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An IoT-Driven Smart Greenhouse System with Integrated Virtual Assistant

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Abstract: *This study presents the development of an IoT-driven smart greenhouse system integrated with a virtual assistant (VA), designed to enhance agricultural sustainability in Mauritius. Addressing critical challenges posed by climate change, such as extreme weather events and water scarcity, the system leverages solar energy to power its components, thereby reducing reliance on conventional energy sources. Additionally, the system incorporates a water collection mechanism from an inclined roof, ensuring efficient water usage and conservation. The hybrid application developed allows farmers to remotely monitor and control greenhouse parameters, receive real-time alerts, and access AI-driven decision support. The implementation of solar-powered solutions, coupled with rainwater harvesting and efficient battery storage, underscores the system's commitment to sustainable farming practices. Preliminary assessments indicate the system's potential to improve resource management and crop yield, highlighting the promise of integrating renewable energy with advanced agricultural technologies to promote resilience and sustainability in Mauritius' agricultural sector. Future work will focus on empirically evaluating energy consumption effectiveness and optimizing system performance.*

Keywords— IoT, Smart Greenhouse, Solar Energy, Virtual Assistant, Sustainable Agriculture, Renewable Energy, Climate Resilience

1. INTRODUCTION

Agriculture has long been at the heart of Mauritius' economy, offering sustenance and employment, and contributing greatly to the country's GDP. The agricultural industry, with its vast amount of outdoor plantation of crops such as sugar cane, tea, and a plethora of fruits and vegetables, is a testament to the island's rich farming tradition dating from the early 1500s when the Portuguese first visited the island. However, this traditional approach to farming is increasingly under threat [1]. Drastic changes in weather patterns have severely affected traditional farming processes. Due to global warming, anti-cyclones, torrential rainfall, and other unprecedented climatic changes, farmers are obliged to take necessary precautions to cater for their crops, highlighting severe challenges to agricultural productivity and food security in Mauritius.

As per the World Risk Report, Mauritius occupies 14th place amongst countries with the highest disaster risk and 7th amongst countries most exposed to natural hazards [2]. Statistics Mauritius showed that even though there was an increase in plantations in 2020, crop production was 7 percent below the previous five-year average compared to 2019: a figure which reflects adverse weather conditions in Mauritius directly affecting crop yields [3]. Unprecedented climatic changes have taken a severe toll on the existing agricultural system, leaving Mauritius with an overall self-sufficiency of only 25 percent [4]. The vulnerability of traditional farming methods in the face of climate change has sparked a critical need for innovative solutions to ensure sustainability, efficiency, and resilience in agricultural practices. In this context, the integration of analytics through Internet of Things (IoT), Artificial Intelligence (AI), and other emerging technologies in agriculture could be a promising alternative to traditional farming [5]. Smart farming technologies offer the potential to revolutionise agricultural practices by eliminating dependencies on weather conditions, optimising resource use, boosting crop yields, and minimising carbon footprints [6]

2. LITERATURE REVIEW

2.1 Traditional Farming System

In Mauritius, traditional farming takes up 7,2% of the labour force. Among the crops grown, sugarcane, tea, and food are the most common ones. While sugarcane occupies the largest proportion grown at around 54,182 hectares, food crops follow far behind with 7780 hectares and tea with 662 hectares. Farmers earn a living with small-scale plantation businesses with an average holding of 0,25 hectares for food crops and less than 10 hectares for sugarcane plantations. They do all their work such as ploughing and weeding manually.

Fig. 1. *Traditional Farming in Mauritius*

The wet season of Mauritius lasts from November to April, while the dry season lasts from May to October. One of the main problems that traditional farmers face in Mauritius is irrigation. The amount of rainfall differs largely across Mauritius and in dry areas, farmers are very dependent on other sources of water such as rivers and canals.

On top of that, being a tropical island it is often subject to increase in temperature, labile rainfall patterns, rise in sea level, and extreme weather conditions. These affect agriculture by decreasing crop yields, increasing pest proliferation, causing soil erosion, disease outbreaks, and natural calamities. According to a survey carried out by Hardware in 2020, 87.8% of Mauritians noted that fluctuations in weather patterns decreased their yields [7]. To counter the effects of climate change, it is important that farmers put into practice climate-smart farming such as optimum use of water and fertilisers, integrated crop management, conservation agriculture, intercropping, improved seeds, and diversification of crops.

While farming is a must in Mauritius, it is a vulnerable sector subjected to multiple setbacks such as irrigation and climate change. Farmers need to make use of more sustainable and resilient ways to increase crop productivity and policymakers need to provide them with more incentives and support. A landscape approach, integrating the social, economic, and environmental aspects of land management, could be an important framework for developing and implementing climate-smart agriculture in Mauritius.

2.2 Smart Greenhouses

The first greenhouse was introduced in Rome around 30 CE, to provide an artificial and controlled environment for crops to grow. These greenhouses did not have any technological equipment to monitor or control the environment but rather relied on their basic structure and design to leverage benefits that would otherwise not be gained from traditional farming. From boosting crop yield to allowing crops to grow outside their normal growing season, this innovation was a game changer.

Fast forward to 2024, we now have hands-on smart greenhouse systems. With little or no manual effort from farmers, these make use of automation through the Internet of Things, Artificial Intelligence, and or other technologies to boost efficiency and yield more than could have been achieved previously. To do this, it utilises several conventional sensors, actuators, and microcontrollers to provide monitoring and control of the basic factors including but not limited to temperature, relative humidity, soil moisture content, and light levels inside the greenhouse. As a result, there is a more efficient and sustainable approach to the agricultural industry which is important to ensure that the global food need is met.

Fig. 2. : *Image describing a Smart IoT based Greenhouse System.*

2.3 Technological Foundation

At the core of smart greenhouses are sensors, actuators, and microcontrollers that help in collecting fundamental environmental parameters such as relative humidity, soil moisture, temperature, and light levels. These data are then processed by a small computer using either a rule-based (If-else) algorithm or an AI-based algorithm which can leverage the benefits of machine learning to make the whole system autonomous. Based on the output of the processed data, actuators such as fans, grow lights, water pumps, and others are activated when required to ensure that the internal environmental condition of the greenhouse remains optimal for crop growth. This aims to boost crop yield and reduce electricity costs, water usage, and dependency on manual labour [8].

2.4 Role of AI in agriculture

Current agriculture systems involve lots of manual operations which is costly and exhaustive. AI can assist in streamlining complex and exhaustive tasks that are done daily. Its capacity to process and analyse large amounts of data can be beneficial to choose the best course of action for a particular task such as seedling and trigger actions to be performed by other devices. It can also be used to detect crop diseases, pest detection, and more.

The global Artificial Intelligence in the agricultural market is expected to grow by 24.5% and reach USD 10.2 billion in the next 10 years [9]. This will be a result of the increasing demand for food due to the rising global population and the need for sustainable farming practices.

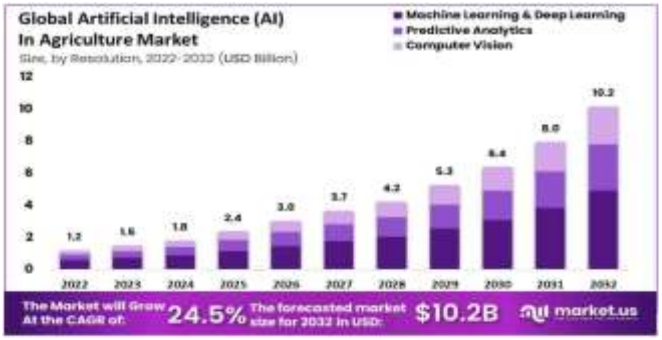

Fig. 3. : *Global Artificial Intelligence (AI) In Agricultural Market [9]*

The application of AI systems in agriculture, specifically for crop monitoring and early-stage disease detection is a growing area of interest due to its potential in reducing crop losses and increasing yields [10]. To do this, cameras are used to capture images of plant leaves or stems of the crops. These images are then sent for processing using deep learning algorithms such as CNN or Vision Transformers to identify patterns indicative of specific diseases. This process involves training the deep learning algorithms with a huge dataset of both healthy and diseased plant images for the model to be able to learn the distinguishing patterns between healthy and unhealthy plants [11]

2.5 Shortcomings of existing IoT-based Smart Greenhouse Systems

There are a few Greenhouse Systems that have been implemented in Mauritius. These have been studied. However, they all have shortcomings and their application to farming are difficult. For instance, water level sensors are not present, since they do not make use of water tanks for rainwater harvesting. Many of them do not utilise extraction fans, heaters, and grow lights to regulate the internal humidity, temperature and light levels respectively, inside the greenhouse. This lack of regulation may increase the likelihood of fungal diseases and lower the quality of the crop. Furthermore, the studied systems do not leverage the benefits of using a compact and advanced microcontroller such as ESP32 Wrover, which offers dual-core processors and built-in WI-FI and Bluetooth capabilities. The use of this efficient device could significantly enhance wireless communication performance and provide the remote management of the greenhouse.

3. Methodology

The proposed prototype is an IoT-Driven Smart Greenhouse System with Integrated Virtual Assistant. The system will leverage the benefits of a two-tier architecture as illustrated in Figure 4. Thee system will make use of a powerful microcontroller that comes with Wi-Fi, a list of sensors and actuators, a real-time database and lastly a tailor-made hybrid app which will be powered by an Intelligent VA configured for the domain of greenhouse farming. This setup will enable a remote and wireless monitoring and controlling of the greenhouse.

Additionally, the physical greenhouse will be designed and built to be sustainable, ensuring minimal environmental impact and promoting long-term agricultural practices. This will include the use of eco-friendly materials, energy-efficient systems, and water-saving technologies to support the overall goal of creating a resilient and efficient agricultural solution.

The hybrid application system allows the same code to be used to build native iOS and Android apps as well as a web app that is accessible on all devices via a web browser.

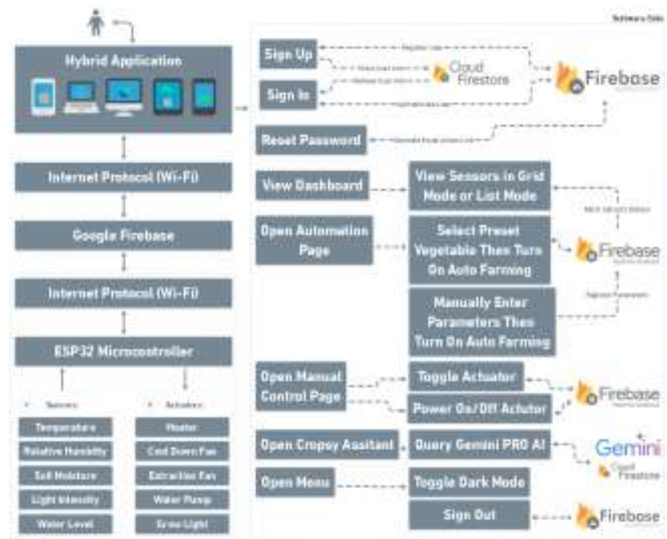

Fig. 4. : *Proposed System Architecture*

4. System Implementation

The prototype includes the use of eco-friendly materials, energy-efficient systems, and water-saving technologies to support the overall goal of creating a resilient and efficient agricultural solution. The system makes use of the following sensors:

- Temperature Sensor: To measure the temperature inside the greenhouse.
- Humidity Sensor: To measure the relative humidity of the greenhouse atmosphere.
- Soil Moisture Sensor: To measure the moisture content of the soil.

- Photoresistor: To measure the luminosity inside the greenhouse.

- Water Level Sensor: To measure the water level inside the water tank.

These sensors discern changes in environmental and soil conditions and continuously send the data to a real-time database through the microcontroller. If parameters inside the greenhouse go outside the optimal range set by the user, a notification will be sent to the user client. Using an API call, the data of the sensors stored in the real-time database are fetched wirelessly and consciously to preserve precision and are displayed in real-time in the mobile app in a clean structure. Actuators such as cool down fan, extraction fan, water pump, heater and glow light are used to regulate the different environmental and soil factors gathered by the sensors. The actuators are controlled through the app either through an automation framework or manual control.

Inside the app there will be an Intelligent Virtual Assistant facility which may assist farmers' queries related to crop management, climate conditions, pest control or any other topics that falls under Smart Greenhouse Farming. Farmers may also get troubleshooting advice or inquire about optimal growing conditions of any crop that exists contributing to efficient decision making and improving crop yield.

To promote sustainable farming, the system makes use of a 12v battery to power actuators and sensors that requires 12v DC and a 9v battery to power the ESP32 board. To keep juice in the batteries, a solar panel will be used to charge them continuously. To ensure that water is available for irrigation even during a water interruption from the Water Authority, the use of a water tank connected to the pipes is considered. A rainwater harvesting system is integrated into the greenhouse design, utilizing an inclined roof to collect and channel rainwater into a storage tank. This serves as an alternative water source, reducing dependency on external water supplies. Basic filtration ensures the water is suitable for irrigation before being directed into the automated watering system. The combination of rainwater harvesting and soil moisture sensors allows for efficient water management, promoting sustainable irrigation or fertigation practices. Figure 5 illustrates the final product for the greenhouse, detailing the placement of sensors and actuators for automated water management, climate control, and solar-powered operation.

Fig. 5. : *The implemented prototype*

5. SYSTEM EVALUATION

Most the existing greenhouse systems are manually controlled, majority of them do not make use of key sensors, actuators nor do they have advanced automation capabilities. In contrast, the Virtual Assitant facility and IoT-Driven Smart Greenhouse System proposed addresses these issues by incorporating an array of sensors and actuators to monitor and control critical parameters such as temperature, relative humidity, soil moisture, luminosity and water level. As such, there is an optimal environment where crops can flourish, and resources can be used wisely without being too costly.

To ensure that farmers are up to date with their IoT-driven farming, a notification system is put into place allowing them to take corrective actions on time. For instance, if the internal temperature goes beyond the preset thresholds, then firebase cloud function will be triggered, and an alert will be sent to the user's device. This is especially important when the system is under manual control as the farmer will have to know when to virtually water his crops, increase or decrease temperature and so on. It also allows the user to know if ever an actuator have failed during automated farming as the system shall not allow the environmental conditions to go off track.

What makes the system stand out is the fact that it is built using Flutter and Firebase technology which makes it very easy to compile the same code for different platforms. As for this system, a native android and iOS version and a web app version have been released. This allows farmers to virtually take care of their greenhouse no matter where they are, or what kind of device they are using provided they have access to a browser connected to the internet. Unlike previously studied IoT software, the one developed in this project offers a level of offline functionalities, allowing user to stay signed in, view the last fetched sensorial data, modify presets or perform any actions as they would normally do, which will be synced with Firebase RTDB on reconnection to the internet. This special feature has been possible using local storage and through Firebase persistence technology.

6. Conclusion

The IoT-Driven Smart Greenhouse prototype designed with the integrated Virtual Assistant is the future of smart greenhouse systems. Through automated control, it provides an optimal environment independent of external weather conditions where crops can grow, and resources can be used wisely without being too costly. The system is designed to be sustainable by combining solar power and rainwater harvesting practices thereby reducing dependence on carbon use and other external energy and reinforcing green practices. Unlike other greenhouses that are dependent on grid electricity and susceptible to power cuts, this prototype uses a solar panel coupled with a 12V battery to power all the electronic components ensuring continuous farming operations. Additionally, the rainwater harvesting mechanism allows water from the roof of the greenhouse to be collected in a water tank which can be used during periods of water shortages or cut offs from the Water Supply Authority. These two sustainability features reduce carbon footprints, promote a greener economy and is cost-efficient, all while maintaining a continuous 24/7 farming operations.

7. References

[1] Singh, L. (2023). How the UN is assisting Mauritius to secure its food systems, Africa Renewal. https://www.un.org/africarenewal/magazine/july-2023/how-un-assisting-mauritius-secure-its-food-systems

[2] Garschagen, M., Mucke, P., Schauber, A., Seibert, T., & Welle, T. (2014). WorldRiskReport 2014. United Nations University – Institute for Environment and Human Security (UNU-EHS). https://i.unu.edu/media/ehs.unu.edu/news/4070/11895.pdf

[3] Food and Agriculture Organization (FAO). (2021). FAO GIEWS Country Brief on Mauritius. https://www.fao.org/giews/countrybrief/country.jsp?code=MUS&lang=en

[4] International Trade Administration (ITA). (2021). Mauritius - Agricultural Sectors. https://www.trade.gov/country-commercial-guides/mauritius-agricultural-sectors

[5] National FFA Organization. (2023). FFA New Horizons - How AI Can Impact Agriculture. https://www.ffa.org/technology/how-ai-can-impact-agriculture/#:~:text=AI%20can%20predict%20the%20weather

[6] Plantae. (2020). The carbon footprint and precision agriculture. https://plantae.garden/en/carbon-footprint-and-precision-agriculture/#:~:text=Precision%20agriculture%20can%20help%20reduce

[7] Jönsson, M. (2011). The Impact of Climate Change on Agriculture in the Republic of Mauritius a Socio-Econometric Study on Mauritian Farming, p. 57.

[8] Vishwakarma, D.K., Yadav, D., Kumar, R., Kumar, A., Wani, A.W., & Qayoom, S. (2025). Green House Technology for Controlled Environment—Advances in Green House Automation and Control. In: Greenhouse Technology for Sustainable Agriculture, pp. 111–139. Apple Academic Press.

[9] Market.us. (2023). Global Artificial Intelligence (AI) in Agriculture Market by Technology (Machine Learning & Deep Learning, Predictive Analytics, and Computer Vision), by Application (Precision Farming, Drone Analytics), by Component (Hardware, Software, Service, and AI-as-a-Service), by Region and Companies - Industry Segment Outlook, Market Assessment, Competition Scenario, Trends, and Forecast 2023–2032. https://market.us/report/artificial-intelligence-ai-in-agriculture-market

[10] S., Vijayakumar, S., & Elakkiya, N. (2025). Yield prediction, pest and disease diagnosis, soil fertility mapping, precision irrigation scheduling, and food quality assessment using machine learning and deep learning algorithms, Discover Food 5(1), 1–23.

[11] Kavimani, B., & Vellalapalayam Subramaniam, A. (2025). Plant disease prediction using ensemble deep neural network architecture with salp swarm optimization algorithm, Traitement du Signal 42(3).