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SMARTAGRI: A DESIGN, DEVELOPMENT, AND PILOT TESTING OF AN ARDUINO-BASED SOLAR-POWERED ENVIRONMENTAL CONTROL SYSTEM PROTOTYPE FOR PINILISA RICE PRODUCTION

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ABSTRACT

Smart Agriculture aims to develop a technology-based agricultural system that addresses climate resiliency, sustainability, and productivity of upland rice. The application of the internet of things to agricultural production effectively convey contemporary farm production to warrant food security. The agile model methodology was used in this study in developing an agricultural system that automates and controls temperature, relative humidity, and soil moisture. Microcontrollers are programmed to gather environmental data remotely utilizing internet technology. Environmental data was used as a stimulus to trigger irrigation and cooling system. Descriptive statistics had been used to assess the functional suitability, performance quality, compatibility, usability, reliability, security, maintainability and portability of the system developed by IT experts and upland rice farmers of Isabela. In general, in descriptive statistics, mean and standard deviations had been used to analyse the data relating to the reliability of the application produced and the assessment of IT experts and farmers. The developed application was found to adhere to ISO 25010 in terms of ISO 25010 compliance.

Keywords: internet of things, microcontroller, data acquisition.

INTRODUCTION

The most popular crop in the Philippines is rice, it is a semi-aquatic that ideally grows in highly irrigated areas. But due to irrigation constraints in the country, rice is being grown in rain-fed areas as well as on rolling to steep farmlands. In 2020, the Department of Agriculture (DA) aims to produce 19.6 million metric tons (MMT) of unhusked rice (palay) [1]. However, these goals have been challenged by climate variability, which has a significant impact on yield production. 82.4 percent of the overall Philippine rice losses from 1970 to 1990 were caused by natural disasters such as hurricanes, floods and droughts. [2].

As a part of Southeast Asia, the Philippines lies in the zone categorized for drought-prone agricultural areas. With the absence of an irrigation system in hilly terrains of Isabela, upland rice production is the most common rice planting method in agriculture production, but due to climate change, environmental factors greatly affect crop yields and local farmers to improve productivity in addressing the challenging demands of food security.

Climate variability is a major challenge in the development of upland rice. climate variability can lead to changes in spatial variability and crop production [3].

In 2007, the Intergovernmental Panel on Climate Change's assessment report suggested that regional and international weather patterns are also likely to become more complex than they actually are, with changes in the frequency and intensity of severe events including such cyclones, floods, windstorms and water shortages. [4], [5].

Higher beyond threshold temperatures, the El Nino phenomenon, and the worsening vulnerability of agricultural systems especially small-time farmers demand a technology-based solution to step up in reducing these factors to increase productivity and sustainability of food security.

Climate changes have an effect on plant growth and production, and the uncertainty and incidence of increasing temperatures can significantly reduce yields, particularly during critical rice crop periods [6]. They can negatively influence the stability of food production and thus food security by bringing large variations in crop yields and fresh produce supplies and increase risk of soil erosion.

Microcontroller based crop production system was designed to monitor environmental variables that affect the growth of crops. Data acquisition equipment will harvest data particularly soil moisture, relative humidity, and temperature. Data acquisition devices include electronic sensors that will constantly monitor changes in temperature and soil moisture. The user will have the capacity to control environmental entities such as temperature, soil moisture, and relative humidity through electronic devices. This technology will greatly increase their production yield, highly resilient crops, and sustainable irrigation system for better productivity and optimized production for upland rice. The Internet of Things (IoT) is considered the third wave of creativity in technology. It is also possible to view the IoT as a global network facilitating connectivity between electronic devices and humans. [7].

RELATED LITERATURE

This section addresses the analysis and observations made by previous researchers as an account of what was written in connection with this project. It is a concentrated analysis on the advancement of technology used in the project.

In various studies, The IoT-based architecture provides real-time data realization and analysis that can be

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used worldwide in conjunction with the parameter tracked in other parts of the world to understand the abnormal behaviour of the crop of the same kind [8]. IOT is a smart farming term that can thus control the parameters, eliminating the need for manual intervention [9]. IoT development has made it possible to collect real-time data in many applications, especially in agriculture [10]. Agriculture relies on many factors, such as the amount of soil moisture, probability of precipitation, plant diseases, etc. [11]. Several methods have been developed to help farmers using machine learning algorithms and wireless sensor networks. In their study, Mat, *et al*., discusses the efficacy of the greenhouse crop irrigation feedback control system and supports saving water by this means [12]. The amount of soil moisture is the greatest soil feature. Irrigated farms rely on the management of water and soil, the two fundamental raw materials. Putting unnecessary water increases the expense of pumping, decreases the influence of water on the soil and induces pollution or contaminants [13].

A system for monitoring crop fields using sensors (soil moisture, temperature, humidity, light) and automating the irrigation system was developed in the Rajalakshmi research. Sensor data is transmitted to a Web server database utilizing wireless communication [14]. Authors in [15] consider the production of SNs that can calculate parameters affecting crop growth and quality and create a data output visualization tool. Some experimental projects to establish a realistic IoT-enabled solution for agriculture can be located in [16]. Although there are some theoretical studies and considerations related to application of agricultural Internet of Things, (17-21), there is still minimal practical work to design and allow Internet of Things for upland rice production particularly Pinilisa Rice.

Figure-1. Agile model.

METHODOLOGY

This research utilized the Adaptive Project Framework (APF) Agile methodology. In the case of the Adaptive Project Framework (APF) Agile model, steps include Plan, Design, Build, Test, and Review. The complete system was divided into independent and smaller project modules. These modules were described as sprints. Based on the participant's feedback, increments were added and continue to the next sprint. An IoT based production technology application was developed, a microcontroller-based device that will monitor temperature humidity, and soil moisture. It was installed in the field and will send data via a wireless connection to the remote server that will constantly monitor, control, and record data and information. The system was composed of a microcontroller that facilitates a closed feedback control system that was designed to maintain the ambient temperature, soil moisture, and desired humidity at the field at optimal growing conditions for maximum production of the crops.

The system's data collection, tracking, and assessment results in deciding which solution is successful and where those modifications are most needed. Therefore ICT engaged strategies are more effective in the agricultural sector than traditional methods. Technical and financial assistance is a crucial requirement for farmers to migrate to an inclusive and efficient process. The ICT-based information sharing models should overcome these challenges to share the knowledge that increases production, social, and environmental sustainability of farmers and farmers' societies. The following figure shows the block diagram for the framework built.

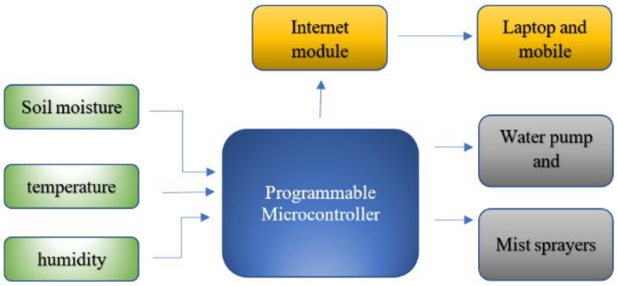

Figure-2. Block diagram of the SmartAgri system.

DESIGN AND OVERVIEW OF THE SYSTEM

This paper focuses on the development of the implementation of a smart agricultural system based on microcontrollers and experimental-scale wireless communication within upland rice farms in Isabela. The goal of the implementation was to show that the temperature, relative humidity, and soil moisture can be controlled automatically and data can be gathered remotely.

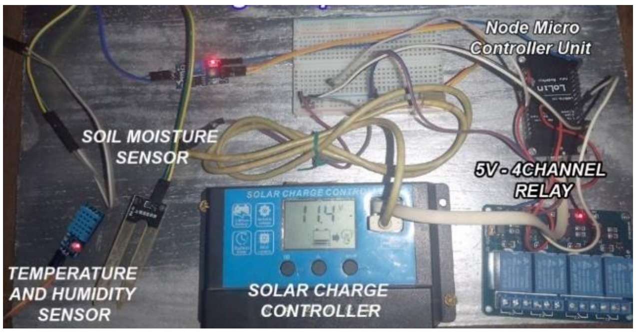

Figure-3. Primary components of the data acquisition sensors and microcontroller.

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Hardware

Soil Moisture Sensor

The soil humidity device was used to calculate the soil's moisture level. The two big pads, functioning together as a variable resistor, serve as sensor probes. Therefore more moisture in the soil, the higher the capacitance and the lower the resistance between the pads.

Technical Specification

3 to 5V Power

An analog production of the quality of moisture. Digital moisture material production with adjustable set-point.

Figure-4. Soil moisture sensor.

Temperature and Humidity Sensor

The DHT11 is a simple and ultra-low-cost digital temperature and humidity sensor. It utilizes a capacitive humidity sensor and a thermistor to measure the surrounding air, and throws out a digital signal on the data pin (no analog input pins needed). It is fairly easy to use, but data capture involves careful timing. The relative humidity is measured that when there is a temperature difference, the relative humidity also increases. The amount of water droplets released into the air will increase afterirrigation. This causes the temperature to decrease, which in turn increases the relative humidity surrounding it. The user is also notified about the measurements of temperature and humidity so that the user can understand the conditions of the field from anywhere.

Technical Specification

Power 3 to 5V

2.5mA max current usage (when requesting data) during conversion

Great for humidity readings of 20-80 per cent with 5 per cent precision

Strong ±2 ° C precision for 0-50 ° C temperature readings

Figure-5. The DHT11 temperature and humidity sensor.

Photovoltaic Power System

A 4-100W solar photovoltaic panel, solar charge controller, inverter, and battery are part of the photovoltaic power system. To energize the SmartAgri system, the solar power system was installed since there is no existing electrical service in the experimental area.

Figure-6. The power source of the electrical system.

Irrigation and Cooling System

Mist sprayers are also installed for the regulation of temperature and humidity. A high-pressure misting system is essential to regulate the temperature of the rice-growing area. Rotating sprinkler was also used for the irrigation system. A split stream of water is sprayed by fully revolving sprinklers from 6 m to 12 m (20-40 ft.). The sprinklers can be spaced from 18 to 35 feet apart, anywhere.

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Figure-7. Rotating sprinkler for irrigation.

Figure-8. Misting sprayer for temperature and humidity control.

Software

Fuzzy Logic

A fuzzy-logic algorithm is used in the control of temperature, humidity, and soil moisture. This algorithm is implemented in the microcontroller. The input parameters are soil moisture level, relative humidity level, and temperature level. The membership functions for the inputs are low-moisture, normal moisture, high-moisture, lowRH, normalRH, highRH, lowTemp, normalTemp, and highTemp. The output parameters consist of the period for each corrective action set-up to open the valve for mist sprayer and rotating sprinklers.

User Interface

Graphical user interface software was developed based on soil moisture and temperature data for real-time monitoring and data storage. The software application allows the user to graphically simulate the data from each online weather variable using any laptop or mobile devices with an internet connection. The web application shows average daily data about temperature, soil humidity, and humidity.

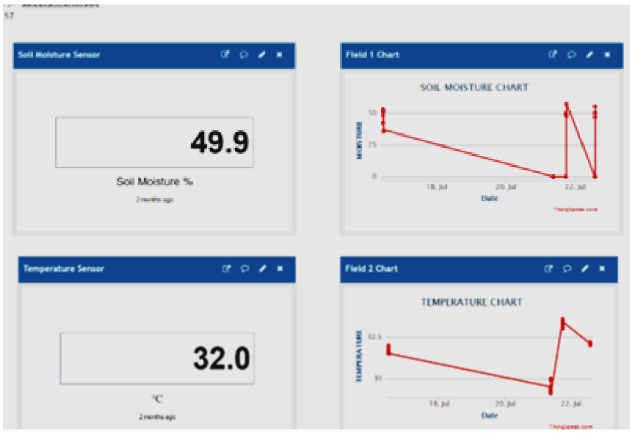

Figure-9. Web application for data monitoring.

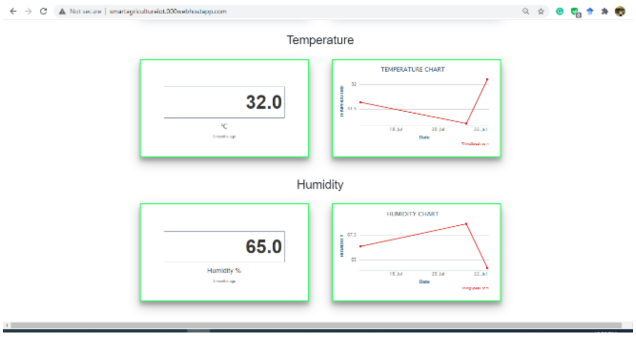

Figure-10. Web application for data monitoring.

RESULT AND DISCUSSIONS

The designed prototype used IoT devices to collect temperature and humidity data derived from the DHT11 sensor, soil moisture extracted from the soil moisture sensor, this knowledge can be shown to the farmer on a laptop, smartphone or tablet, and is used for automatic irrigation on / off control. In addition, the farmer can turn on / off the irrigation manually. An administrator can manipulate the information from the IoTs collected and monitor the data from each installation. To discover information, the admin can also mine the data. This expertise is used to optimize seasonal agriculture.

EVALUATION

In terms of functional suitability, performance quality, compatibility, usability, reliability, security, maintainability, and portability, both IT experts and upland rice farmers strongly agree that the established application is highly compliant with ISO 25010. It can be addressed by meeting the real and implied needs of local agricultural producers in the development of Pinilisa rice from the developed system and is highly approved by the respondents.

Table-1. Assessment of the participants on accordance with ISO 25010 software quality requirements of the Developed Application.

Characteristics	IT Experts	Farmer	Over All Mean	Descriptive Rating
Functional Suitability	4.73	4.67	4.7	Very High Extent
Performance Efficiency	4.8	4.53	4.67	Very High Extent
Compatibility	4.9	4.8	4.85	Very High Extent
Usability	4.77	4.73	4.75	Very High Extent
Reliability	4.7	4.7	4.7	Very High Extent
Security	4.76	4.88	4.82	Very High Extent
Maintainability	4.6	4.6	4.6	Very High Extent
Portability	4.8	4.8	4.8	Very High Extent

The evaluation of the compliance of the established application by the participants in terms of functional suitability, performance quality, compatibility, usability, reliability, protection, maintainability and portability is presented in Table-1. They obtained a qualitatively interpreted mean category from 4.6 to 4.85 as very high. This means that the respondents perceived that the system's function produces reliable results, covers all the defined objectives, and promotes the execution of the specified tasks.

CONCLUSIONS

The device showed that with Pinilisa Rice Farming, IoTs can be used to help and assist farmers. In addition, farmers can use the time they have saved on other profitable activities. To monitor the on-off switching of water sprinklers and mist sprayers automatically, real-time information from IoT devices at Pinilisa Farming was used. Initially, we collected environmental information and conducted yield analysis with these data for 5 months (150 days). The information from the IoTs obtained consists of temperature, humidity, and soil moisture, and was collected every hour, but the daily averages were used for analysis. Moreover, Pinilisa's yields were reported to determine the relationship between information on IoTs and agricultural products. The study conducted will help improve upland rice production. The IoT based agricultural system works to improve time productivity, water management, environmental monitoring, and control. It also minimizes human efforts, simplifies farming techniques, and leads to the growth of smart farming.

As demonstrated by its very large scale of compliance with ISO 25010 Software Quality Standards in terms of Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Maintainability, Security, and Portability, the agricultural system is ready for full use by its intended users. As suggested in ISO 25010, the defined application fulfills the specified and expected needs of the users as it provides accessibility at any period or anywhere. Internet connectivity, however, must be addressed for application because it was one of the constraints of the application.

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