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ValenaGrow: A Soil Monitoring and Irrigation System

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ABSTRACT

Using descriptive and developmental research design, the study focused on the development of a prototype for soil monitoring and irrigation with mobile interface to be used at the Cagayan State University at Lal-lo coffee nursery, Lal-lo, Cagayan, Philippines. It sought to determine the practices of the campus in the irrigation of seedlings, identify issues and gaps of the current irrigation practices, and propose a practical solution through application of emerging technology for smart irrigation. Interviews with faculty members of the College of Agriculture were conducted to determine the inputs in regard to the conceptual paradigm of the study. Using Arduino microcontroller, Wi-Fi module, sensors, and switches, the automated soil moisture monitoring and irrigation system prototype was developed. Using Agile methodology, the mobile application was designed for control and customization. Fifteen (15) system evaluators and end users evaluated the developed project. Findings show that the project is compliant to a great extent with ISO 25010:2011 criteria. The project supports sustainability in agriculture particularly coffee production by increasing productivity through technology-based innovation.

Keywords: *Irrigation System, Soil Monitoring System, Arduino Microcontroller*

INTRODUCTION

Coffee (*Coffea*) is known as the awakening beverage for almost all people. It stands out not only for its economic significance but also for its cultural and social impact. However, the production of coffee seedlings is considered a challenging task due to the various factors that may affect productivity and sustainability. The dynamics of soil moisture are critical for planning and managing water resources, agricultural productivity and for modeling numerous hydrological processes like water irrigation. Soil moisture is a critical parameter in agriculture where both the shortage or overabundance of water cause plants to die. With this, the use of soil monitoring and irrigation system is essential and guarantees successful crop production, providing water in the right quantity, at the ideal time and in an appropriate manner.

The use of ICT in agriculture continuously evolve to address numerous technological needs. Particularly, the widespread adoption of ICT has significantly enhanced the efficient allocation of resources, reduced production costs, and stimulated greater demand and investment across various economic sectors (Khatatbeh and Moosa 2022). For example, the use of an irrigation system in a nursery is essential and guarantees successful production, providing water in the right quantity, at the ideal time and in an appropriate manner.

Cagayan State University Lal-lo campus specializes in the production of Coffee Valena as its niche commodity. One of the challenges of the campus in coffee production is water scarcity, particularly during the summer months as the campus goes through an extended period of water deficit and very high temperatures. As a result, the difficulty of producing seedlings increases even further.

It is with this issue and concern that this study is conceptualized. It focused on the practices of the campus in the irrigation of coffee seedlings, the underlying issues and gaps of the current irrigation practices, and the implementation of a practical solution to the problems. The output is an Arduino-powered prototype that automates irrigation based on predefined soil moisture level. The utilization of the project would ease the work of agriculture faculty and students who are tasked to maintain the coffee nursery. At a larger context, the project is in support to sustainability in agriculture particularly coffee production by increasing productivity through technology-based innovation.

Statement of the Problem

The main objective of this project is to use an Arduino, integrated with ESP32 and plant sensors to develop a Soil Monitoring and Irrigation System for coffee seedlings. Specifically, it sought to answer the following questions: (1) What are the existing practices of CSU Lal-lo campus in the irrigation of coffee seedlings? (2) What are the problems and needs in the implementation of the existing irrigation practices for coffee seedlings? (3) What are the risks of improper soil moisture monitoring concerning the health of coffee seedlings? (4) What new and existing technology for plant irrigation and soil moisture monitoring can be developed and implemented to mitigate the risks of improper soil moisture monitoring and irrigation? (5) What is the assessment of the participants on the extent of compliance of the developed project to ISO 25010 Software Quality Standards in terms of the following criteria: (a) Functionality (b) Reliability (c) Usability (d) Efficiency (e) Maintainability (f) Portability (6) What enhancements can be done to improve the developed project?

MATERIALS AND METHODS

Descriptive research was used to understand the current practices, challenges, and risks faced by the agriculture faculty and students in growing coffee seedlings while developmental methemoglobinemia model, and 1 for histopathological examination. Rats were randomly selected and assigned to groups based on their respective tests. method was used in the development of a prototype. The Agile Model in system development was

employed in the development of the system including the mobile application.

The study was conducted at Cagayan State University Lal-lo Campus - College of Agriculture. Participants were agriculture faculty and students who were primary informants and sources of major information inputs to the project. IT Experts who are IT faculty members and staff served as evaluators of the developed project vis-à-vis software quality standards who likewise provided feedback on the performance of the project.

Figure 1. Agile Model

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IT Experts who are IT faculty members and staff served as evaluators of the developed project vis-à-vis software quality standards who likewise provided feedback on the performance of the project. Using an interview guide, formal interviews were done with agriculture faculty and students to elicit information as regards the objectives of the study. The standardized ISO 25010:2011 software quality standards was used as evaluation tool for the system evaluators. The product quality model defined in ISO 25010 comprises eight quality characteristics.

Mean was used to analyze the rating of the IT experts with respect to the compliance of the application which was developed in this study in relation to ISO standards. The extent of compliance of the system was rated using the following matrix:

Table 1: Likert Scale for the Measurement of the Extent of Compliance of the System to ISO 25010:2011 Software Quality Standards

Mean Range	**Descriptive Equivalent**	**Interpretation**
4.20 - 5.00	Very Great Extent	The measure described in the item is compliant to the very high extent or OUTSTANDING
3.40 – 4.19	Great Extent	The measure described in the item is compliant to a high extent or VERY SATISFACTORY
2.60 – 3.39	Moderate Extent	The measure described in the item is compliant to the moderate extent or SATISFACTORY
1.80 – 2.59	Low Extent	The measure described in the item is compliant at low extent or FAIR
1.00 – 1.79	Very Low Extent	The measure described in the item is compliant at the lowest extent or POOR

RESULTS AND DISCUSSION

Existing practices of the campus in the irrigation of coffee seedlings

Watering cans are the most common method utilized on campus to irrigate coffee seedlings. This method, considered a traditional kind of irrigation, frequently requires manually filling cans with water and transporting them to seedlings. It can cause unequal water distribution and takes a lot of time and work, especially when dealing with a large number of seedlings. Moreover, advanced irrigation methods that could increase water efficiency, reduce waste, and encourage more consistent growth of the coffee seedlings are not integrated into this process, which is the traditional

process. Relying on this outdated technique emphasizes the need for potential developments or innovations that improve productivity in agriculture and ease the watering procedure.

Problems and needs in the existing irrigation practices

The labor-intensive technique of gathering water is one of the major problems with the irrigation methods used today. It takes a lot of time and physical work to draw and carry water by hand, especially for extensive irrigation projects. Also, water extraction needs to be done twice a day, in the morning and the afternoon. According to stakeholders, the procedure could be considerably more effective and less time consuming if equipment or contemporary technologies were available.

Risk of improper soil moisture monitoring in regard to coffee seedlings health

Coffee seedling's health is at risk from two primary causes when soil moisture is not properly monitored. First, waterlogging and the development of dangerous germs might result from overwatering or a high amount of moisture in the soil. Waterlogging causes the roots to lose oxygen, which affects the seedlings' ability to take up nutrients and may result in conditions like root rot. Second, if soil dryness is not properly monitored, seedlings may not absorb enough water. A lack of sufficient water hinders their growth and reduces their general health and productivity.

Existing technology on plant irrigation and soil moisture monitoring in mitigating risks of improper soil moisture monitoring and irrigation

Systems like drip irrigation are used to reduce the risks related to improper soil moisture monitoring. By precisely and carefully delivering water to plant roots, drip irrigation makes sure that just the necessary amount of water is delivered. This technique reduces water waste and avoids problems like waterlogging or overwatering.

Assessment of the participants on the compliance of the system/project developed with ISO 25010 Software Quality Standards

Table 2. Assessment of System Compliance with ISO 25010 Software Quality Standards by Participants and IT Experts

Attributes	IT Experts	Users	Mean	Qualitative Description
Functional Suitability	3.58	3.53	3.56	Great Extent
Reliability	3.13	3.07	3.10	Moderate Extent
Usability	3.65	3.55	3.60	Great Extent
Performance Efficiency	3.69	3.55	3.62	Great Extent
Maintainability	3.50	3.07	3.28	Moderate Extent
Portability	3.58	3.58	3.58	Great Extent
Security	3.34	3.50	3.42	Great Extent
Compatibility	3.67	3.80	3.74	Great Extent
Overall Mean	3.52	3.39	3.45	Great Extent

The table provides an overview of how user participants and IT experts assessed the system's compliance with software quality standards. Although "Reliability" received the lowest rating which means that the system's reliability in regard to ISO standard is compliant only at a "Moderately Extent", still the system has generally operated effectively and fulfilled its intended purposes in the majority of situations.

Functionality, Efficiency, Usability, Portability, Performance Security, and Compatibility were the five attributes evaluated that consistently received a compliance rating of "Great Extent." With a weighted mean of 3.74, compatibility ranked as the first and greatest attribute among others, indicating that the system can be installed and run on various types of devices as applicable.

With a mean score of 3.62, performance efficiency came in second, highlighting how crucial it is that the system or

product is able to perform its functions efficiently. Conversely, reliability had the lowest mean, 3.10, indicating that there may be issues with the system's ability to offer performance in various scenarios and that additional measures may be taken to increase the system's reliability.

The system received an overall weighted mean rating of 3.45 from the participants, which is consistent with the "Great Extent" compliance rating for the evaluation criteria. These findings demonstrate the system's adherence to stringent software quality requirements while also providing useful information for targeted improvements, particularly in the reliability characteristic.

Recommendations for Enhancements

Evaluators suggested the inclusion of data on soil temperature and rainfall. The use of solar batteries as backup to power the water pump ensuring an eco-friendly and sustainable energy source is also suggested. Voltmeter may be included to monitor battery charge levels, enabling efficient maintenance of the system. Incorporating a feature to adjust the water output settings that allow users to control the amount of water dispensed, tailored to the growth stages of the coffee seedlings is also suggested. The prototype chassis and physical design may be also be improved. Finally, the system is recommended to be deployed in an actual field to further test its efficiency and accuracy.

CONCLUSION

Based on the findings of the study in which the developed project and system is compliant to the ISO 25010 software quality criteria, the project is an efficient and practical solution to the issues and gaps of the traditional irrigation system for coffee nurseries thereby supporting the government's vision of sustainable coffee production. This initiative highlights the potential of blending ICT with farming and thus it is a big leap forward along green technology.

RECOMMENDATION

Based on the findings and conclusion made, the following recommendations are highly suggested: (1) The Cagayan State University Lal-lo Campus may consider the utilization of the prototype and finance the development and deployment of a full scale project to be implemented at the campus' coffee nursery; (2) The researchers may consider the suggestions of the evaluators towards to improvement of the project; and (3) Future researches may conduct parallel study focusing on the suggested enhancements and other areas to improve the application

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