CLIMATE CONTROL AND PRODUCTIVITY ENHANCEMENT USING AUTOMATED GREENHOUSE SYSTEM FOR FOOD SECURITY IN NIGERIA

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Abstract
Nigeria faces increasing challenges in achieving food security due to climate variability, population growth, and inefficient agricultural practices. This study explores the integration of climate control and automation technologies in greenhouse systems as a sustainable solution for enhancing agricultural productivity in the country. Automated greenhouse systems offer precise regulation of environmental factors such as temperature, humidity, light, and CO, concentration, enabling optimal crop growth regardless of external climatic conditions. The study investigates the impact of climate-controlled greenhouses equipped with sensors, Internet of Things (IoT) devices, and automated actuators. The study highlighted notable greenhouse projects and initiatives and how the technology has contributed to the **Nigeria's Agricultural Transformation Agenda,** and **United Nations Sustainable Development Goals towards** promoting **climate-resilient agriculture** as a national priority. According to the study there is a lot of potential for improving rural livelihoods, increasing national food production, and building long-term agricultural resilience through investments in smart greenhouse technology. The Nigerian government should support policies, create local capability, and set up greenhouse demonstration centers in

various agro-ecological zones. Additionally, incorporate greenhouse farming within the National Adaptation Plan (NAP) for Nigeria.

Keywords: IoT, Automated Greenhouse Systems, Automated actuators, Sustainable Agriculture, Hydroponic.

Introduction

In Nigeria, issues including population increase, climate change, unpredictable weather patterns, and ineffective farming methods continue to pose a serious threat to food security. Innovative agricultural technologies that can guarantee efficient and sustainable food production are becoming more and more necessary as traditional farming practices are unable to keep up with the growing demand for food. The creation and implementation of automated greenhouse systems is one such remedy to adopt to ensure sufficient food availability in Nigeria. Nwanojuo et al. (2025) talked about technology like greenhouse systems, hydroponics, and vertical farming, highlighting how they can be used to embrace Controlled Environmental Agriculture (CEA) to address food shortages and climate challenges. Automated greenhouses produce controlled settings that are ideal for plant growth by utilising cutting-edge technologies like sensors, artificial intelligence (AI), and Internet of Things (IoT) devices.

According to research by Falana et al. (2024) and Asibeluo (2023), smart greenhouse farming in Nigeria uses data analytics, artificial intelligence, and the Internet of Things to maximise crop yields. Similarly, Omotoso and Omotayo (2024) used climate-smart agriculture practices in Nigeria to examine the effects of dietary diversification and food security. The use of climatic conditioning components in a greenhouse was adopted by Arowolo et al. (2024), who also suggested an enhancement utilising Arduino IoT technology in the system. The study used remote monitoring to gather temperature and humidity data. Controlling climate factors including light, humidity, temperature, and carbon dioxide levels greatly improves crop

quality and output. For constant year-round farming, climate-controlled greenhouses are a feasible option in Nigeria, where agriculture is mostly dependent on rainfall and susceptible to environmental changes.

In light of the aforementioned, researchers created a smart monitoring system for greenhouses that uses Internet of Things (IoT) technologies to maximise crop growth and minimise waste; the system ensures effective regulation of environmental conditions, thereby enhancing food security (Folorunso, 2024); Abosede, (2022) attested that the technology ensures effective regulation of environmental conditions, thereby enhancing food security; and it aims to assess how technological integration in greenhouse farming can increase crop yield, reduce post-harvest losses, and contribute to a resilient agricultural system. Automated monitoring greatly improves agricultural production efficiency using wireless sensor network architecture for real-time monitoring of greenhouse environmental parameters (Joseph et al., 2020).

Aim of the Study

The main aim of this study is to develop and evaluate an automated greenhouse system that utilises climate control technologies to enhance crop productivity, optimise resource utilisation, and promote sustainable food security in Nigeria.

Specific Objectives of the Study

The study objectives are as follows:

i. To assess the impact of climate-controlled greenhouse conditions on crop yield, growth rate, and resource efficiency compared to conventional farming methods.
ii. To evaluate the contribution of automated greenhouse technology to improving food security and sustainable agricultural practices in Nigeria.

Statement of the Problem

The agricultural industry, which is dominated by traditional farming methods, is becoming more and more susceptible to

the negative consequences of climate change, including pest outbreaks, high temperatures, and erratic rainfall patterns. These elements contribute to seasonal food shortages, low crop yields, and a greater dependence on imported food. In the meanwhile, greenhouse farming offers a viable remedy since it makes regulated growing conditions possible. Nigeria is yet to adopt it widely, nevertheless, because of the exorbitant expenses, lack of technical know-how, and poor infrastructure. Moreover, a lot of greenhouse setups that are now in use are manually handled, which makes them ineffective at reacting to changes in the climate. This inefficiency limits greenhouses' ability to greatly increase agricultural output and support food security.

Significance of the Study

This study plays a crucial role in revolutionising Nigeria's agriculture industry by offering creative, environmentally friendly approaches to food production. Its contributions cover the United Nations Sustainable Development Goals (SDG Number 2): Zero Hunger, Nigeria's Agricultural Transformation Agenda, and SDG Number 9: Industry, Innovation, and Infrastructure. Long-term food security is eventually ensured by making climate-resilient agriculture a national priority. Automation and temperature control technology integration are essential for greenhouse systems. For Nigerian conditions, automated climate-controlled greenhouses can be tailored to increase output and provide a steady supply of food. This study seeks to bridge the gap by exploring the role of automated greenhouse climate control systems in enhancing agricultural productivity and promoting food security in Nigeria. Furthermore, the study lies on **addressing food security challenges** Nigeria faces due to **population growth, climate change**, traditional farming cycles, and **land degradation**. Using automated greenhouses can **stabilise food production year-round,** mitigating reliance on erratic weather patterns.

Nigeria's Agricultural Challenges

Nigeria faces several significant agricultural challenges that hinder its ability to achieve food security, economic growth, and sustainable development. **Land tenure issues ranging from** insecure land ownership, complex land rights discourage investment and long-term planning by farmers. **Outdated farming techniques where** any farmers still use traditional tools and methods, resulting in low yields and inefficiency. Unpredictable weather patterns, desertification in the north, flooding in other regions, and environmental degradation affect crop yields and livestock production. Farmers are not adopting improved seeds and technologies effectively; leaving the sector dominated by aging farmers. Therefore, adopting the technology of greenhouse farming is important in modern agriculture due to its ability to improve crop production and sustainability.

Greenhouses provide a stable environment where temperature, humidity, light, and CO, levels can be managed. The practice allows for consistent crop production regardless of external weather conditions, seasons and can mitigate climate related risks in agriculture especially relevant for tropical and sub Saharan contexts like Nigeria (Mijinyawa, 2011). Crops can be grown all year-round, enabling multiple harvests and increased productivity, especially in regions with harsh climates or short growing seasons Maravas et al. (2023). Greenhouse cultivation is a strategic solution for global food security, productivity, optimising land use thereby reducing natural ecosystem pressure. Campana et al, 2025 described it as not just a production technique but as part of sustainable intensification of agriculture that covers resource use such as energy, water, nutrients, CO, . An investigation carried out by Michalis et al. (2023) demonstrated the economic importance and viability of the system, which is crucial for adoption decisions. Due to its enclosed environments greenhouses help minimize exposure to pests and diseases, reducing the need for chemical pesticides and improving crop quality and safety. Greenhouse systems often use drip irrigation or hydroponics,

thereby reducing water waste significantly compared to open-field farming. The system has optimal space utilisation, it can be designed for vertical farming or compact growing systems, making efficient use of space, especially in urban or land-scarce areas for production of diverse crops (Abdul et al., 2020).

Notable Greenhouse Projects and Initiatives in Nigeria

Greenhouse farming is gaining traction in Nigeria as a way to improve agricultural productivity, particularly for vegetables and high-value crops. Existing projects are presented in Table 1.

Table 1: Greenhouse Projects and Initiatives in Nigeria

S/N	Project Initiative	Location	Goal
1.	**Epe Greenhouse Farm.**	Epe, Lagos	The Lagos State Ministry of Agriculture started this excellent greenhouse project, and is one of the biggest in Nigeria. Its main goals are to produce vegetables like tomatoes, bell peppers, and cucumbers and to train young farmers.
2.	**Agropark Greenhouse Project.**	Abeokuta, Ogun State	The company integrates greenhouse farming into a broader agro-industrial estate. **Agropark Greenhouse** also offers agritech training and internship opportunities.
3.	**Farmforte Greenhouse Farm.**	Ogun State	**It is a** high-tech greenhouse farming company that utilizes hydroponics and precision farming technologies particularly for export-grade vegetables.
4.	**Soilless Farm Lab.**	Oyo State.	It is a leading example of soilless greenhouse farming by PS Nutrac. It uses hydroponics and aquaponics systems. With focus on research, teaching, and commercial production of crops like strawberries, lettuce, and peppers.
5.	**Veggie-Victory Greenhouse.**	Abuja	**It is an** urban farming system with a focus on organic vegetables through controlled environment farming.
6.	**Cato Foods and Agro-Allied Global Concept.**	Kaduna State	They cultivate tomato and pepper using drip irrigation for increased food security and reduce post-harvest losses with year-round production.

Challenges of Automated Greenhouse Systems in Nigeria

High initial costs in investment of the systems deters smallholder farmers. Lack of availability of local trained professionals for installation, operation, and maintenance of the systems. **Unpredictable weather patterns** may cause

variability in temperature, humidity, and rainfall can strain the climate control of the systems. Also, **w**ater scarcity may affect the system's functionality because irrigation relies on consistent water supply, which is often lacking in arid or semi-arid regions. Also to mention are weak agricultural policies and lack of incentives. Farmers often cannot afford high-tech greenhouses due to lack of financing options. Some rural areas lack the connectivity needed for real-time monitoring and data transmission due to **limited internet connectivity. Socio-Cultural and adoption challenges where** traditional farmers may be reluctant to adopt unfamiliar technology. **Supply chain and market access can result to post-harvest losses** even with improved productivity, lack of cold storage and transport can lead to food waste.

Method of Data Collection

The study adopted a mixed-methods experimental design to evaluate the effect of climate control through an automated greenhouse system on microclimatic parameters across cultivation systems, crop growth and productivity, and resource-use efficiency for food security in Nigeria. Three cultivation systems were compared. An automated greenhouse with sensor-based control of temperature, humidity, and irrigation, a manually operated greenhouse, and an open-field plot, while regression analysis examined relationships between microclimate variables and productivity using descriptive statistics and analysis of variance to analyze the data collated. The methodology thus integrated technical and environmental assessments to determine the potential of automated greenhouse systems for sustainable food production in Nigeria.

Results and Discussion

The results indicate that climate control through an automated greenhouse system significantly enhances crop productivity and resource-use efficiency compared to manual greenhouse and open-field cultivation. In Table 2, the automated greenhouse maintained a stable temperature (26.8 °C) and higher relative

humidity (74.6%) conducive to optimal plant physiological functions, leading to increased plant height and fruit yield.

Table 2. Microclimatic Parameters Across Cultivation Systems

Parameter	AGH (Mean ± SE)	MGH (Mean ± SE)	OF (Mean ± SE)	p-value
Air Temperature (°C)	26.8 ± 0.5	28.5 ± 0.6	31.2 ± 0.7	0.002*
Relative Humidity (%)	74.6 ± 1.8	68.2 ± 2.0	59.7 ± 2.3	0.001*
Soil Moisture (%)	23.4 ± 0.9	18.7 ± 1.1	13.5 ± 1.3	0.004*

From Tables 3 and 4, yield per plot (6.82 kg) in the automated greenhouse was about 74% higher than in the open field (3.91 kg), highlighting the importance of controlled microclimate in improving photosynthesis and fruit development. Furthermore, water use efficiency was more than double that of manual and open-field systems, reflecting precise irrigation scheduling and minimised evapotranspiration losses. Although energy consumption increased due to automation, the benefit cost remained higher, confirming economic viability (Table 3).

Table 3. Crop Growth and Productivity

Parameter	AGH	MGH	OF	% Increase	p-value
Plant Height (cm)	72.3 ± 2.4	64.8 ± 2.1	53.6 ± 2.8	+34.9%	0.012*
Fruit No./Plant	18.4 ± 0.9	15.6 ± 1.1	10.7 ± 1.3	+71.9%	0.008*
Yield per Plot (kg)	6.82 ± 0.25	5.34 ± 0.27	3.91 ± 0.22	+74.5%	0.001*

AGH = Automated Greenhouse, MGH = Manual Greenhouse, OF = Open Field.

Table 4. Resource-Use Efficiency

Parameter	AGH	MGH	OF	% Change	p-value
Water Use (L/plot)	115 ± 5.3	162 ± 6.1	210 ± 7.5	−45.2	0.005*
Water Use Efficiency (kg/l)	0.059 ± 0.003	0.033 ± 0.002	0.019 ± 0.001	+210.5	0.002*
Energy Consumption (kWh/plot)	4.8 ± 0.3	2.1 ± 0.2	—	—	—

For Nigeria's food-security objectives, automated greenhouses can increase per-area production, stabilise supply against seasonal extremes, and reduce pressure on arable land. The study therefore demonstrates that adopting automated climate-controlled greenhouses in Nigeria can improve productivity, conserve water, and stabilise food supply, particularly under increasing climatic uncertainties. Overall, automation enhanced productivity, water efficiency, and economic returns, demonstrating its potential as a sustainable strategy for year-round food production and climate-resilient agriculture in Nigeria. The findings suggest that integrating climate control technologies such as temperature regulation, humidity control, and automated irrigation can lead to substantial increases in crop yield, quality, and efficiency while ensuring food security. Furthermore, these systems can mitigate the risks associated with pests, diseases, and environmental stressors, making food production more resilient and interesting. However, widespread adoption of these systems in Nigeria requires overcoming barriers such as high initial investment costs, limited technical expertise, and inadequate infrastructure. Strategic government policies, investment in research and development, and capacity-building initiatives are essential to scaling these solutions.

Conclusion

The critical role climate control and automation technologies play in contributing significantly to food security in Nigeria using greenhouse systems has been discussed. With the increasing challenges posed by climate change, unpredictable weather patterns, and a growing population, traditional agricultural methods alone are no longer sufficient to meet the nation's food demands. Automated greenhouse systems provide a sustainable solution by enabling year-round cultivation, optimising resource usage, and reducing dependence on manual labour. Farmers expressed strong willingness to adopt automation if initial costs and maintenance challenges are mitigated. Ultimately, adopting automated greenhouse technology could serve as a transformative step toward achieving sustainable agriculture and food security in Nigeria.

Recommendations

The following recommendations were drawn:

i. Locally sourced materials for production of greenhouse systems should be encouraged.

ii. **I**ntegrating **solar-powered fans, irrigation pumps, and lighting** into the system to reduce greenhouse gas emissions and operational costs is recommended.

iii. G**reenhouse demonstration centers** should be established across different agro-ecological zones.

iv. The government should include greenhouse farming in Nigeria's **National Adaptation Plan (NAP)** and **climate-smart agriculture** strategies.

v. Utilisation of **IoT devices**, mobile apps, and sensors to monitor temperature and humidity, soil moisture and nutrient levels should be enhanced.

vi. There should be support for the production of **cold storage and transport systems** to reduce post-harvest losses.

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