irrigation systems. This study provides important insights into the use of the Arduino platform in automated irrigation but lacks a specific focus on applications for chili plants. Furthermore, Junaid *et al*. investigated an IoT-based smart irrigation system that offers a low-cost solution for agricultural land [17]. Although this study shows great potential in the use of wireless technology for precision agriculture, the developed system is more complex and expensive, making it less suitable for small-scale and low-cost applications. This suggests that while advanced technologies can improve efficiency, there is a need for simpler and more affordable solutions for small-holder farmers. The study conducted by Ihuoma *et al*. focused on the development of an automated irrigation system that takes weather factors into account, using data from weather stations to predict crop water requirements [18]. Although this approach is innovative, the developed system is more complex and requires additional infrastructure, which may be unaffordable for small-scale farmers. This suggests that there are challenges in integrating various environmental factors in the design of automated irrigation systems.

This study is different from previous studies because it focuses on the development of a simple, effective, and low-cost automatic irrigation system for chili seedlings using the Arduino Uno platform. This study not only tests the effectiveness of soil moisture sensors in controlling watering but also integrates relay modules and water pumps to form a complete and practical system. In addition, this study specifically discusses the water requirements of chili plants, which are different from other plants that are often the focus of automatic irrigation research. This study also provides an in-depth analysis of the system's performance under dry and wet soil conditions, as well as identifying limitations and providing suggestions for further development. Thus, this study makes a significant contribution to the development of a more affordable and easy-to-implement automatic irrigation system for small-scale farmers.

5. Conclusion and Recomendations

Based on the results of research and testing that has been conducted, the Arduino Uno-based automatic plant sprinkler shows success in its design and operation; This tool has been designed and made using the Arduino Uno microcontroller and YL-69 sensor, as well as other supporting devices, which work according to their purpose and function with good performance in automatic watering. This tool can work effectively when the humidity sensor sends data to the Arduino, where if the received data is below the specified limit, the relay automatically activates the water pump to perform watering. During the process, if the sensor detects soil moisture levels above the limit, the relay will turn off the pump and stop watering. However, it is important to note that the YL-69 sensor cannot be combined with a time-based irrigation system (RTC) due to limitations in its functionality.

The Arduino Uno-based automatic crop sprinkler still has many opportunities for improvement and development, so steps are needed to create a better and more effective system. First, this tool, which is currently in the form of a prototype or small scale, is expected to be developed for use in a wider agricultural area, providing more significant benefits to farmers and increasing irrigation efficiency. Second, to improve the function and performance of the system by considering the use of more sophisticated components and additional features, such as integration with more complex monitoring systems or the addition of additional sensors to improve the accuracy of determining crop watering needs.

References

[1] Alfonsius, E., Kalengkongan, W., Caesar, S., & Ngangi, W. (2024). Sistem Monitoring Dan Kontroling Prototype Penyiram Tanaman Otomatis Berbasis Iot (Internet Of Things). *Teknoinfo: Jurnal Bidang Teknik Informatika dan Sistem Informasi*, *18*(1), 44–55. Retrieved from https://ejurnal.teknokrat.ac.id/index.php/teknoinfo/index

[2] Wibowo, A. (2023). *Revolusi Industri 4.0 Dan Society 5.0*. Penerbit Yayasan Prima Agus Teknik. Retrieved from https://penerbit.stekom.ac.id/index.php/yayasanpat/article/view/457

[3] Denada, T., Nirmala, T. A., & Wulandari, A. (2021). Dinamika Nasionalisme Di Masa Pandemi Covid 19 Dan Di Era Revolusi 4.0. *Jurnal Bina Ilmu Cendekia*, *2*(2), 182–197.

[4] Thahir, M. I., Semmaila, B., & Arfah, A. (2021). Pengaruh Pertumbuhan Ekonomi, Pendidikan Dan Kesehatan Terhadap Kemiskinan Di Kabupaten Takalar. *Journal of Management Science (JMS)*, *2*(1), 61–81.

[5] Wibowo, A. (2023). *"Internet Of Things (Iot) Dalam Ekonomi Dan Bisnis Digital."* Penerbit Yayasan Prima Agus Teknik.

[6] Ekonomi, F., & Kuala, U. (2024). Peran Inovasi Teknologi Dalam Meningkatkan Efisiensi Ekonomi Pertanian. *Jurnal Ekonomi dan Bisnis*, *2*(1), 90–97.

[7] Sofyan, W. (2023). *Pemanfaatan Teknologi Informasi Di Berbagai Sektor Pada Masa Society 5.0.* PT. Sonpedia Publishing Indonesia.

[8] Sabardila, A., Budiargo, A. D., Wiratmoko, G., Himawan, J. A., Triutami, A., Intansari, A., ... & *et al.* (2020). Pembentukan Karakter Peduli Lingkungan Melalui Kegiatan Penghijauan Pada Siswa Mim Derasan Sempu, Boyolali. *Buletin KKN Pendidikan*, *1*(2), 35–41.

[9] Orlando, E., & Chandra, Y. I. (2022). Penerapan Metode Prototype Dalam Membuat Alat Penyiraman Tanaman Otomatis Berbasis Mikrokontroler Arduino Uno. *Tekinfo: Jurnal Bidang Teknik Industri dan Teknik Informatika*, *23*(2), 9–23.

[10] Effendi, N., Ramadhani, W., & Farida, F. (2022). Perancangan Sistem Penyiraman Tanaman Otomatis Menggunakan Sensor Kelembapan Tanah Berbasis Iot. *Journal of Computer Science and Information Technology (Coscitech)*, *3*(2), 91–98.

[11] Suparyanto, & Rosad. (2020). Implementasi Sistem Informasi. *Jurnal Ilmiah Teknologi Informasi Asia*, *5*(3), 248–253.

[12] Mustaqim, R. (2021). *Rancang Bangun Alat Kendali Smart Sawah Berbasis Wemos D1 R1* (Unpublished doctoral dissertation). Politeknik Harapan Bersama Tegal.

[13] Novianto, A. D., Farida, I. N., & Sahertian, J. (2021). Alat Penyiram Tanaman Otomatis Berbasis Iot Menggunakan Metode Fuzzy Logic. *Prosiding Seminar Nasional Inovasi Teknologi*, 316–321.

[14] Rahmadiyanti, M. (2021). Strategi Pemulihan Sektor Pertanian Dan Pengembangan Sumber Pangan Dalam Meningkatkan Perekonomian Di Masa Pandemi. *Jurnal Agroforestri Indonesia*, (March).

[15] Osanaiye, O., Mannan, T., & Aina, F. (2021). An iot-based soil moisture monitor. *African Journal of Science Technology Innovation and Development*, *14*(7), 1908-1915. https://doi.org/10.1080/20421338.2021.1988413

[16] Kamaruddin, F., Malik, N., Murad, N., Latiff, N., Yusof, S., & Hamzah, S. (2019). Iot-based intelligent irrigation management and monitoring system using arduino. *Telkomnika (Telecommunication Computing Electronics and Control)*, *17*(5), 2378. https://doi.org/10.12928/telkomnika.v17i5.12818

[17] Junaid, K., Sukhi, Y., & Anita, S. (2023). Low-cost smart irrigation for agricultural land using iot. *IETE Journal of Research*, *70*(3), 2659-2672. https://doi.org/10.1080/03772063.2023.2178535

[18] Ihuoma, S., Madramootoo, C., & Kalácska, M. (2021). Integration of satellite imagery and in situ soil moisture data for estimating irrigation water requirements. *International Journal of Applied Earth Observation and Geoinformation*, *102*, 102396. https://doi.org/10.1016/j.jag.2021.102396.

