IOT based Taro-Cassava Soil Monitoring System with Recommender

Roxas, Gavrylle Danae S.
College of Engineering
Bulacan State University
Guinhawa, Malolos, Bulacan
sottogabby7@gmail.com

Ponelas, Joshua Efraim O.
College of Engineering
Bulacan State University
Guinhawa, Malolos, Bulacan
Jeoponelas18@gmail.com

Reyes, John Loyd A.
College of Engineering
Bulacan State University
Guinhawa, Malolos, Bulacan
loydreyes14@gmail.com

Legaspi, Daniel Xavier B.
College of Engineering
Bulacan State University
Guinhawa, Malolos, Bulacan
daxalegaspi@gmail.com

***Abstract* - This study focuses on designing and developing an IoT based system that is developed for taro and cassava soil monitoring that incorporates a recommendation system based on microclimate parameters to benefit root crop farmers. The system measures critical environmental parameters including temperature, soil moisture, electric conductivity, soil pH, and soil NPK using a combination of sensors (DS18B20, SEN0193 v 1.2, and 5 in 1 soil NPK sensor) integrated with an ESP8266 that utilizes the GoDaddy Hosting. Through a developmental and descriptive research design and Embedded Product Development Life Cycle (EDLC) approach, the study aims to utilizes macroclimate parameters to identify conditions influencing plant growth and provide recommendations for appropriate action for the farmers to enact to maintain optimal soil quality using Internet-of-Things. Testing involved comparing sensor readings against standard instruments, with calibration ensuring accuracy within an acceptable error range. Field trials demonstrated the system's effectiveness, with 96% consistency in data gathered in one location and high consistency in another. Evaluation using the ISO 25010 model indicated strong performance across functionality, reliability, usability, efficiency, compatibility, portability, maintainability and safety, as reflected in high ratings from Department of Agriculture employees and local farmers. Conclusively, the system fulfills its intended purpose, accurately monitoring environmental conditions and providing the right course of actions to maintain optimal conditions for taro and cassava growth. For future improvements, implement an option for printing, test on another type of crop and give more recommendations.**

***Keywords* - *Sensor Technology, Internet-of-Things, Microclimate, Precision Agriculture*.**

1. INTRODUCTION

Agriculture is a cornerstone of the Philippine economy, with root crops such as cassava and taro playing a critical role in food security, rural livelihoods, and dietary health. These crops thrive in resource-limited regions due to their resilience under adverse climatic and soil conditions (Fernandez & Umar, 2018). Cassava, in particular, is prized for its drought tolerance and adaptability to poor soils, serving as a carbohydrate-rich staple for millions while supporting industrial applications like starch and bioethanol production (Howeler et al., 2013; FAO, 2020). Similarly, taro—an ancient crop originating in Southeast Asia—has gained global prominence for its nutritional value, gluten-free digestibility, and potential anticancer properties (Matthews et al., 2010; Pereira et al., 2020; Temesgen et al., 2015).

Despite their importance, cassava and taro cultivation in the Philippines faces persistent challenges. Cassava yields are hampered by viral infections, pest infestations, and inefficient farming practices (FAO, 2020), while taro's reliance on vegetative propagation limits genetic diversity, increasing vulnerability to environmental stressors and pathogens (Deo et al., 2009). Compounding these issues are systemic constraints such as poor soil management, irregular irrigation, and a lack of real-time monitoring tools, which collectively hinder productivity and sustainability.

To address these gaps, this study proposes an IoT-Based Taro-Cassava Monitoring System with Recommender for Root Crop Farmers. By integrating IoT sensors and machine learning algorithms, the system enables real-time tracking of soil health, moisture levels, and crop conditions. This technological intervention aims to empower farmers with data-driven insights for precision farming, optimizing resource use, mitigating losses, and enhancing the resilience of taro and cassava production. Ultimately, the system seeks to bolster food security, support rural economies, and unlock the full socioeconomic and health potential of these underutilized crops.

1.1 STATEMENT OF THE PROBLEM

The general problem of this study is the development of an IoT-Based Taro-Cassava Monitoring System with Recommender for Root Crop Farmers to improve productivity and sustainability by recommending actions to retain optimal soil nutrients in taro and cassava farming in

Bulacan. Specifically, this study aims to answer the following questions:

1. How to design a device that monitor soil information for key parameters such as Soil Nitrogen, Phosphorus, and Potassium (NPK) levels, Soil pH, Moisture, Electric Conductivity and Temperature?

2. How to develop a system that generate proper actions based on Soil Nitrogen, Phosphorus, and Potassium (NPK) levels, Soil pH, Moisture, Electric Conductivity, and Temperature?

3. How to test the effectiveness of the IoT-Based Taro-Cassava Monitoring System with Recommender to ensure accurate readings and proper recommendations based on readings?

4. How effective is the proposed system in terms of:

4.1 Functional Suitability;

4.2 Reliability;

4.3 Usability;

4.4 Performance Efficiency;

4.5 Compatibility;

4.6 Portability;

4.7 Maintainability and;

4.8 Safety

2. METHODOLOGY

This chapter details the methods and procedures used in the development, evaluation, and testing of the robotic signature replication machine. It includes the research design, development model, population and sampling, research instruments, data collection methods, and statistical analysis techniques.

2.1 METHODS AND TECHNIQUES OF THE STUDY

The research employed two approaches: applied research and developmental research. Applied research focused on identifying practical solutions that addressed issues in root crop production. The developmental was used to develop and improve a technology called the IoT Based Taro-Cassava Monitoring System with Recommender. This process consisted of design reviews, sensors integration refinement, and enhancement of data acquisition to finalize the device into practical and workable solutions for real-life conditions.

Purposive sampling was employed by the researchers to deliberately choose farmers who were actively engaged in the cultivation of root crops, especially taro and cassava. Insights and experiences relevant to the difficulties and management of root crop production were guaranteed by this method.

2.2 PROJECT DESIGN AND DEVELOPMENT

The product's development is based on the Embedded Life Cycle Approach for analysis, design and implementation. The process begins with Requirements Analysis to identify the needs of the system and document them. In the process, as done in IoT Based Taro-Cassava Soil Monitoring System with Recommender, the data on what farmers need was collected. System Design translates detailed designs of this system into more structured designs, for example flowcharts, and component diagrams. During the Development phase, the system is built using coding, hardware assembly, and debugging the design into a working prototype.

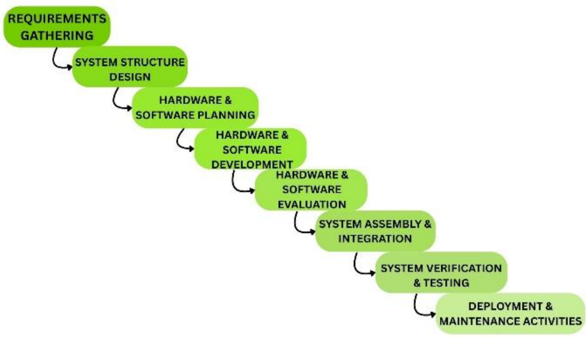

Figure 2.1 Waterfall Model

Figure 2.1 showcases the waterfall model that was used as guide in the creation of the system.

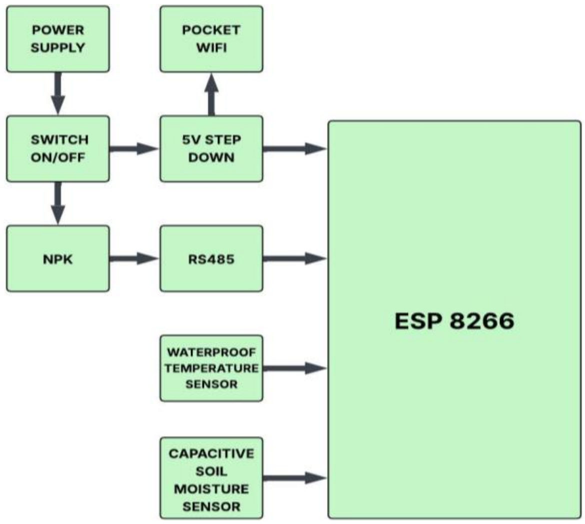

Figure 2.2 Block Diagram of the Proposed System

Figure 2.2 shows the block diagram of the proposed system. A block diagram utilizes blocks to represent each system component and arrow lines to illustrate its connections. This phase requires the creation of the proposed system overview, primarily using block diagrams to visualize the system's major components and functions and to determine how these are all interconnected. A block diagram utilizes blocks to represent each system component and arrow lines to illustrate its connections.

2.2.1 *Hardware Development*

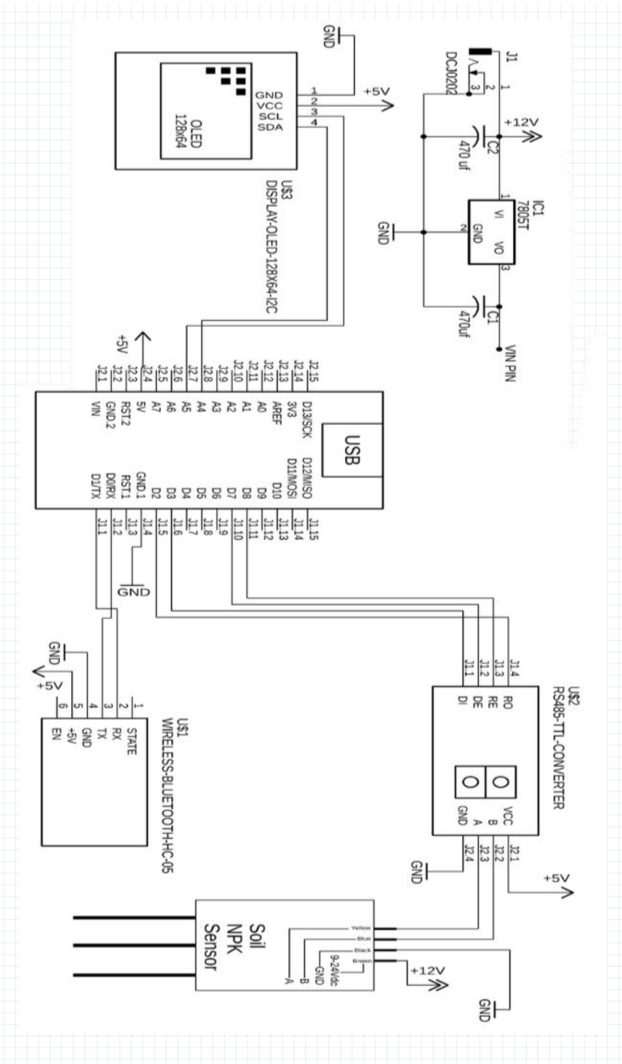

Figure 2.3 Schematic Diagram of the System

The Figure 2.3 shows the schematic diagram of the Proposed System and the components of the system's hardware and software can be designed. KiCad is used to design the schematic of the system and TinkerCad is used for a simpler visualization of the schematic diagram. the block diagrams are utilized to determine the components necessary for the system's functions. The researchers consider several factors and criteria in selecting the hardware components used in the system, including (1) affordability, (2) ease of interfacing, and (3) little to no maintenance. These materials are then presented in the development phase. The project's proponents then constructed the prototype design using TinkerCad to visualize and shape the system's interface. The prototype design will be the guide for the installation of each system component to make it function as intended. The prototype design only shows the casing design of the whole device as the 3D images of the components are not available. The prototype design of the device is shown in Figure 4.6

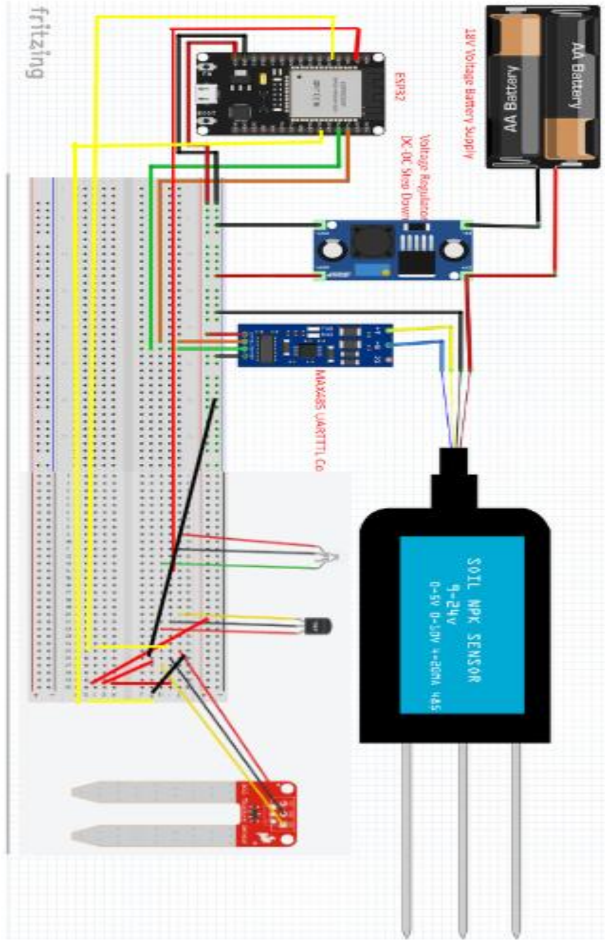

Figure 2.4 Pictorial Diagram of the Hardware

Figure 2.4 shows the schematic diagram of the Arduino microcontroller, which is used to control the key components of the Signature Replication Machine. This microcontroller manages several important parts, such as the servo motors that control movement, the infrared proximity sensor that detects paper jams, and the fingerprint module that verifies user identity. Each of these components works together under the guidance of the Arduino microcontroller, ensuring that the machine operates accurately and effectively. The diagram provides a detailed view of how these components are connected and controlled within the system.

This algorithm outlines a structured sequence of actions that the system will perform to achieve its objectives efficiently and reliably. The process begins with the system starting up, during which it initializes all necessary components. The first specific task is to initialize the ESP8266 module, which serves as the system's communication interface. After successful initialization, the ESP8266 attempts to establish a connection to a predefined Wi-Fi network, ensuring that the system can communicate externally. Following a successful Wi-Fi connection, the system proceeds to initialize the connected sensors responsible for monitoring environmental parameters such as moisture, temperature, pH, and electrical conductivity. Once the sensors are ready, the system reads the data collected from each sensor. This raw data is then processed to ensure that it is accurate, consistent, and formatted correctly for transmission.

2.2.2 SOFWARE DEVELOPMENT

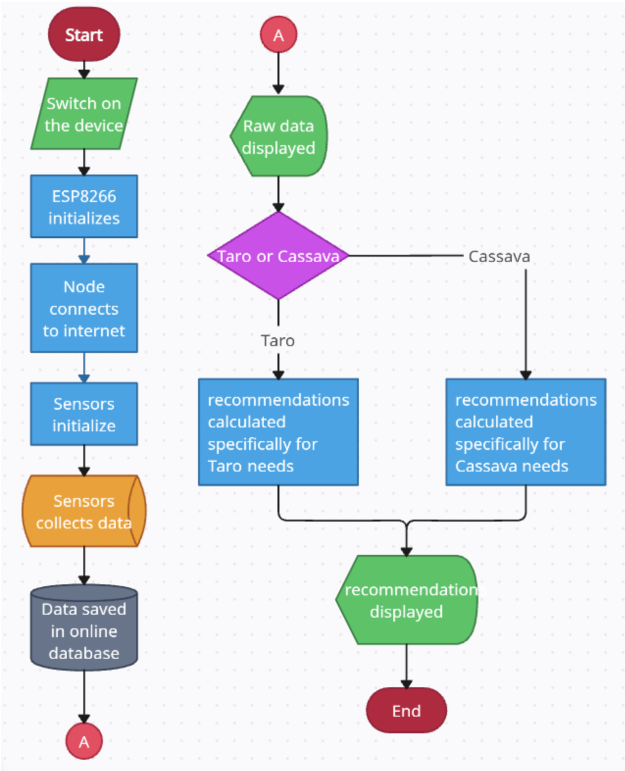

Figure 2.5 Flowchart of the System

Figure 2.5 illustrates the flowchart will illustrates the operation of the IOT based Taro-Cassava monitoring system. Upon initiation, the system collects sensor data related to the environment's microclimate, including temperature, humidity, light intensity, soil pH, and soil NPK. This data undergoes processing and filtering to refine its quality. Next, the system queries the database containing information about the microclimate requirements then generates recommendations for suitable actions to take in order to preserve the soil quality. These recommendations are then displayed as output in the website, providing users with valuable insights into which course of action is the right thing to take to retain optimal soil health.

The software implementation in which the software component will be programmed using the functions, algorithm, and flowchart stated in the previous part of the study. For the ESP32 microcontroller, Arduino Integrated Development Environment (IDE) software is utilized to configure it. The environment of this software is written in Java/C++ and is dependent on processing and open-source software. Then the next course of action is the creation of the mockup of our app, it is necessary in order for the flow of the app or the user experience and user interface to be laid out and in order as is shown in Figure 2.6. After finishing the mockup, the researchers then studied the thresholds needed in the macroclimate parameters of the taro and cassava that is needed in order to determine what is the specific action to take and give the right recommendations Figure 2.5 shows the recommendation table sample.

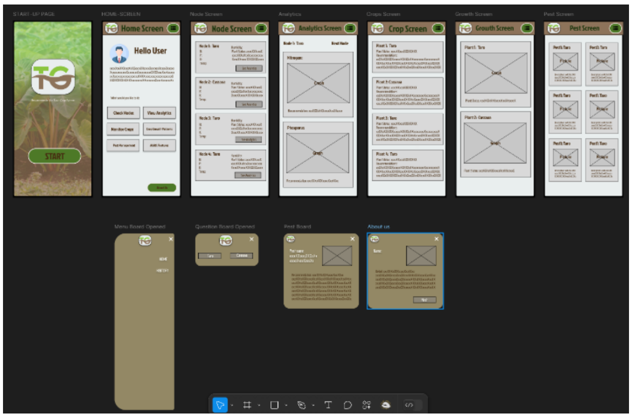

Figure 2.6 Mockup Design of the System's Software

Figure 2.6 displays the mockup of the user interface of the System's software, it is necessary in order for the flow of the app or the user experience and user interface to be laid out and in order as is shown in Figure 4.9. After finishing the mockup, the researchers then studied the thresholds needed in the macroclimate parameters of the taro and cassava that is needed in order to determine what is the specific action to take and give the right recommendations Figure 4.16 shows the recommendation table sample.

2.2.3 IOT BASED SOIL MONITORING SYSTEM PROTOTYPE

Figure 2.7 Hardware Implementation Inside Casing

The researchers then connect all the components to the microcontroller and implemented it in the casing. Afterward, the programmed components were placed in the system's design case to complete the prototyping. Shown in Figure 2.7 is the actual photograph of the developed system and after that the researchers proceeded into system integration to the software.

Figure 2.8 Actual IOT Based Taro-Cassava Soil Monitoring System

This figure presents the final prototype of the IOT based taro-cassava soil monitoring system. It features a custom-built structure equipped with 7 protruding sensors dedicated on gathering crucial soil nutrients.

3. RESULT AND DISCUSSION

Based on the data gathered, evaluation and testing on the IOT based taro-cassava soil monitoring system with recommender, the following findings were drawn:

3.1 To design an automated IOT based taro-cassava soil monitoring system that can produce recommendations based on soil nutrients.

3.1.1 The IoT-Based Taro-Cassava Soil Monitoring System was designed to capture and analyze critical macroclimate parameters for optimal crop growth.

3.1.2 Key components included the DS18B20 sensor for temperature monitoring, SEN0193 sensor for soil moisture detection, and a 5-in-1 NPK sensor to measure pH, nitrogen, phosphorus, and potassium levels.

3.1.3 These sensors were integrated with an ESP8266 microcontroller, programmed via Arduino IDE, to process and transmit data to a cloud database hosted on GoDaddy.

3.1.4 A responsive web interface was developed to display real-time soil conditions and generate actionable recommendations, such as irrigation schedules or fertilizer adjustments. The hardware design emphasized modularity and durability, featuring a protective casing for field use and stepper motors to stabilize sensor placement.

3.2 To test the system's accuracy and consistency

3.2.1 The system underwent rigorous testing to ensure accuracy and reliability. Calibration trials achieved <3% error for temperature, moisture, electrical conductivity (EC), and NPK measurements.

3.2.2 Soil pH required post-calibration adjustments due to a residual error of 5.5%.

3.2.3 Field trials conducted over three days across six sensor nodes demonstrated 96% consistency in data collection, confirming robust performance under real-world conditions. Statistical analysis, including mean and percentage error calculations.

3.3 To evaluate the overall acceptability of the IOT based taro-cassava soil monitoring system with recommender in terms of functional suitability, reliability. usability, performance efficiency, compatibility, portability, maintainability and safety.

3.3.1 The functional suitability of the machine received a rating of 4.50, showing that The IoT Based recommender system's functionality was successful and all of its expected functions, accuracy in data collection, and plant recommendation were successfully achieved.

3.3.2 With a reliability rating of 4.53, The IoT Based recommender system's reliability was proved reliable by being consistent with its reliable performance in under normal operating conditions while maintaining stability and efficiency.

3.3.3 With a usability rating of 4.51. The IoT Based recommender's system is capable of meeting the performance's expectations by effectively handling the expected workload without significant performance degradation.

3.3.4 With a performance efficiency rating of 4.37, The IoT Based recommender's system is intuitive and easy to use with users quickly become proficient in using the system and allows them to perform tasks efficiently with minimal effort.

3.3.5 The IoT Based recommender's system is adaptable and easy to configure in different environments. The system adheres to relevant standards and specifications, ensuring smooth portability reinforcing its flexibility scoring 4.55 in compatibility.

3.3.6 In terms of portability, the machine earned a 4.51 rating, showing that The IoT Based recommender's system is highly effective in integrating with other systems demonstrating its reliability in interoperability while running precisely as intended.

3.3.7 The IoT Based recommender system's maintainability is ensured by being reliable and easy to maintain. The system is well-suited for implementing effective testing procedures, ensuring smooth updates and issue resolution gaining a 4.55 score.

3.3.8 The safety of the machine, rated at 4.49, ensures that sensitive information is well protected. With strong authentication measures, users feel confident that their signatures are safe from unauthorized access.

4. CONCLUSIONS

Based on the testing and evaluation of the designed and developed IOT based taro-cassava soil monitoring system with recommender, the following conclusions are drawn:

1. The hardware components of the machine were successfully integrated and are functioning as expected, responding accurately to commands from the microcontroller. These components are monitored by the website application developed specifically for the machine, ensuring smooth and coordinated operation throughout the process.

2. The IOT based taro-cassava soil monitoring system with recommender was successfully designed and developed effectively demonstrating the functionality of the monitoring in identifying key parameters influenced by microclimate factors that impact taro and cassava growth.

3. The machine successfully gives proper recommendations in consideration of the soil nutrients gathered. Monitoring soil information and generating accurate actions for key parameters such as Soil Nitrogen, Phosphorus, and Potassium (NPK) levels, Soil pH, Moisture, Electric Conductivity, and Temperature.

4. The machine was designed to gather crucial soil nutrients and give recommendations based on thresholds tailored for taro and cassava.

5. The IOT based taro-cassava soil monitoring system with recommender proves to be accurate and consistent compared to standard instrument devices.

6. The machine was thoroughly evaluated by selected evaluators, ensuring an accurate and honest assessment of its performance. The evaluation covered aspects such as functional suitability, reliability. usability, performance efficiency, compatibility, portability, maintainability and safety all of which confirmed that the machine meets the necessary standards for practical use.

ACKNOWLEDGEMENT

We would like to thank God above all for providing us with the strength, wisdom, and guidance throughout the completion of this study.

We are sincerely grateful to our subject instructor, Dr. Monaliza S. Jimenez, for her continuous support, encouragement, and valuable advice during the course of our research.

We would also like to express our appreciation to our technical adviser, Engr. Alexander M. Aquino, for his technical guidance, helpful suggestions, and assistance that contributed greatly to the development of our system.

Our heartfelt thanks go to our panel members, Engr. Sheila May Liwag, Engr. Alberto C. Cruz Jr., Engr Bernard G. Yasay, and Engr. Hiroyoshi Arai, for their time, constructive feedback, and insightful comments which helped improve the quality of our study.

We are thankful to our parents for their support and invaluable assistance in our study. Their guidance, encouragement, and sacrifices have been vital to our academic pursuits. Their constant presence and belief in our abilities have been a pillar of strength, motivating us to reach our full potential. We are truly thankful for their unconditional love, understanding, and the countless ways they have contributed to our educational journey. Our achievements are a testimonial to their unyielding dedication and the value they place upon our success.

Lastly, we are thankful to our faculty, classmates and friends specifically CPE-4B, for their assistance and support throughout the study.

REFERENCES

[1] Howeler, R. H. 1991. Field Crops Researc Volume 26, Issue 1, March 1991, Pages 1-18 Long-term effect of cassava cultivation on soil productivity.

https://doi.org/10.1016/0378-4290(91)90053-X.

[2] Deo, P. C., Tyagi, A. P., Taylor, M., Becker, D. K., & Harding, R. M. (2009). Improving taro (Colocasia esculenta var. esculenta) production using biotechnological approaches. The South Pacific Journal of Natural and Applied Sciences, 27(1), 6.

https://doi.org/10.1071/sp09002

[3] Berame, J., Elazegui, E., Arenas, M., & Orozco, J. (2021). Microclimatic factors and soil characteristics of Arroceros Forest Park in the City of Manila, Philippines. Biodiversitas, 22(1412-033X), 2085–4722.

https://doi.org/10.13057/biodiv/d221130