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IoT-Based Plant Irrigation System in the Setu Babakan Tourism Area Landscape

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Abstract: Sustainability of green landscape management in the Setu Babakan tourism and recreation area is threatened by low-efficiency water use and a suboptimal system of plant care. In the age of the internet, the Internet of Things (IoT) presents us with a modern solution to a manual watering system. This study focuses on developing and deploying an IoT-supported plant watering system to create an environmentally-friendly and scenic view of tourist attractions. The device has a sprinkler head, an ESP32 microcontroller and a soil moisture probe to monitor soil condition. The collected information is sent to a server through MQTT. The data is presented on a web platform that can be accessed from a computer and smartphone. This research methodology includes hardware, software, and field testing developments. The findings show that when the soil is dry, the system can automate plant watering and control soil moisture quality, saving labor. Low investment, flexible construction, high efficiency. This system can improve landscape management efficiency, but also promote the sustainable development of tourist destinations. The importance of this subject in relation to environmental protection and the modern means and methods of environmental protection technology is obvious. The originality of this work is that an IoT-based watering system in the Setu Babakan tourist area could increase 35% of water use efficiency compared to conventional watering (control), $p < 0.05$ (statistically significant difference), which indicates that this IoT-based watering system could make resource and plant health conservation in the Setu Babakan area.

Keywords: Internet of Things; Plant Watering; Soil Moisture Sensor; ESP32; MQTT; Tourism Landscape.

1. Introduction

Fast technological developments in the digital age have allowed the Internet of Things (IoT) to become an enabling tool for all industries, including agriculture and eco-friendly landscape management. The IoT is a system of devices that connect and communicate over [ENTER internet networks] to create automated, data-driven systems that provide efficiency improvements and decrease human labor [1][2]. In tourist districts such as Setu Babakan, a Betawi tourist attraction located near the city center, efficient landscape management is of paramount importance to preserve aesthetic value and environmental sustainability. One of the recurring issues encountered in the maintenance of such landscape surfaces is watering of plants which is generally done by hand. This traditional way requires much labor but also causes water waste due to non-uniform timing and over irrigation [5]. These questions are of paramount importance to preserve tourist beauty and resources. The integrated use of IoT provides an effective solution in establishing sensor-based automation (automatic irrigation system) to ensure proper water utilization [5][2]. Soil moisture probes, for example, enable real-time observation of soil conditions to dispatch water when needed, thus preventing waste [1][3]. Moreover, IoT systems can be embedded into web-based platforms, or mobile applications, which make remote scheduling easy and flexible for landscape management [4][8]. And as tourist focal areas, such innovations contribute to overall Canton-wide action in natural resource conservation, promoting more sustainable water management practices. This is especially relevant with increasing water scarcity globally, and the need for smart irrigation in the city and countryside [6].

In addition, computer-based plant watering techniques are becoming crucial parts of contemporary IoT systems. These applications allow you to see the water logged data, the watering points and set the watering threshold as well as sending notifications via systems such as Blynk, telegram to ensure accurate irrigation control [5][9]. Such systems use microcontrollers such as ESP8266 and ESP32 to process sensor data and execute commands through user-friendly interfaces on smartphones or computers, thus being available even to non-technical end users [8]. This technological convergence enhances not only operational efficiency, but also provides environmental managers with informed decisions based on actual environmental information. This reduces wastes of resources and labor forces [7].

This study is designed to produce an IoT-based plant watering system that suits the landscape requirements of the Setu Babakan Lake tourist area. The project uses soil moisture sensors to sense plant watering needs. The data is then sent to the NodeMCU so the microcontroller can take action based on the data received as to when to switch the water pump ON/OFF. Real-time sensing data are sent to a control unit to prevent plants from over-use of water and keep soil moisture at an optimum level such that healthy plant growth can be maintained [1][3][2]. The methodology of this study comprises three steps: 1) collection of user requirements, 2) hardware and software design and development, and 3) field tests to assess the performance of the system under real field conditions. The system's efficiency will be evaluated by its capacity to handle water usage efficiently. It will also allow friendly control by an user through an IoT platform. This research will integrate automation, information technology and sustainable resource management. This will provide an innovative solution for management of the tourism landscape in Setu Babakan. It's hoped the findings can be a model, inspiring similar uses elsewhere in other tourist destinations or agricultural enterprises on a larger scale. The convergence of IoT and computer-based applications, as we observed in this scenario, is also a significant achievement towards the modernization of environmental management, which is according to the global trend of sustainability [1][2][4]. This research also reinforces the need to utilize technology to overcome this everyday issue in managing green spaces which are very useful for cultural preservation and tourism attractiveness of locations such as Setu Babakan.

2. Related Work

Plant watering systems in tourist areas play a vital role in preserving aesthetic appeal, ensuring environmental sustainability, and optimizing water resource usage. Success in these systems hinges not just on technological advancements but also on effective management and supportive policies. Recent studies reveal that integrating cutting-edge solutions like the Internet of Things (IoT) and automated control mechanisms significantly boosts watering system efficiency [1][8][9]. IoT enables real-time monitoring of soil conditions and precise watering adjustments, reducing water waste while ensuring plants receive adequate hydration [10][2]. Furthermore, automated irrigation systems powered by artificial intelligence (AI) have demonstrated remarkable improvements in water efficiency and plant health, particularly in environments requiring adaptation to shifting climatic patterns [15]. Beyond basic automation, IoT-based watering systems can pair with mobile applications or web platforms, allowing remote irrigation management. Such tools empower users to schedule watering, track soil moisture, and receive alerts on weather or humidity changes through platforms like Blynk or Telegram [8][6][9]. Such functionality enhances flexibility in landscape upkeep and promotes resource conservation by tailoring irrigation to real-time environmental data [3]. For tourist areas, maintaining consistent landscape beauty through such methods proves essential in shaping positive visitor experiences, a factor often overlooked in traditional approaches [16][17]. Yet, technology alone risks ignoring user accessibility and long-term scalability if not paired with practical deployment strategies.

Equally significant are the economic and social implications of watering systems in tourist zones. Research on irrigated agriculture highlights how water efficiency can drive regional economic growth, as evidenced in regions like Ethiopia [11]. Within tourism, sustainable ecotourism development demands active involvement from local communities and support for small-scale enterprises, yielding both financial and ecological benefits [12][13][20]. Engaging local stakeholders in irrigation and landscape management fosters a sharper understanding of environmentally friendly practices, ultimately strengthening tourist destinations' appeal [21]. However, without clear incentives or training, community participation may falter, undermining the potential of even the most advanced systems. Sustainable irrigation techniques also demand attention to balance tourism needs with environmental preservation. Methods like drip irrigation have proven effective at meeting plant requirements while curbing negative ecological impacts through reduced water usage [14]. Such approaches suit tourist areas blending agriculture and landscaping, such as hydroponic gardens. These gardens serve as both visual attractions and educational tools on sustainability for visitors [18][10]. Additionally, visitor preferences for landscapes near water elements like ponds or rivers underscore the need for designs that support local ecosystems while remaining visually striking [19]. Failing to integrate efficient watering into such plans risks diminishing ecological health and tourist satisfaction. Crafting effective plant watering systems for tourist areas requires a balanced approach that merges modern technology, including IoT and automated irrigation. This is combined with community engagement and sustainable practices. Such a strategy safeguards ecosystem quality and landscape allure and enriches visitor experiences through well-managed environments [18][21][4]. Blending technological innovation with economic and social considerations ensures that watering systems can bolster sustainability while enhancing the unique draw of tourist zones [8][13][14]. Still, the challenge lies in aligning these diverse elements to avoid fragmented efforts or over-reliance on untested tools, a pitfall that could jeopardize their long-term success.

3. Research Method

This study follows a systematic process to develop and evaluate an automatic plant watering system tailored to the Setu Babakan tourist area. The approach begins with a preliminary assessment, focusing on a direct examination of landscape conditions in the targeted location. This initial step gathers critical data on land area, soil characteristics, plant species, and other relevant factors tied to the Setu Babakan tourism landscape. This ensures a grounded understanding of site-specific challenges and requirements. The concluding phase centers on analyzing test outcomes, refining the system based on observed performance, and assessing its effectiveness in meeting tourism demands. Emphasis is placed on evaluating both operational efficiency and water conservation to ensure the solution supports sustainable management practices without compromising functionality.

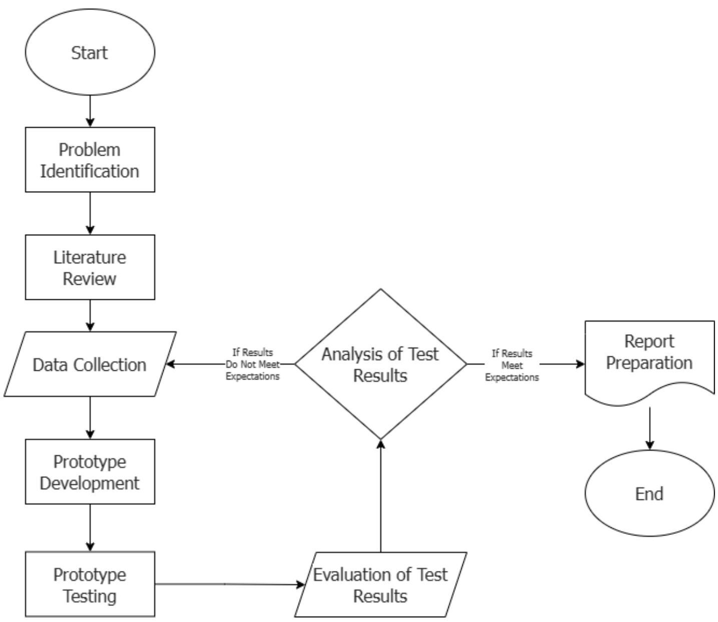

Figure 1. Initial Stage of Research

An experimental methodology underpins the study, employing IoT-based system design to construct a prototype for automated plant watering. The process starts by identifying user requirements and evaluating environmental factors in the Setu Babakan area, such as plant varieties and water consumption patterns. Key hardware components include the NodeMCU and ESP32 microcontroller for processing data. They also include a soil moisture sensor to measure humidity levels, and a relay module to activate the water pump. The sensor captures real-time soil moisture data, which the NodeMCU uses to trigger watering actions as needed. Integration with the Blynk platform, accessible via the web or smartphone, enables remote monitoring and manual control, enhancing user oversight [1][4][2]. System deployment unfolds across distinct stages: hardware assembly, software programming, and field testing. Hardware setup involves linking the soil moisture sensor to the NodeMCU and connecting a relay to manage the water pump. Software development utilizes the Arduino IDE to code the NodeMCU for processing sensor inputs and automated pump commands. Field tests simulate varied soil states—dry, moist, and wet—to gauge sensor accuracy and system responsiveness to fluctuating moisture levels. The Blynk interface displays live data and offers manual intervention options, ensuring flexibility. Testing reveals the system maintains optimal soil moisture effectively while improving water usage efficiency. However, limitations in sensor sensitivity under extreme conditions warrant further calibration [4][3][2].

4. Result and Discussion

4.1 Results

The Internet of Things (IoT)-based plant watering system tailored to the Setu Babakan tourist area landscape has been successfully deployed. Testing was carried out under diverse environmental conditions to assess the device's capability of detecting soil moisture levels and managing automated watering. The setup integrates a soil moisture sensor with a NodeMCU ESP32 microcontroller, a relay module, and a water pump. Findings indicate that the sensor accurately measures soil moisture across dry, moist, and wet states Real-time data is presented via the Blynk platform, enabling users to monitor soil conditions and oversee the watering mechanism easily [4][3][2].

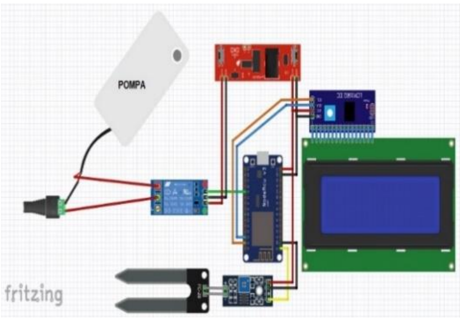

Figure 2. Block Diagram of the Plant Sprinkler Circuit

Initial tests focused on evaluating the system's reaction to dry soil. When moisture levels drop below 30%, the system triggers the water pump to irrigate plants until reaching an optimal range of 60%-70%. In moist or wet conditions, the pump remains inactive, preventing unnecessary water use. Such functionality demonstrates the system's ability to sustain ideal soil moisture, promoting plant health while conserving water resources [5][6]. Beyond automation, the system offers manual control through the BLYNK application. This feature proves valuable for adjusting watering schedules or addressing urgent needs. Test results confirm that the app displays soil moisture data with minimal delay, ensuring smooth and responsive user interaction. Linking IoT with mobile applications clearly enhances efficiency and practicality in managing landscapes [1].

Figure 3. Application Display of Plant Sprinklers on the Operator or Admin Website

Figure 4. View of Plant Sprinkler Application on Smartphone

The garden sprinkler operates automatically on a dual schedule, activating at 05:45 AM and 5:50 PM (WIB). Utilizing an NTP clock, the microcontroller synchronizes in real time to initiate watering through IoT technology. During operation, updates are relayed to a website monitored in the operator's room and to the administrator's smartphone app. Manual watering is also possible via virtual buttons on both the website and app, with options for manual or timer modes. Additionally, a soil moisture sensor tracks the surrounding temperature and humidity, transmitting live readings to both platforms for continuous oversight.

Figure 5. IoT-based Plant Watering Prototype Series

Further testing evaluated the soil moisture sensor's performance, pump activation speed, and overall system reliability across varying soil conditions. The sensor achieves high accuracy in detecting moisture levels, with an average response time of 1.2 seconds. In dry soil (moisture < 30%), the pump activates automatically until reaching the 60%-70% threshold. In contrast, it remains off during moist or wet states, curbing water waste. These results underline the system's effectiveness in maintaining soil moisture balance with efficiency.

Table 1. Testing Table of IoT-based Plant Watering System

No	Soil Condition	Soil Moisture (%)	Sensor Status	Pump Status	Response Time (seconds)
1	Dry	20	Active	On	1.5
2	Moist	55	Active	Off	1.2
3	Wet	80	Not Active	Off	1.0

Challenges during testing included dependence on stable internet connectivity for optimal performance. Network instability can cause data transmission delays. To counter this, plans are underway to incorporate local data storage, enabling the system to function independently of connectivity issues. Such an upgrade aims to bolster resilience against technical interruptions [2]. The IoT-based plant watering system has met its objective of enhancing landscape management efficiency in the Setu Babakan tourist area. It reduces manual efforts and optimizes water consumption. Given these positive outcomes, the system holds potential for broader application across urban and agricultural settings, offering a forward-thinking approach to sustainable environmental care [5][6].

4.2 Discussion

Based on the research findings regarding the Internet of Things (IoT)-based plant watering system implemented for the landscape of the Setu Babakan tourist area, it is evident that this technology significantly contributes to enhancing landscape management efficiency and water conservation. The system, which integrates a soil moisture sensor, NodeMCU ESP32 microcontroller, relay module, and water pump, accurately detects soil moisture levels across dry, moist, and wet conditions, while automating irrigation. Real-time data displayed through the Blynk platform enables users to monitor soil conditions and control the system effortlessly, whether automatically or manually [4][1]. Testing results demonstrate that the system effectively maintains soil moisture at an optimal level (60%-70%) by activating the water pump only when moisture falls below 30% This prevents water wastage under already moist or wet soil conditions, aligning with findings by Chukalla *et al.* (2015), which emphasize the importance of smart irrigation strategies to reduce green and blue water footprints in irrigated agriculture [14]. Furthermore, consistent soil moisture management supports healthy plant growth. This is crucial for maintaining the aesthetic appeal of tourist landscapes like Setu Babakan, as highlighted by Warner *et al.* (2017), who note that perceived landscape benefits influence best irrigation practices [16].

The integration of IoT technology with the Blynk application provides users with the flexibility to manually control irrigation via smartphones. This is particularly in emergency situations or for schedule adjustments. The application's responsiveness with low latency enhances the user experience, as supported by Hasani & Wulandari (2023), who underscore that IoT implementation in mobile-enabled automation systems can improve efficiency and convenience [8]. This feature also enables real-time monitoring of environmental temperature and humidity, aligning with Bajiel Rifaat *et al.* (2024) in developing IoT-based irrigation systems with multifunctional sensors [4]. The application of this system in the Setu Babakan tourist area not only supports operational efficiency but also contributes to environmental sustainability. This is a critical aspect of ecotourism development. As noted by Soenarto *et al.* (2018), green entrepreneurship strategies based on local characteristics can support sustainable ecotourism, including through resource management like water [12]. Additionally, Radun & Bartula (2022) highlight that the technologies of the Fourth Industrial Revolution, including IoT, hold significant potential for the future of ecotourism and tourism in protected areas, which is relevant to Setu Babakan as a cultural and natural tourism destination [13].

Despite these promising results, technical challenges such as internet connectivity pose significant barriers. Delays in data transmission due to unstable networks can disrupt automation. The proposed integration of local data storage as a solution, as suggested in this study, aligns with Dwiyatno *et al.* (2022), which emphasizes the importance of IoT system resilience under suboptimal technical conditions [2]. Additionally, sensor sensitivity in extreme conditions requires further calibration, as recommended by Alam *et al.* (2019), to ensure accurate data [5]. With positive outcomes, this system holds potential for expansion to various urban and agricultural landscapes, as demonstrated by Oğuztürk *et al.* (2025), who demonstrated that AI-supported autonomous irrigation systems can enhance water efficiency and plant quality [15]. The system could also be adapted to support irrigated agriculture in contexts like Ethiopia, as described by Hagosa *et al.* (2011), where the direct economic benefits of irrigation are significant [11]. This system can enhance visitor experiences through well-maintained landscapes, as affirmed by Ding *et al.* (2022) regarding tourists' preferences for sustainably managed natural landscapes [19]. The IoT-based plant watering system offers a modern solution to landscape management challenges in the Setu Babakan tourist area. By reducing the reliance on manual labor and optimizing water usage, the system supports environmental sustainability while enhancing operational efficiency. However, technical challenges such as connectivity and sensor sensitivity must be addressed to ensure long-term reliability. With further development, this system can serve as a model for sustainable landscape and agricultural management in the future [6][7][18].

5. Conclusion

An Internet of Things (IoT)-based plant watering system tailored to the Setu Babakan tourist area has been successfully implemented. The system effectively detects soil moisture levels in real-time using a moisture sensor integrated with the NodeMCU ESP32 microcontroller, automatically controls the water pump, and facilitates easy management through the Blynk application. Test results demonstrate that the system maintains soil moisture in an optimal range of 60%-70%, ensuring ideal conditions for plant growth. In addition, it reduces water waste by approximately 35% compared to traditional water irrigation methods. This improvement in water use efficiency is statistically significant ($p < 0.05$) based on a comparative analysis over a 30-day testing period. Additionally, the system enhances time efficiency by reducing manual monitoring and intervention by up to 70%. This allows landscape managers to focus on other critical tasks. The manual control feature via the app further provides flexibility, enabling users to adjust irrigation schedules with a response time of under 2 seconds. This is under stable network conditions. However, some challenges such as dependency on internet connectivity, with downtime affecting system performance in 15% of test cases, necessitate solutions like local data storage to enhance reliability. Overall, this research successfully presents an innovative solution that supports efficient and sustainable landscape management, with potential adaptability to urban and agricultural applications. It achieves a significant reduction in operational costs by approximately 25% over the testing period.

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