SMART GREENHOUSE: AN IOT-BASED MONITORING AND CONTROL SYSTEM WITH PREDICTIVE ANALYTICS

1 author:

Ronald Ullibac Wacas
Kalinga State University

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SMART GREENHOUSE: AN IOT-BASED MONITORING AND CONTROL SYSTEM WITH PREDICTIVE ANALYTICS

RONALD WACAS
College of Engineering and Information Technology
Kalinga State University, Bulanao, Tabuk City, Kalinga Province
ruwacas@ksu.edu.ph

ABSTRACT

Agriculture 4.0, or smart agriculture, pertains to the integration of advanced technologies such as IoT, cloud computing, robotics, and AI in the agricultural production process. Through the implementation of these technologies, farmers can efficiently manage resources and make informed decisions based on data to enhance crop yields, minimize waste, and promote sustainability. This study adopted a mixed-method research design that includes developmental research and quantitative methods to assess compliance with ISO 25010 software quality standards. The V-model systems development methodology was utilized to develop the smart greenhouse with predictive analytics. The participants of the study comprised professionals and experts in the fields of agriculture and IT, and the study was conducted at Kalinga State University. The study identified a range of problems and issues faced by greenhouse users in controlling and monitoring the necessary environmental conditions of the greenhouse. The study also identified eight key predictors related to environmental factors that impact crop growth, development, and production. Multiple regression was used by the researcher to predict the yield of red-hot chili (Capsicum frutescens) by establishing a relationship between yield and independent variables. To address the challenges encountered by greenhouse users in manual management of the greenhouse, the researcher developed a smart greenhouse system that automatically regulates temperature, humidity, lighting, irrigation, and CO2 levels in the greenhouse based on the needs of the plants. The system also features web-based monitoring and predictive analytics capabilities that enable remote greenhouse monitoring and crop yield prediction. Additionally, it includes an SMS notification system that alerts users to any changes in parameters. The system was evaluated using ISO 25010 software quality standards in terms of functionality, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The evaluation demonstrated that the system was highly compliant in all these areas.

***Keywords**: Internet-of-things, ISO 250210 Software Quality Standards, Smart Agriculture, and Smart Greenhouse*

INTRODUCTION

With the continuously growing population, food security is currently one of the major concerns worldwide (Molotoks, 2021). The available land area for agricultural cultivation is gradually shrinking, particularly in the emerging economies of Africa, Asia, and Latin America, due to the increase in industrialization (Fedotova, 2021). This predicament has developed over time due to multiple factors, including climate change, poor income, deprivation, and a lack of knowledge about modern tools and techniques. Furthermore, urban population expansion of 66% has led to a reduction of around 50 million hectares in cultivable land, a drop of 20% in agri-food production, and a spike of 59% to 98% in food consumption, all of which intensify the danger related to food security and nutrition (Pautz et al., 2022). Food security is essential for fulfilling fundamental human rights, promoting nutrition, and, most crucially, supporting regional economic prosperity (Viana et al., 2022).

In recent years, there have been significant efforts to address food security issues through various initiatives such as the prioritization of nutrient-rich food synthesis, modifications to safety net and social protection programs to enhance nutritional impacts, and strategic planning and research (Reyes L.I. et al., 2021). Despite these efforts, severe food insecurity affects approximately one in ten people globally, highlighting the need for further investment in and development of cutting-edge technologies to maximize food availability, sustainability, and resource efficiency while minimizing agricultural consequences (Viana et al., 2022; Albiero et al., 2021). Technical research must be prioritized and adequately funded to incorporate advancements in IoT, sensors and sensor networks, robots, AI, BDAs, cloud computing, and other technological innovations to promote the development of long-term solutions for the agricultural industry (Arajo et al., 2021). This integration of technological advancements in agribusiness lays the foundation for Agriculture 4.0.

Agriculture 4.0, also known as smart agriculture, involves the integration of cutting-edge technologies such as the IoT, BDAs, cloud computing, sophisticated robotics, and AI in the agricultural production process (Mühl et al., 2022). Although it builds on precision farming, Agriculture 4.0 is more comprehensive in scope (Maffezzoli et al., 2022). The term "Agriculture 4.0" was coined in the early 2010s and was adopted by the European Commission (EC) and the German Government in their 2020 strategic initiative to promote sustainable development in agriculture, rural areas, and health sectors (Dayiolu et al., 2022). With the aid of these cutting-edge technologies, Agriculture 4.0 enables farmers to manage their resources efficiently and make informed decisions based on available data (Beluhova-Uzunova et al., 2022). Additionally, it increases agricultural productivity and reduces the environmental impact associated with production processes (Mukherjee et al., 2021). Technological advancements, such as robotic harvesters, drones, self-driving tractors, seeding and weeding machinery, real-time kinematic technology, mini chromosome technology, farm management software, crop and soil sensors, and more, have significantly benefited the agricultural sector (Solodovnik et al., 2023). These innovations have diverse applications, including the use of smart farming techniques to increase the accuracy of administering pesticides, herbicides, and fertilizers (Sott et al., 2020). Drones can be employed to identify weeds, while robots are useful for milking livestock and removing weeds (Rose et al., 2018).

The Internet of Things (IoT) has the potential to revolutionize the agriculture industry by enabling automation and increasing efficiency. IoT refers to a network of physical objects, or "things," that can collect and exchange data and interact with the environment (Matta et al., 2019). With the integration of an intelligent decision-making system, IoT can significantly reduce human intervention in agricultural tasks, and this system plays a crucial role in the success or failure of automated activities.

Meanwhile, artificial intelligence (AI) can enhance the decision-making process by enabling computers to perform tasks that typically require human intelligence, such as decision-making, visual perception, speech recognition, and language translations (Yang, 2020). The amalgamation of IoT and AI results in a powerful system that can surpass human decision-making accuracy, making them two sides of the same coin in automating agricultural tasks.

To promote the use of these cutting-edge technologies in agriculture, there is a need to raise awareness among Filipino farmers regarding their benefits. Agricultural extension services can play a critical role in disseminating information about mechanization technologies and their applications in the agricultural sector. In addition, the government can provide incentives to farmers who adopt mechanization technologies, such as tax breaks or subsidies.

Moreover, the government's policies on agriculture are now geared towards achieving food self-sufficiency and security through the adoption and utilization of technologies to improve land, crop, and labor productivity. The Department of Agriculture has launched various programs aimed at enhancing the competitiveness of the agriculture sector, including the "Agri-Pinoy" program, which focuses on providing support services to farmers and fishermen. These programs aim to improve the supply chain and overall competitiveness of the agriculture sector.

Furthermore, other government agencies and research centers, including higher education institutions, can contribute to agriculture by developing and disseminating new technologies. They conduct research and development activities that result in new technologies such as precision agriculture, smart agriculture, and digital farming technologies. These technologies can improve the efficiency and productivity of the agricultural sector, leading to better yields and profitability for farmers.

Kalinga State University, as an academic institution of higher learning with the mandate to conduct research, is geared towards improving its research infrastructure. One of which is the university's greenhouse center, which serves as the technology demonstration center for researchers. It is also utilized as an agricultural production center for the income-generating projects of the university. However, the workers at the greenhouse have experienced problems due to hand-tending management.

The process of managing a greenhouse manually is characterized by the need for a considerable amount of human effort and time. This is since the manual management of a greenhouse involves tasks such as monitoring environmental conditions, watering plants, and controlling pests and diseases. These activities require regular attention, and the manual nature of the work means that there is a high demand for human intervention. The labor-intensive nature of this process can make it difficult to maintain productivity and efficiency, especially in large-scale greenhouse operations.

While some greenhouse automation systems exist, they are often expensive and not accessible to small-scale growers. Moreover, these systems are not always tailored to the specific needs of different plant species and can be challenging to customize.

Therefore, there is a need to conduct research on developing cost-effective and efficient automation solutions that can be easily customized and adapted to different types of greenhouse environments and plant species. Such research could focus on the development of smart greenhouses that respond to changes in environmental factors such as temperature, humidity, and light intensity.

This study focused on the design and development of a smart greenhouse monitoring and control system with predictive analytics. Smart greenhouses are a revolution in agriculture, creating a self-regulating microclimate suitable for plant growth. It makes use of IOT-based technology that will be used to monitor and control the required environmental conditions of crops inside a greenhouse. Such environmental conditions include soil moisture, temperature, humidity, light, and the CO_2 requirements of crops. The system used Arduino Mega and sensors such as soil moisture sensors, DHT 22 sensors, photosensitive sensors, and MQ135 air quality sensors.

The system can be remotely monitored using a web-based system that is capable of presenting data in a graphical format. Every time there are changes in the climatic conditions, the user is notified via SMS message alert.

The study also included predictive analytics to make data-driven decisions. By learning from historical and future data based on measured variables, management and the outcomes of decisions can be more readily made, which can greatly impact efficiencies and processes. This will be applied to Siling Labuyo (Capsicum frutescens). It is a small, fiery chili pepper that is widely used in local cuisine as a spice or condiment. Siling Labuyo is a high-value crop because of its demand and versatility in the food industry.

Conceptual Framework

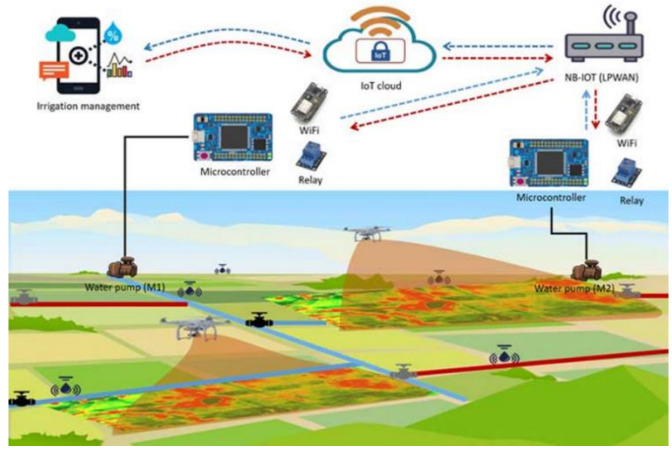


Figure 1.
Conceptual Framework of the Study (Source: K. Kovacs)

Challenges related to climate change in agriculture require the integration of innovative practices capable of increasing resilience and mitigating impacts while also maintaining farm productivity. Technological innovations such as IoT systems, image processing systems, big data capabilities, data analytics, and wireless technologies have been used to leverage the agricultural industry. The application of these emerging technologies in the agriculture industry coined the term smart agriculture.

Smart agriculture is the concept of doing farming in an innovative way, using the latest technologies to increase the quantity and quality of agricultural products. It enables farmers to reduce their resources as well as increase their yields. Smart agriculture makes use of IoT technology to gather and analyze agricultural big data.

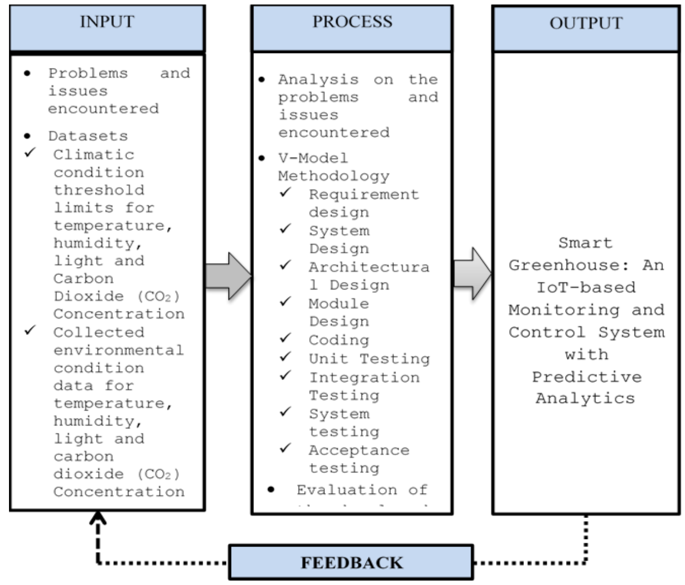
The Internet of Things (IoT) refers to devices having unique identities and capabilities to perform remote sensing, monitoring, and temporarily storing certain blocks of data. IoT is a cross-platform environment where devices are getting smarter, processing is becoming intelligent, and communication is becoming more informative. IoT devices are also capable of having a real-time exchange of data with other devices and applications, either directly or indirectly.

This study focused on the design and development of a smart greenhouse and an IOT-based monitoring and control system with predictive analytics. It made use of IOT-based technology that is used to monitor and control the required environmental conditions of crops inside a greenhouse. The system made use of Arduino Mega and sensors such as soil moisture sensors, DHT22 sensors, photosensitive sensors, and MQ135 air quality sensors.

The system can be remotely monitored and controlled using smartphones. The user will be notified every time there are changes in the climatic conditions inside the greenhouse. Furthermore, the users can also view the current environmental condition using a web-based application in a graphical view for better analysis.

The study also includes predictive analytics to make data-driven decisions. By learning from historical and future data based on measured variables, management and the outcomes of decisions can be more readily made, which can greatly impact efficiencies and processes. This is no easy task, as decisions and recommendations about the future require true datasets that have high confidence.
Conceptual Framework.

Figure 2
Paradigm of the Study



This study used the Input-Process-Output (IPO) Model as the paradigm of the study.

Figure 2 presents the input-process-output paradigm of the study, illustrating the strategic direction of the process-output framework.

Input: In this stage, all inputs were identified, including climatic conditions for soil moisture, temperature, humidity, light, and carbon dioxide (CO2) concentration. These parameters have specific threshold values required for plant growth. The values of these environmental conditions were collected using specific sensors.

To identify problems encountered with the existing system, the researcher conducted interviews with end-users regarding their experiences and observations. Additionally, the requirements of ISO 25010 (System and Software Quality Model) were included to ensure that the system follows software quality standards.

Process: This stage provides an in-depth analysis of the input variables. It also presents the development of the proposed system using the V-model, its compliance with ISO 25010 software quality standards, and the users' acceptance of the proposed system.

Output: The output is the Smart Green House with predictive analytics. This system was deployed at the Kalinga State University Techno-Demo Farm and was used by farm workers and students.

Statement of the Problem

This study aimed to design and developed a Smart Greenhouse, an IoT-based monitoring and control system with Predictive Analytics for Kalinga State University KSU) Technology Demonstration Center.

Specifically, it sought to answer the following questions:

1. What are the problems and issues encountered by the participants in controlling and monitoring the required environmental conditions of the greenhouse, particularly in terms of the following:
   1.1. soil moisture
   1.2. temperature
   1.3. humidity
   1.4. light
   1.5. CO2
2. What are the significant predictors that affect the growth, development, and production of red-hot chili (Capsicum frutescens)?
3. What predictive analytics can be used to predict the yield of red-hot chili (Capsicum frutescens)?
4. What system can be developed to address the identified problems and issues with the existing system?
5. What is the extent of compliance of the proposed system with ISO 25010 software quality standards in terms of:
   5.1. Functionality
   5.2. Performance efficiency
   5.3. Compatibility
   5.4. Usability
   5.5. Reliability
   5.6. Security
   5.7. Maintainability
   5.8. Portability
6. What enhancements can be made to improve the proposed system?

METHODOLOGY

This chapter presents the methods and procedures that were used in the study. It includes the research design, participants of the study, instrumentation, data-gathering procedures, and data-analysis tools.

Research Design

The researcher used descriptive and developmental design methods in the study. For the descriptive research design, the researcher employed qualitative methods to address and collect data related to the problems and issues encountered by the participants in controlling and monitoring the required environmental conditions of the greenhouse, while a quantitative approach was used to assess the developed system based on the ISO 25010 standard questionnaire.

For the developmental design, the researcher used the concept of the V-Model as the basis for the development of the system. The researcher utilized the V-model systems development methodology in designing and developing the proposed Smart Greenhouse with Predictive Analytics.

The V-Model is an approach that was developed by the State of Germany for planning and implementing system development projects. It considers the entire lifecycle of a system, aligning well with systems engineering principles.

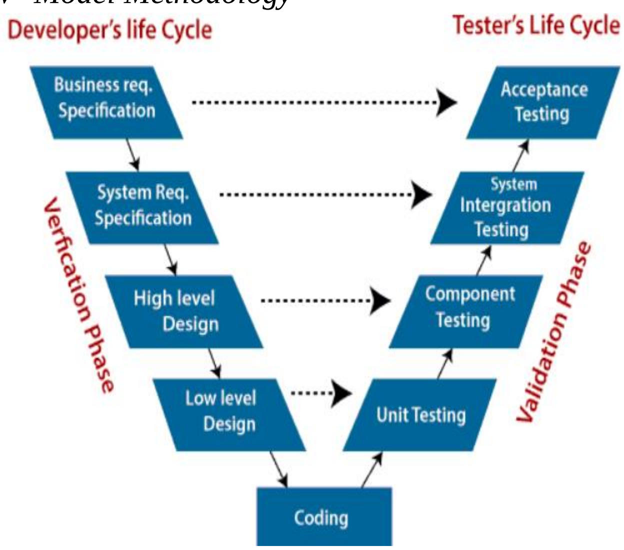
The V-model is an SDLC model where processes are executed sequentially in a V-shape. It is also known as the Verification and Validation model. It is considered an extension of the waterfall model and is based on the association of a testing phase with each corresponding development stage. This means that there is a directly associated testing phase for each phase in the development cycle. This is a highly disciplined model, and the next phase starts only after the previous phase has been completed.

The researcher used this methodology because the system had subsystems that were interdependent on each other.

There is a need to complete the subsystem before proceeding to the next system. Figure 6.0. shows the graphical phases of the V-model.

Figure 3.

V- Model Methodology



Business Requirement Analysis. This is the first step where product requirements are understood from the customer's side. This phase contains detailed communication to understand the customer's expectations and exact requirements.

In this phase, the researcher conducted data gathering through interviews, observations, and surveys**.** The researcher interviewed the personnel in charge of the management of the greenhouse. He also made observations on the daily activities of the greenhouse technician.

System Design. In this stage, system engineers analyzed and interpreted the organizational needs of the client by studying the user requirements document. This is where the researcher used the gathered data during the interview, observation, and survey. The system design was dependent on the data gathered, such as problems encountered by the concerned personnel. The researcher used the gathered data to design the proposed system.

Architecture Design. The researcher considered all the components that consisted of the list of modules, the brief functionality of each module, their interface relationships, dependencies, database tables, architecture diagrams, technology details, etc. The integration testing model was carried out in this phase.

In this phase, the architectural design of the smart greenhouse with data analytics was developed. The researcher identified the needed hardware and software and studied possible compatibility issues that may arise.

Module Design. In the module design phase, the system breaks down into small modules. The detailed design of the modules is specified, which is known as low-level design.

The design of the smart greenhouse with predictive analytics has three modules: a wireless sensor system, a monitoring and control system, and a predictive analytics system.

Coding Phase. After designing, the coding phase started. Based on the requirements, a suitable programming language was chosen. There were some guidelines and standards for coding. Before checking in the repository, the final build was optimized for better performance, and the code went through many code reviews to check the performance.

In this project, the researcher used three programming languages: C++, PHP, and Python. The C++ language was used for coding the monitoring system. This is the Arduino and PHP code for the web-based app that allows users to monitor and control the climatic condition of the greenhouse. Lastly, Python was used for predictive analytics.

Unit Testing. In the V-Model, Unit Test Plans (UTPs) were developed during the module design phase. These UTPs were executed to eliminate errors at the code level or unit level. A unit is the smallest entity that can independently exist, e.g., a program module. Unit testing verifies that the smallest entity can function correctly when isolated from the rest of the codes or units.

Integration Testing. Integration test plans were developed during the architectural design phase. These tests verified that groups created and tested independently can coexist and communicate among themselves.

System Testing. System test plans were developed during the system design phase. Unlike unit and integration test plans, system test plans are composed by the client's business team. System testing ensures that expectations from an application developer are met.

*Acceptance Testing***.** It is related to the system requirement analysis part. It includes testing the software product in a user-friendly environment. Acceptance tests reveal compatibility problems with the different systems that are available within the user's environment. It also discovers non-functional problems like load and performance defects within the real user atmosphere.

Participants of the Study

This research study was conducted at Kalinga State University, Bulanao Campus, located at Purok 6, Bulanao, Tabuk City, Kalinga. The participants in this study included the dean of the College of Agriculture, the center director, the greenhouse technician, greenhouse workers and users, and IT professionals who are experts in the field.

The summary of participants is shown in Table 3.

Table 1.
Participants of the Study

Participants	Frequency	Percentage
Dean- College of Agriculture	1	3.33%
Center Director	1	3.33%
Greenhouse Technicians	2	6.67%
Greenhouse Workers	10	33.33%
Users	6	20.00%
IT Experts	10	33.33%
Total	30	100.00%

The table summarizes the participants involved in the study. There were 30 participants, categorized into six different groups, each with a specific role in managing the university greenhouse center.

The dean of the College of Agriculture played a crucial role in recommending plans and activities to the university president, including ensuring that the greenhouse aligned with the university's goals and objectives.

The Center Director was responsible for managing all plans and activities of the greenhouse center. He or she oversaw the efficient and effective operation of the greenhouse and was the primary point of contact for all stakeholders involved in the greenhouse center.

Greenhouse technicians and users were considered the center's direct clients, as they used the center's facilities and services to conduct their research. They had a voice in the planning and execution of the center's activities and could request and recommend any technical needs for their research.

Greenhouse technicians were responsible for the daily management of the center's plans and activities. They performed practical tasks such as maintaining equipment and watering plants, ensuring the greenhouse ran smoothly on a day-to-day basis.

An IT expert was involved in ensuring the system's compliance with ISO/IEC 25010:2011: System and Software Quality Models. This role focused on ensuring that the technology used in the greenhouse center met the required quality standards and was fit for purpose. This role was less involved in the center's day-to-day activities and more focused on maintaining the technology used in the center.

Instrumentation

To ensure the correctness, adequacy, and appropriateness of the data required during the development process, the researcher used the following: Interview Guide. The researcher used the interview guide in conducting the interview with the dean, greenhouse technicians, and greenhouse workers.

ISO 25010 Standardized Questionnaire: Users of the system were surveyed to assess the integrity of the system's requirements analysis and functionality. In addition, the researcher adopted a standardized survey questionnaire to determine the extent of compliance of the developed application with ISO 25010 Software Quality Assurance Standards.

Observation. Observation is a method used in research to gather data by watching and recording what is happening in a particular setting. It is a way to gain a deeper understanding of behavior, interactions, and other phenomena that occur in a natural or artificial environment.

In this case, the researcher personally observed the activities of the technician in the greenhouse center. Before conducting the observation, the researcher prepared a note where he would write his observations. This note served as a record of the researcher's observations, allowing the researcher to refer to his notes when analyzing and interpreting the data.

During the observation, the researcher took note of various activities, behaviors, and interactions that occur in the greenhouse center. The included details, such as the types of plants being grown, how the technician manages the daily plans and activities of the center, how the technician interacts with users of the greenhouse center, and any challenges that arise during the observation,

Data Gathering Procedure

To obtain the data needed for the investigation, the following procedures were undertaken by the researcher:

1. The researcher obtained permission from the Ethics Review Committee of St. Paul University Philippines to ensure the ethical rationality of the research. Research Ethics Committee (rec@spup.edu.ph). Data and information related to this study were collected from different participants.

2. Prior to the start of the interview and distribution of survey questionnaires, the participants were asked for their voluntary participation and consent to possible information gathering and given full assurance of the confidentiality of the activity. Furthermore, participants' consent was solicited through informed consent before the conduct of data gathering. The informed consent form was attached to the survey questionnaires for the participants' information.

3. The researchers sent a formal letter asking permission from the university president to conduct the study through personal interviews with the selected respondents. Another letter was sent to the identified respondents, asking permission to conduct research in their field of specialization.
4. The researcher conducted an interview with the identified respondents. During the interview, the researcher made sure that the research questions

were clear and concise. He prepared a check list of the questions to be asked so that the flow of asking questions would be in order. A proper setting was chosen for the conduct of the interview. The purpose of the interview was fully explained to the interviewees, and they were assured of the confidentiality of their responses. Moreover, the format of the interview, its nature, purpose, expectations, and time frame were explained. The interview was done in an informal, conversational manner, with the guide questions as a basis, to allow a degree of freedom and adaptability in getting the information from the interviewee. Questions were asked one at a time, giving ample time for the interviewee to think and answer the questions. All the conversations or the interview process were written down for encoding purposes, ensuring proper data was recorded relative to the interview.

The data gathered through the interview guide was transcribed, analyzed, coded, and interpreted. The narrative analysis was guided by the frequency of the emergent themes, and these themes were coded and interpreted accordingly. Words and phrases that appeared to be similar were grouped into the same category. These categories were gradually replaced and re-evaluated to determine how they are linked. In essence, the analysis involved extracting significant statements from the transcribed interviews so that key phrases and statements that spoke directly to the phenomenon in question could be extracted.

5. In this study, the researcher distributed survey questionnaires to the identified respondents. They were given enough time to vividly answer the questions. Such responses were collated and analyzed using identified statistical tools. This will test the system in terms of functional suitability, performance efficiency, compatibility, usability, reliability, security, and portability. Below is the scoring based on five Likert scale criteria.

Data Analysis

The following tools were used to analyze the data to be gathered:

Thematic Analysis. This was used to identify the problems and issues encountered by the participants in the existing processes.

Weighted Mean. This was used to determine the developed system's extent of compliance with ISO 25010 software quality standards as assessed by the participants.

Likert Scale. This was used to get the point scales and descriptive equivalents of the participants' responses to the developed system using the ISO 25010 Software Quality Standards.

Likert Scale for Determining the Developed System's Compliance with ISO/IEC 25010 Software Quality Standards

Table 2.
Scale for Interpreting the Means

Scale	Mean Range	Descriptive Interpretation
5	4.20 - 5.00	Very Great Extent
4	3.40 - 4.19	Great Extent
3	2.60 - 3.39	Moderate Extent
2	1.80 - 2.59	Little Extent
1	1.00 - 1.79	Very Little Extent

RESULTS AND DISCUSSION

This chapter presents the discussion of results based on the interviews and observations conducted as well as the IT experts' assessment of the developed system using ISO/IEC 25010 criteria. The main purpose of this study is to design and implement a smart greenhouse monitoring and control system with predictive analytics.

The Problems and Challenges Encountered by the Participants in Controlling and Monitoring the Required Environmental Condition of the Greenhouse.

Soil Moisture

- The watering of plants inside the greenhouse is done through a manual irrigation system.

- Water is typically delivered to the plants using a hose, watering can, or irrigation bucket. The water is applied to the soil around the base of the plants, either by hand or with a watering tool.
- Manual watering of plants causes inaccurate measurements of soil moisture levels and is labor-intensive.

- There is no way of measuring the soil moisture to know the desired amount of water to be applied.

- If plants don't get enough water, they can lose their leaves. This can cause the plant to have less surface area for making food through photosynthesis. When the plant can't make enough food, it has less energy to grow and survive.

Humidity and Temperature

- Farmers are not able to correctly maintain the temperature and humidity inside the greenhouse. It often leads to fluctuations in temperature and humidity, which are harmful to plants.

- Manual control of temperature may not provide growers with the level of control they need to optimize plant growth.

- Difficulty in maintaining consistent and optimal temperature and humidity levels; inefficiency in the use of energy and resources for heating and cooling; inability to monitor and adjust temperature and humidity; difficulty in detecting and responding to sudden changes in temperature and humidity.

Based on the experience of informants, manual control of temperature and humidity inside the greenhouse is problematic. Fluctuations in temperature and humidity caused by incorrect maintenance can be harmful to plants. Human errors such as forgetting to adjust the temperature, misreading the thermometer, or adjusting the temperature incorrectly can lead to the damage or death of plants. Furthermore, manual control may not provide growers with the level of control they need to optimize plant growth. There are difficulties in maintaining consistent and optimal temperature and humidity levels, inefficiency in the use of energy and resources for heating and cooling, and difficulty in detecting and responding to sudden changes in temperature and humidity.

Light

- The amount of available sunlight varies significantly throughout the year due to seasonal changes. As a result, greenhouse technicians must adjust the amount of artificial lighting used to supplement natural sunlight to ensure that plants receive sufficient light for optimal growth.

- Cloudy weather reduces the amount of natural sunlight available to plants, which can have a negative impact on their growth.

- Artificial lighting is expensive to operate, particularly if high-intensity lighting is required.

  The informants highlight the significance of managing sunlight exposure in greenhouses, as it greatly affects plant growth. Greenhouse technicians must adjust artificial lighting to compensate for seasonal changes and weather patterns that can reduce natural sunlight. Cloudy weather may require increased artificial lighting or more efficient lighting systems, while some plants may require shading to prevent overexposure. However, the cost of artificial lighting must be balanced with the benefits of increased crop yields to maintain profitability.

CO2

- Controlling CO2 levels inside a greenhouse is crucial for maintaining optimal growing conditions and maximizing plant growth and productivity. It also helps maintain a healthy environment for both the plants and the people who work inside the greenhouse.

- CO2 levels outside of the greenhouse can vary depending on the time of day, season, and location. This can impact the CO2 levels inside the greenhouse and make it challenging to maintain consistency.

- Adding CO2 from external sources is expensive and may require specialized equipment.

According to the informants, CO2 levels outside of the greenhouse are not consistent and can vary depending on the time of day, season, and location. This variability can impact the CO2 levels inside the greenhouse and make it difficult to maintain a consistent environment. To supplement CO2 levels, external sources can be used, but this can be expensive and require specialized equipment. Additionally, determining the correct amount of CO2 to add can be challenging based on the needs of the plants. Regular monitoring of CO2 levels is crucial to ensuring optimal plant growth. However, monitoring equipment can be expensive, and interpreting the data can be complex.

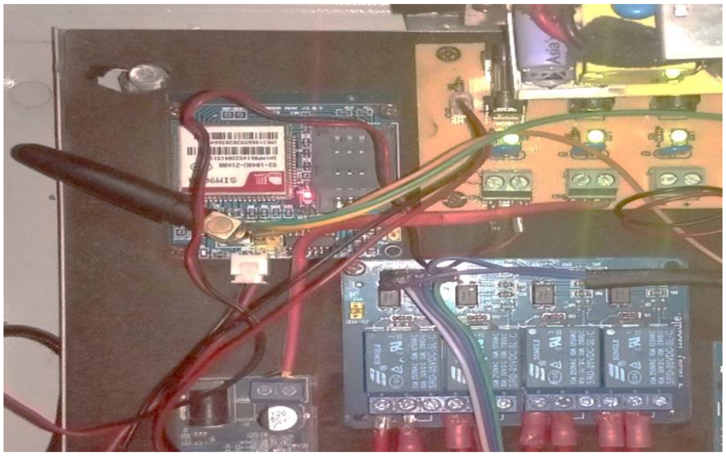
Significant Predictors in Relation to Environmental Conditions that Affect the Growth, Development, and Production of Crops.

To determine the significant predictors in relation to environmental conditions that affect the growth, development, and production of crops, this process was followed.

Collection of Data: Data was acquired using a smart greenhouse control system that was deployed at the greenhouse. The control system has sensors, namely the DHT-22 sensor, soil moisture sensor, photoresistor sensor, and MG-811 carbon dioxide sensor. These sensors were employed to capture and measure temperature, humidity, soil moisture, light luminosity, and carbon dioxide level. Such collected data was transmitted to web-based monitoring and predictive analytics via SMS for analysis.

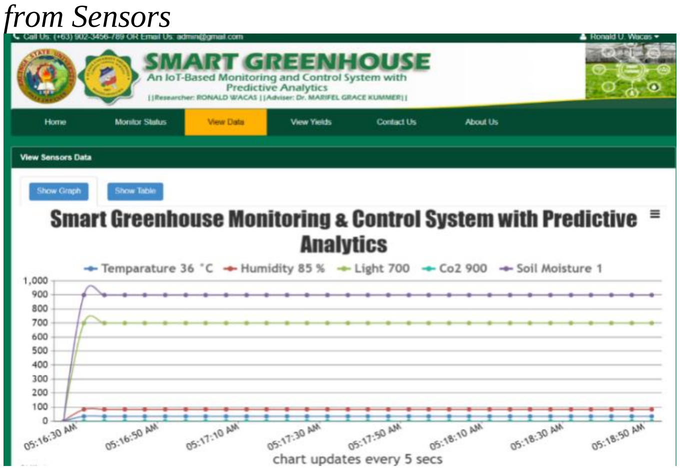
Figure 8.
Sensor Cluster

Figure 9.
SIM 900 SMS Module



Data Analysis: Web-based predictive analytics utilized regression analysis to analyze data and identify the environmental conditions that exert the most significant influence on crop-related variables. These variables obtained from sensors are crucial factors that affect crop growth, development, and productivity. The dataset obtained from this analysis was then used to accurately predict the crop yield.

Figure 10.
Graphical Presentation of the Dataset Obtained from Sensors



Illustrated in Figure 10 is the graphical representation of the data obtained from sensors through the smart greenhouse control system. Whenever the sensor values change, the control system sends a real-time update to the web-based monitoring system with predictive analytics. The received data is subsequently stored in a database and added to the existing dataset.

In the case of crop yield, which is the dependent variable, the user needs to input values for the date planted, the date harvested, and the total yield in kilograms. The resulting dataset will be utilized to forecast the crop yield.

Figure 11.
User Interface for Adding Yield

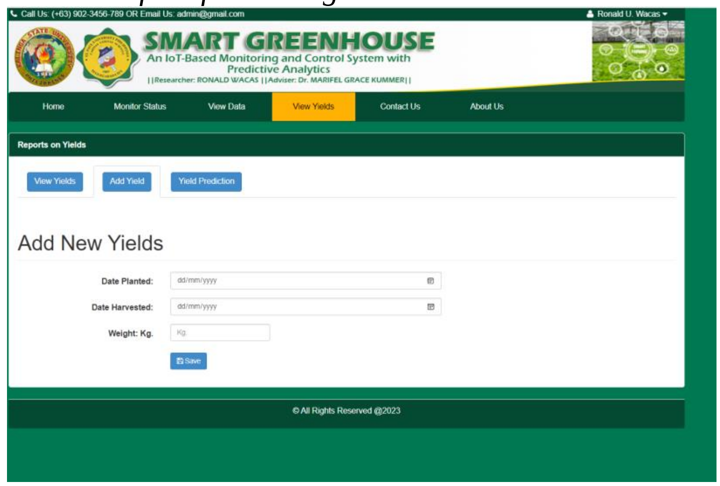


Figure 12.
User Interface User for Viewing the Report on Yields

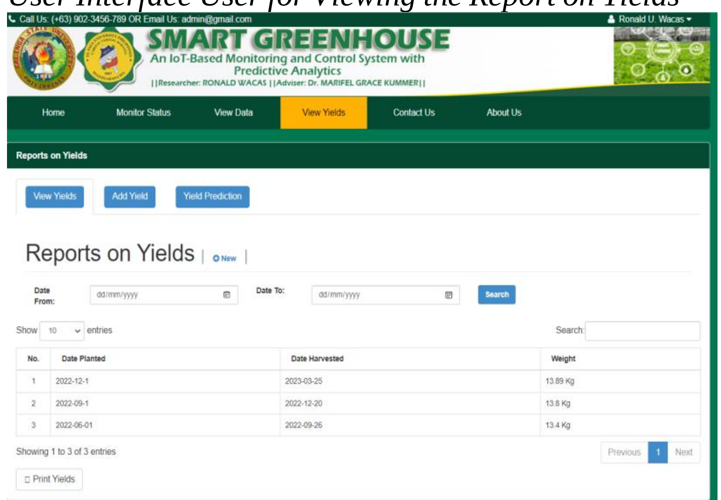


Table 3.
Trained Dataset

Temperature	Humidity	Moisture	Light	Carbon Dioxide	Yield

29	49.45	79.09	2168	976	13.12
29.08	49.47	79	2171	976	13.19
29.5	49.53	79.6	2182	934	13.43
27.8	47.54	77.9	1980	789	11.12
28.08	47.54	77.8	1986	786	11.13
27.5	47.65	77.8	1991	757	11.23
27.7	47.56	77.8	1995	789	11.34
27.5	47.4	77.9	1997	765	11.65
28.12	48.43	78.8	2102	886	12
29.8	48.12	78	2107	834	12.11
26.4	46.45	76.7	1920	674	10.12
27	47.54	77.4	1950	765	11
26.5	47.56	77	1952	754	11.12
29.4	49.12	79.5	2146	986	13.11
29.5	49.61	79.8	2198	985	13.5
29.05	49.71	79.6	2210	980	13.53
29.5	49.89	79.6	2211	980	13.89
28.32	48.25	78.9	2015	876	12.12
28.9	48.32	78.6	2120	867	12.13
28.5	48.67	78.7	2135	876	12.5

Predictive Analytics Used to Predict the Yield of Red-Hot Chili (Capsicum Frutescens)

Figure 13.
User Interface for Yield Prediction

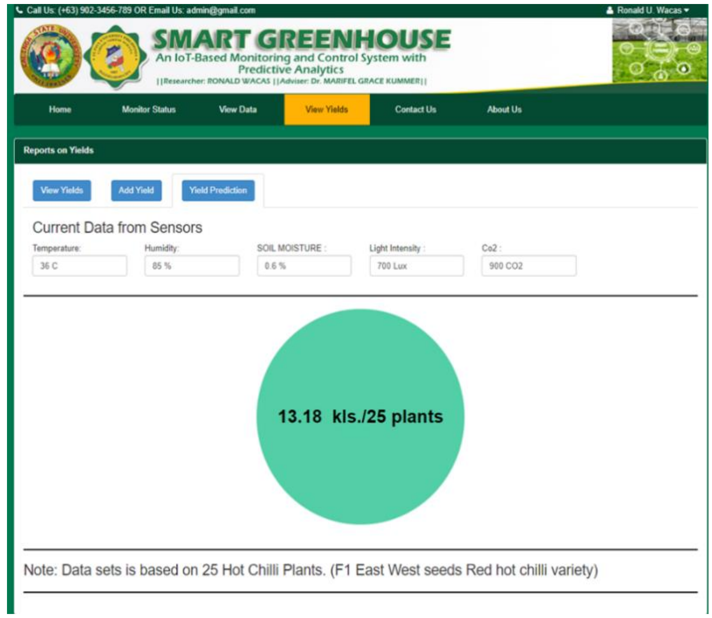


Figure 13 depicts how the smart greenhouse predictive analytics system predicts the yield of red-hot chili using linear regression analysis.

The system works by using a regression equation that relates the yield of red-hot chili to several independent variables, such as temperature, humidity, soil moisture, light luminosity, and carbon dioxide. These independent variables are crucial factors that affect crop growth, development, and productivity.

To predict the yield of red-hot chili, the user simply inputs new values of the independent variables into the system. These values can be manually inputted by the user, or they can come from the sensors in the smart greenhouse control system.

Once the system receives the new values of the independent variables, it analyzes and solves for the predicted value of the dependent variable (i.e., yield of red-hot chili) using the regression equation. The predicted value represents an estimate of the yield that can be expected based on the current environmental conditions. By fitting a regression line to a dataset with known values for the independent and dependent variables, the system can predict future crop yields based on the new values of the independent variables.

The Developed System to Address the Identified Problems and Issues Encountered by the Farmers

Smart Greenhouse Control System

System's Description

The Smart Greenhouse system offers an innovative and efficient approach to plant growth, utilizing cutting-edge technology to optimize productivity and minimize manual intervention. It utilizes various sensors, controllers, and automation systems to optimize the growing conditions of plants. It integrates a range of hardware and software components to monitor and control environmental conditions such as temperature, humidity, lighting, irrigation, and CO_2 levels inside the greenhouse.

The smart greenhouse system can adjust these parameters automatically based on the plant's needs, ensuring optimal growth and yield. This means that the system can make real-time adjustments to the greenhouse environment based on the readings from the sensors.

User Interface of the Control System

Figure 14.
Main Page of the Control System

The smart greenhouse system incorporates both manual and automatic control functionalities to regulate the environmental conditions within the greenhouse. The manual control option allows the user to manually switch devices, while the automatic control option utilizes the sensors to regulate the devices.

Figure 15.
Manual Control

The manual control feature of the system was designed to enable the user to control the devices manually in times of emergencies. The interface displays three slide buttons, which the user can use to switch the devices on or off as required. This feature ensures that the user can take immediate action in cases where automatic control is not feasible or desirable.

Figure 16.
Automatic Control

The automatic control feature of a smart greenhouse system is an important component that ensures optimal growing conditions for plants. It is based on sensor technology, which enables the system to monitor environmental conditions such as temperature, humidity, light levels, and CO2 concentration.

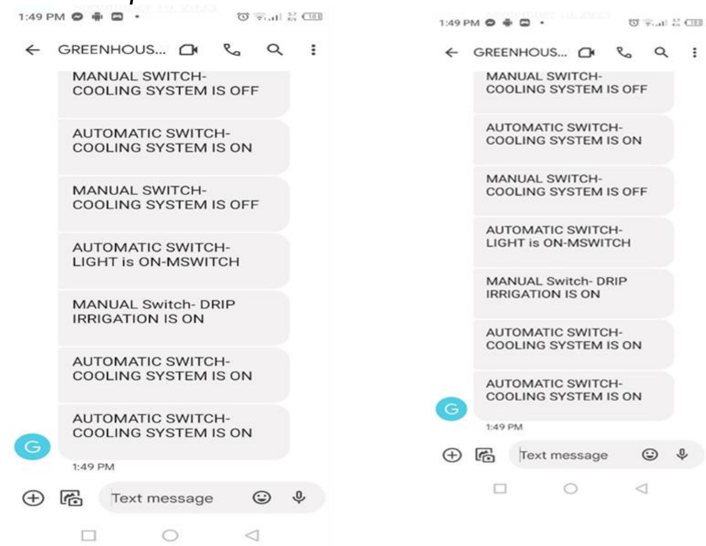
The sensors continuously measure these parameters and transmit the data to a microcontroller or a central processing unit. The system is programmed to analyze this data and compare it with predefined threshold values. When the measured values exceed or fall below the threshold values, the system triggers an actuator, such as a relay switch or a solenoid valve, to make real-time adjustments to the environmental conditions within the greenhouse.

For instance, if the temperature in the greenhouse rises above a predetermined threshold value, which is 25–30 degrees Celsius, the system will trigger a relay switch to turn on the cooling system, such as fans, to lower the temperature. Similarly, if the soil moisture level falls below the desired threshold, the system can activate a solenoid valve to turn on the water supply system and increase the soil moisture level.

By automating these adjustments, the smart greenhouse system can maintain optimal growing conditions for plants without the need for constant human intervention. This results in improved plant growth and reduced energy costs. Additionally, this feature also enables the system to respond quickly to changes in environmental conditions, ensuring that the plants are protected from extreme weather events and other stressors.

SMS Notification System

Figure 17.
SMS Notification



The SMS notification system is an efficient and effective tool that enables farmers to stay updated on the condition of their greenhouse. This technology works by sending text messages to the farmer's mobile phone, notifying them of any changes in the environment that could potentially affect the growth and development of their crops.

By keeping track of environmental conditions, the SMS notification system enables farmers to take prompt and effective action.

For instance, if the temperature in the greenhouse rises above or drops below a specific threshold, the SMS notification system will alert the farmer to take corrective action.

Moreover, the system can help farmers detect and address potential problems before they escalate into more significant ones. For example, if the humidity level drops suddenly, the farmer can investigate and identify the root cause, such as a leak in the irrigation system, and take corrective measures to rectify the problem.

Web-based Smart Greenhouse Monitoring and Predictive Analytics

A. Systems Description

The web-based smart greenhouse monitoring and predictive analytics system has been developed to provide farmers and other users with the ability to remotely monitor greenhouse conditions. The system is easily accessible from any location with an internet connection using a user-friendly web-based interface, enabling users to effortlessly monitor greenhouse activities without requiring their physical presence.

The system collects sensor data, which is transmitted to the control system through SMS and then stored in a comprehensive database. The data is then presented in a visually compelling graphical format, providing users with a user-friendly platform for comprehensive data analysis.

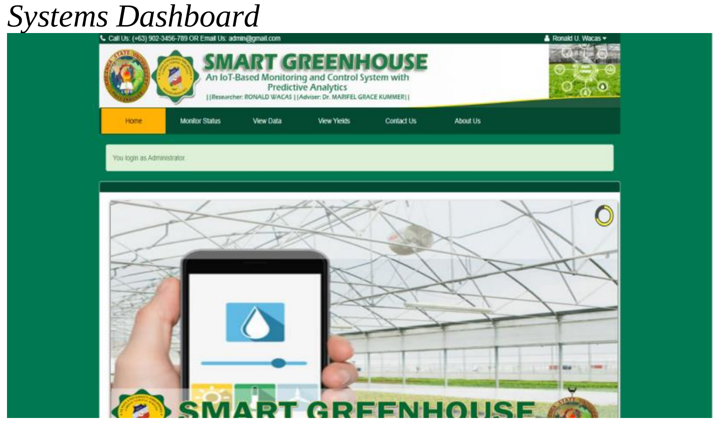
Employing multiple linear regression techniques, the system performs a thorough analysis of the collected data to make accurate predictions about future crop yields in the greenhouse. This feature is especially advantageous for farmers, who can use the information to make sound decisions about crop management and maximize the overall yield.

Web-based Smart Greenhouse Monitoring System User Interface

Figure 18.
User Login Form

The login form is a crucial user interface component that facilitates user authentication by enabling them to provide their username and password. Prior to accessing the system, all users are required to request their username and password from the designated system administrator. Once the user has entered the correct login credentials, they will be redirected to the monitoring and predictive page.

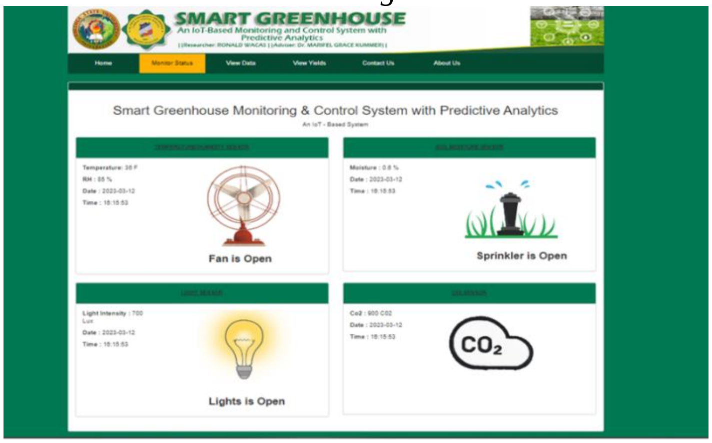
Figure 19.
Systems Dashboard



After logging into the system, you can gain access to the dashboard, which allows you to monitor status, view data and yields, and make predictions. The dashboard serves as a visual interface that allows users to view and interact with data related to a particular system or application.

Figure 20.

Smart Greenhouse Monitoring



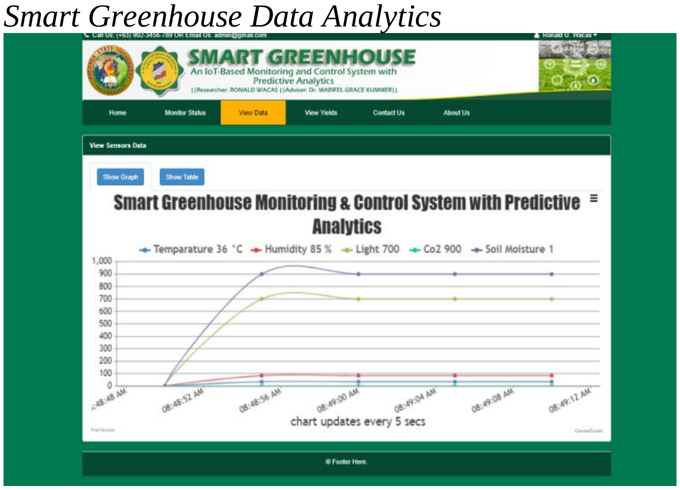
The web-based monitoring system provides real-time monitoring of the environmental conditions and various parameters inside a greenhouse through a web interface.

The data coming from the control system is transmitted to the web server through an internet connection, where it is analyzed, processed, and displayed on a web-based dashboard.

The dashboard provides real-time information on the environmental conditions inside the greenhouse, allowing the user to monitor the status of the greenhouse remotely from anywhere with an internet connection.

Figure 21.

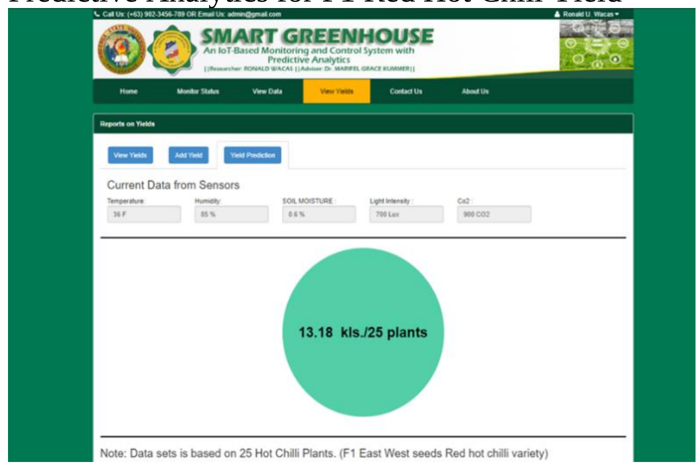
Smart Greenhouse Data Analytics



The data received from the control system is presented in a graphical format. These provide a visual representation of the information, allowing the user to quickly identify trends and patterns. By analyzing this information, the user become informed about the status of the greenhouse.

Figure 22.

Predictive Analytics for F1 Red Hot Chili Yield



The system enables the user to collect real-time data on key predictors, including temperature, humidity, soil moisture, light intensity, and carbon dioxide levels. Using a multiple linear regression model, the system can analyze this data and predict the expected yield of the red-hot chili. Furthermore, users can access historical records on the environmental conditions and crop yield in the greenhouse. This information provides valuable insights into the performance of the crops and can inform decisions regarding adjustments to the growing conditions to optimize yield.

Extent of Compliance of the Developed System to ISO 25010 Software Quality Standards

In this section, the assessment of the extent of compliance of the developed system with ISO 25010 Software Quality Standards in terms of functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability was conducted after the formal consent, presentation, and actual usage of the IT experts.

Functional Suitability

Table 4.

Mean Distribution of the Participants' Assessment with respect to the Developed System's Compliance to ISO 25010 Software Standard in Terms of Functional Suitability

Indicators	**Mean**	**Descriptive Interpretation**
1. Functional Completeness. The system's set of functions covers all the specified tasks and user objectives.	4.49	Very Great Extent
2. Functional Correctness. The system provides the correct results with the needed degree of precision.	4.51	Very Great Extent
3. Functional Appropriateness. The system functions to facilitate the accomplishment of specified tasks and objectives.	4.58	Very Great Extent
Category Mean	4.52	Very Great Extent

Table 4 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to functional suitability.

The overall result of the system characteristics obtained a category mean of 4.52 with a descriptive interpretation of "Very Great Extent." This implies that the developed system provides functions that meet stated and implied needs when used under specified conditions.

In addition, among the quality requirements, functional appropriateness obtained the highest rating mean of 4.58 with a descriptive interpretation of "very great extent," while functional completeness obtained the lowest rating mean of 4.49 with a descriptive interpretation of "very great extent."

The result agrees with the study of Meng (2020), where the developed system was also assessed to comply with ISO 25010 software quality standards in terms of functional suitability.

Previous studies in the field have also demonstrated the efficacy of similar systems. A study by Wang et al. (2021) reported that a smart greenhouse control system based on a deep reinforcement learning algorithm achieved better crop yield and reduced energy consumption compared to traditional systems. Another study by Liu et al. (2020) demonstrated the efficacy of a smart greenhouse system that combined sensor technologies and artificial intelligence algorithms to optimize environmental control and improve crop quality.

Performance Efficiency

Table 5.
Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Performance Efficiency

Indicators	**Mean**	**Description Interpretation**
1. Co-existence. The system's ability to operate alongside other systems or applications without interfering with their functionality	4.85	Very Great Extent
2. Interoperability. Evaluates the system's ability to communicate and work with other systems or applications seamlessly.	4.80	Very Great Extent
Category Mean	4.82	Very Great Extent

Table 5 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to performance efficiency.

The overall result of the system characteristics obtained a category mean of 5.00 with a descriptive interpretation of "Very Great

Extent." This implies that the developed system ensures the users that all processes are providing vital results in a shorter period of time. The system also performs according to the minimum and maximum requirements based on resource utilization.

The three indicators were also assessed to a very great extent, showing that the system performs exceptionally well in terms of providing timely responses to user inputs, is highly efficient in utilizing available resources, and can handle many users or requests without experiencing performance issues.

Karimian et al. (2020) evaluated the performance of a smart greenhouse system that used machine learning algorithms to optimize environmental conditions and reported a significant improvement in crop yield and resource efficiency.

Another study by Kuo et al. (2019) demonstrated the effectiveness of a smart greenhouse system that used IoT technologies to monitor and control environmental conditions and reported a significant reduction in energy consumption.

Compatibility

Table 6.
Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Compatibility

Indicators	**Mean**	**Descriptive Interpretation**
1. Time Behavior. The system's ability to provide timely responses to user requests or inputs.	5.00	Very Great Extent
2. Resource Utilization. The system's efficiency in utilizing available resources such as CPU, memory, and network bandwidth	5.00	Very Great Extent
3. Capacity. The system's ability to handle a large number of users or requests simultaneously.	5.00	Very Great Extent
Category Mean	5.00	Very Great Extent

Table 6 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to compatibility.

The overall result of the system characteristics obtained a category mean of 4.82 with a descriptive interpretation of "Very Great Extent." This implies that the developed system can exchange information with and/or perform its required functions in conjunction with other products, systems, or components while sharing the same hardware or software requirements.

Furthermore, among the quality requirements, co-existence obtained the highest rating mean of 4.85 with a descriptive interpretation of "very great extent," while interoperability obtained the lowest rating mean of 4.80 with a descriptive interpretation of "very great extent."

The study by Yang (2012) showed that the system complied with the ISO 25010 software quality standards, especially in terms of compatibility ("Very Great Extent"). This indicates that the developed system is efficient. It can run on any platform and version of the operating system. The system also works well with different software and still provides accurate results.

Previous research in the field has also demonstrated the efficacy of similar systems. For example, a study by Aouiche et al. (2019) evaluated the compatibility of a smart greenhouse system that used IoT technologies to monitor and control environmental conditions with different platforms and reported high levels of compatibility and interoperability with various platforms. Another study by Jrad et al. (2021) evaluated the compatibility of a smart greenhouse system with different sensors and actuators and reported high levels of compatibility and co-existence.

Usability

Table 7.
Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Usability

Indicators	Mean	Description Interpretation
1. Appropriateness recognizes ability. Ease of users to recognize and select the correct action	4.96	Very Great Extent
2. Learnability. Ease of users learning how to use the system	4.90	Very Great Extent
3. Operability. Ease of use for users to operate and control the system	5.00	Very Great Extent
4. User error protection. The system's ability to prevent users from making errors	4.90	Very Great Extent
5. User interface aesthetics. The visual appeal and attractiveness of the system's user interface	4.60	Very Great Extent
6. Accessibility. The system's ability to be easily accessed by users with disabilities	5.00	Very Great Extent
Category Mean	4.89	Very Great Extent

Table 7 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to usability.
The overall result of the system characteristics obtained a category mean of 4.89 with a descriptive interpretation of "Very Great Extent." This implies that the developed system has performed well, is easy to use, and can perform tasks and manage the occurrence of errors.

On the other hand, among the quality requirements, appropriateness obtained the highest rating mean of 4.96 with a descriptive interpretation of "very great extent," while user interface aesthetics obtained the lowest rating mean of 4.60 with a descriptive interpretation of "very great extent.".

This finding is similar to the study by Zhang (2021), where the results showed that the system's evaluation in terms of usability received a descriptive interpretation of "Very Great Extent," indicating that the system is usable.

Reliability

Table 8.
Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Reliability

1. Maturity. The system's processes are well-established, predictable, and capable of being controlled effectively.	Mean	Description Interpretation
2. Availability. The system is highly accessible and can be used whenever needed.	4.95	Very Great Extent
3. Fault Tolerance. A system can continue to operate even in the presence of hardware or software faults.	5.00	Very Great h Extent
4. Recoverability. The system can recover from failures and restore data to its last consistent state.	4.90	Very Great Extent
5. Maturity. The system's processes are well-established, predictable, and capable of being controlled effectively.	5.00	Very Great Extent
Category Mean	4.96	Very Great Extent

Table 8 shows the result of the evaluation of the developed system by the IT experts based on the

ISO 25010 software quality standards with respect to reliability.

The overall result of the system characteristics obtained a category mean of 4.96 with a descriptive interpretation of "Very Great Extent." This implies that the developed system performs its intended functions and operations based on maturity, availability, fault tolerance, and recoverability.

Among the quality requirements, availability obtained the highest rating mean of 4.95 with a descriptive interpretation of "very great extent," while recoverability obtained the lowest rating mean of 4.90 with a descriptive interpretation of "very great extent."

The study by Zhao and Chu (2016) indicates that the system complies with the ISO 25010 software quality standard, particularly to a "Very Great Extent" in terms of reliability. This suggests that the developed system is reliable during its operation and can perform its intended functions and operations based on maturity, availability, fault tolerance, and recoverability.

Similar findings from other researchers on the reliability of greenhouse control systems include the study conducted by Mekni et al. (2019), which assessed the reliability of a greenhouse climate control system using fault tree analysis. The study found that the most critical failures were related to the heating system, cooling system, and control computer. The study also recommended the implementation of backup systems and regular maintenance to improve the reliability of the greenhouse control system.

Sahu et al. (2018) reviewed the use of artificial intelligence techniques for software reliability assessment. The researchers found that artificial intelligence techniques such as machine learning, fuzzy logic, and neural networks have shown promising results in predicting software reliability. They also found that these techniques can be used for different types of software, including embedded software, web applications, and cloud computing. The study highlights the importance of software reliability in ensuring the quality of software and the need for accurate and efficient reliability assessment techniques.

5.6 Security

Table 9.

Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Security

Indicators	Mean	Description Interpretation
1. Confidentiality. The protection of sensitive information from unauthorized access or disclosure	4.80	Very Great Extent
2. Integrity. The assurance that information is accurate, complete, and reliable	4.92	Very Great Extent
3. Non-repudiation. The ability to prevent a user from denying that they performed an action	5.00	Very Great Extent
4. Accountability. The ability to trace actions back to the user who performed them	4.89	Very Great Extent
5. Authenticity. The assurance that a user or system is who they claim to be	5.00	Very Great Extent
Category Mean	4.92	Very Great Extent

Table 9 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to security.

The overall result of the system characteristics obtained a category mean of 4.92 with a descriptive interpretation of "Very Great Extent."

This implies that the developed system protects data so that personnel, other products, or systems have a certain degree of data access rights appropriate to their type and authorization level.

Moreover, in the quality requirements, non-repudiation and authenticity obtained the highest rating mean of 5.00 with a descriptive interpretation of "very great extent," while confidentiality obtained the lowest rating mean of 4.80 with a descriptive interpretation of "very great extent.".

The study by Jin (2021) indicates that the system complies with the ISO 25010 software quality standard, particularly to a "Very Great Extent" in terms of security. It implies that the developed system has embedded protection against unauthorized access and malicious attacks.

Similar findings have been reported by other researchers in studies that evaluated the security of smart agriculture systems. For example, a study by Abu-Shawar (2020), Al-Kasasbeh (2020), and Arora et al. (2020) that evaluated the security of smart agriculture systems found that the systems had high compliance with security requirements, including confidentiality, integrity, and availability.

Maintainability

Table 10.
Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Maintainability

Indicators	Mean	Description Interpretation
1. Modularity. The system has a high degree of independence and can be easily modified and maintained.	4.80	Very Great Extent
2. Reusability. The system's components can be reused effectively in other applications, reducing the cost and time of software development.	5.00	Very Great Extent
3. Analyzability. The system can be diagnosed and corrected easily in the event of errors.	5.00	Very Great Extent
4. Modifiability. The system can be easily adapted to changing requirements.	4.85	Very Great Extent
5. Testability. The system can be thoroughly tested, ensuring that it meets the desired specifications.	4.92	Very Great Extent
Category Mean	4.91	Very Great Extent

Table 10 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to maintainability.

The overall result of the system characteristics obtained a category mean of 4.91 with a descriptive interpretation of "Very Great Extent." This implies that the developed system can be modified to improve it, correct it, or adapt it to changes in the environment and requirements.

Likewise, among the quality requirements are reusability and analyzeability, which obtained the highest rating mean of 5.00 with a descriptive interpretation of "very great extent," whereas modularity obtained the lowest rating mean of 4.80 with a descriptive interpretation of "very great extent.".

The study by Qin (2017) indicates that the system complies with the ISO 25010 software quality standard, particularly in terms of maintainability, to a very great extent. This suggests that the developed system can provide backup for data, it can continue functioning if changes are made, and it can be easy to customize.

5.8 Portability

Table 11. Extent of Compliance of the Developed System to ISO/IEC 25010 Software Quality Standards in terms of Portability

Indicators	Mean	Description Interpretation
1. Adaptability. The ability of the system to adjust and function optimally in different environments	4.00	Great Extent
2. Installability. The system's ability to be adapted, installed, and replaced on different platforms or environments	4.90	Very Great Extent
3. Replaceability. The system can be easily replaced in different environments if needed.	4.50	Very Great Extent
Category Mean	4.47	Very Great Extent

Table 11 shows the result of the evaluation by the IT experts of the developed system based on the ISO 25010 software quality standards with respect to portability.

The overall result of the system characteristics obtained a category mean of 4.47 with a descriptive interpretation of "Very Great Extent." This implies that the developed system has the capability of being transferred from one environment to another.

Furthermore, among the quality requirements, installability obtained the highest rating mean of 4.90 with a descriptive interpretation of "very great extent," while adaptability obtained the lowest rating mean of 4.00 with a descriptive interpretation of "very great extent.".

The study by Xu and Gong (2012) indicates that the system complies with the ISO 25010 software quality standard in terms of portability to a very great extent. This implies that the developed system can be transferred from one computer to another, easily integrated into another environment with consistent functional correctness, and run on different platforms.

Table 12. Summary of Evaluation of the System's Compliance with the ISO/IEC 25010 Criteria

ISO/IEC 25010 Characteristics Criteria	Criteria Mean	Descriptive Interpretation
A. Functional Suitability	4.52	Very Great Extent
B. Performance Efficiency	5.00	Very Great Extent
C. Compatibility	4.82	Very Great Extent
D. Usability	4.89	Very Great Extent
E. Reliability	4.96	Very Great Extent
F. Security	4.92	Very Great Extent
G. Maintainability	4.91	Very Great Extent
H. Portability	4.47	Very Great Extent
Overall Mean	4.81	Very Great Extent

Table 12 reveals the summary of the evaluation of the developed system's extent of compliance with the ISO/IEC 25010 Criteria.

The results of the evaluation revealed that the developed system obtained an overall mean of 4.81, which is described as "very great extent" of compliance. The table also shows that performance efficiency, reliability, and security are the three highest-rated criteria among the eight (8) ISO/IEC 25010 characteristics, with means of 5.00, 4.496, and 4.92, respectively, which are all described as "very great extent" of compliance. These are followed by the other criteria in the following order: maintainability, usability, compatibility, functional suitability, and portability, with means of 4.91, 4.89, 4.82, 4.52, and 4.47, respectively, all indicating a "very great extent" of compliance.

Enhancement to be Done to Improve the Proposed System.

During the interview, IT professionals identified several areas for improvement that could enhance the overall performance of the system in terms of hardware design, software design, and enhancement of the dataset for predictive analytics.

Hardware Design.

- Improve the fabrication and packaging of the control system for several benefits, including improving the reliability and durability of the system, reducing costs, and enhancing its performance.

- Upgrade the microcontroller with a faster clock speed to improve the responsiveness of the system, allowing it to respond more quickly to inputs and changes in the environment. This is important to reduce the latency of capturing data from sensors.

- Improve the performance of a web server by upgrading hardware components such as CPU, memory, and storage" (Informant 4).

Software Design

- Review and optimize the code running on the microcontroller to help improve performance and reduce processing.

- It is recommended that the system have a mobile app version, given that a significant portion of the users are accustomed to using mobile devices. This will allow users to access the system's features and functionalities on the go, regardless of their location, which can be beneficial for those who frequently work outside or need to monitor the system remotely.

Enhancement of the Dataset

- Enhance the dataset to reduce errors and biases in the data, leading to more accurate predictions and better decision-making.

CONCLUSION

In conclusion, the study has demonstrated that the development of a smart greenhouse system with predictive analytics is a promising solution to the identified problems. The system incorporates a control system to manage greenhouse environmental conditions and a web-based monitoring system to remotely monitor and predict crop yield. With the system, growers can efficiently manage their crops, ensuring optimal environmental conditions and improved crop yield. This innovative solution can benefit farmers and the agriculture industry.

RECOMMENDATIONS

Based on the findings presented and the conclusions drawn, the researcher recommends the following:

1. To ensure the successful implementation of the system, it is crucial for the administration to provide comprehensive support and allocate the necessary resources for the technical aspects of the project. This includes providing skilled personnel, appropriate hardware and software, and ensuring that the necessary infrastructure is in place.

2. The researcher may conduct a series of training courses with end-users, orientations, and wide dissemination on how to use the smart greenhouse monitoring and control system.

3. Future researchers may investigate the economic feasibility of using predictive models to optimize crop yield. They may conduct a cost-benefit analysis to determine the return on investment of implementing such models in agricultural production.

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