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Research article

Improving Tomato Yield in Greenhouse Agriculture Using Internet of Things (IOT) Technologies

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ABSTRACT

The global food crisis bedeviling the polity as a result of dreadful climate change and insecurity has culminated also into poor tomato yield experienced by conventional farmers. Internet of things (IoT) has come in handy at this auspicious time to revolutionize agriculture and in turn improve tomato production. With the possibility of automated greenhouse smart farms, food scarcity will abate. This journal is aimed at developing an internet of things based precision monitoring system for improved greenhouse tomato in Nigeria. This work is predicated on the following objectives geared towards realizing the principal aim of this research. Reviews of recent related works to the subject under study were carried out to imbibe required knowledge for the work, this is swiftly followed by characterization and modeling of tomato yield in normal weather conditions with respect to temperature, humidity, soil moisture and yield. These variables were modeled in Simulink and the model was simulated to produce the characterized parametric values. Thereafter, the effects of either premium or deficiency of the variables and tomato yield were established. A rule base for precision monitoring and improving temperature, humidity and soil moisture in optimizing tomato yield was developed. A wireless sensor network was then modeled for precision monitoring and improving tomato yield in greenhouse agriculture. To actuate the activity of the system, an algorithm was proposed to implement the developed rule base and the sensing operation for precision and monitoring of improved tomato yield in greenhouse agriculture. All the models developed are then integrated and simulated and results generated from it. Finally, results are used to justify and validate the research. From the results, the temperature change from 760F to 83.250F gave a percentage improvement of 9.54%. Also, the humidity and soil moisture changed from 70% to 84% and 75% to 90% respectively. These give percentage improvement of 14% and 15% for humidity and soil moisture respectively. Similarly, tomato yield increased from 35 tons to 42 tons, giving a percentage improvement of 20%. From these results, the research can be said to have been justified and validated.

Keywords: *Tomato Yield; Greenhouse Agriculture; Internet of Things (IOT)*

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Introduction

To survive, every living thing requires food. Both humans and animals are all part of the food chain. No matter how technology grows, we will always be dependent on our farmers to provide us with food. This makes equipping our farmers with the newest technology a general benefit that will provide a range of positive effects. There are many examples of how contemporary technologies are being used in various fields, and these applications are yielding positive outcomes.

Humans are able to complete jobs with the least amount of effort because of technologies like artificial intelligence (AI), machine learning (ML), the internet of things (IoT), and deep learning. The term "Internet of Things" (IoT) was first used by a member of the Radio Frequency Identification (RFID) development community in 1999, and it has recently gained more traction in the real world thanks to the proliferation of mobile devices, embedded and ubiquitous communication, cloud computing, and data analytics (Veerachamy et al 2022).

The poor yield of tomatoes in greenhouse agriculture will be improved using IoT technologies. The Internet of Things, or IoT, is a term used to describe objects or 'things' that have sensors built into them so they can collect data and communicate it via a network (PaLei, Ibibia, and Willie 2019). The structure and resources needed to advance IoT use cases beyond simple real-time decision and automation use cases are provided by artificial intelligence (Revanasiddappa, Suma, and Raghavv 2017). In the context of agriculture, IoT (Internet of things) refers to a family of technologies that use sensors, cameras, and other devices to turn every element and action involved in farming into data (Antonis, Nikolaos, Thomas, and Constantinos 2017),

According to estimates from the Food and Agriculture Organization of the United Nations (FAO), the world's population will exceed 8 billion by 2025 and 9.6 billion by 2050 (FAO2009). This effectively indicates that global food production must increase by 70% by the year 2050. The necessity for modernizing and intensifying agricultural techniques is driven by the significant rise in the global population and the rising demand for high-quality goods. However, a method for increasing crop, vegetable, and fruit yields is greenhouse farming. Greenhouses can regulate environmental variables in two different ways: manually or via a proportional control method (Zhao, Zhang, Feng, & Guo, 2010).

Review of Related Literature

Since there are numerous emerging technologies that have favorably impacted people's daily activities, technology has been altering people's lives. The Internet of Things (IoT), which seems to be reshaping the entire social fabric of civilization, is an example of such emergent technology. The internet of things (IoT) has applications in a number of fields, including connected industries, smart cities, smart homes, and smart energy. It is also used in connected cars, smart agriculture, connected campuses and buildings, and health care logistics, among other fields. IoT uses the internet as a communication and information-exchange medium with the goal of fusing the real world with the digital one. A network of interconnected data processing gadgets, automated instruments, things, animals, or persons that are given unique identifiers and the capability to move data over an arrangement without the need for people-to-people or people-to-computer interaction is referred to as the Internet of Things (IoT) (Olakunle, Tharek and Nour 2018).

The utilization of IoT in agriculture is the main thrust of this research. By 2050, it was predicted that there would be over 9.7 billion people on the globe, which would result in a high need for food. Food security is a key worry for most nations due to this, as well as the depletion of natural resources, the shortage of arable land, and unpredictable weather patterns. In order to fulfill future global food demand, the globe is turning to the internet of things (IoT) and data analytics (DA). By 2020, there will have been 75 million IoT device installs in the agricultural industry, up from 30 million in 2015. Smart agriculture, which is anticipated to produce high operational efficiency and yield, will be made possible through the usage of IoT and DA.

Wireless sensor networks (WSNs) have been used for smart agriculture and food production over time, with a focus on traceability, automation of equipment and process management, and environmental monitoring. WSN is a good option for smart agriculture and the food business because of its potential to self-organize, self-configure, selfdiagnose and self-heal. Radiofrequency transceivers, microcontrollers, power sources, and sensors make up the WSN as a system. However, with the rise of IoT, there has been a paradigm change away from using WSN for smart agriculture and toward IoT serving as its primary engine. The IoT integrates a number of pre-existing technologies, including WSN, RFID, cloud computing, middleware platforms, and end-user apps (Miguel, Zamora-Izquierdo, and Antonio 2019).

The goal of the Internet of Things (IoT) use in agriculture is to equip farmers with decision-making instruments and automation technologies that seamlessly connect goods, information, and services for improved productivity, quality, and profitability (Brewster, Roussaki, Kalatzis, Doolin and Ellis 2017). Figure 3 shows the conceptual arrangement of IoT applications in agriculture.

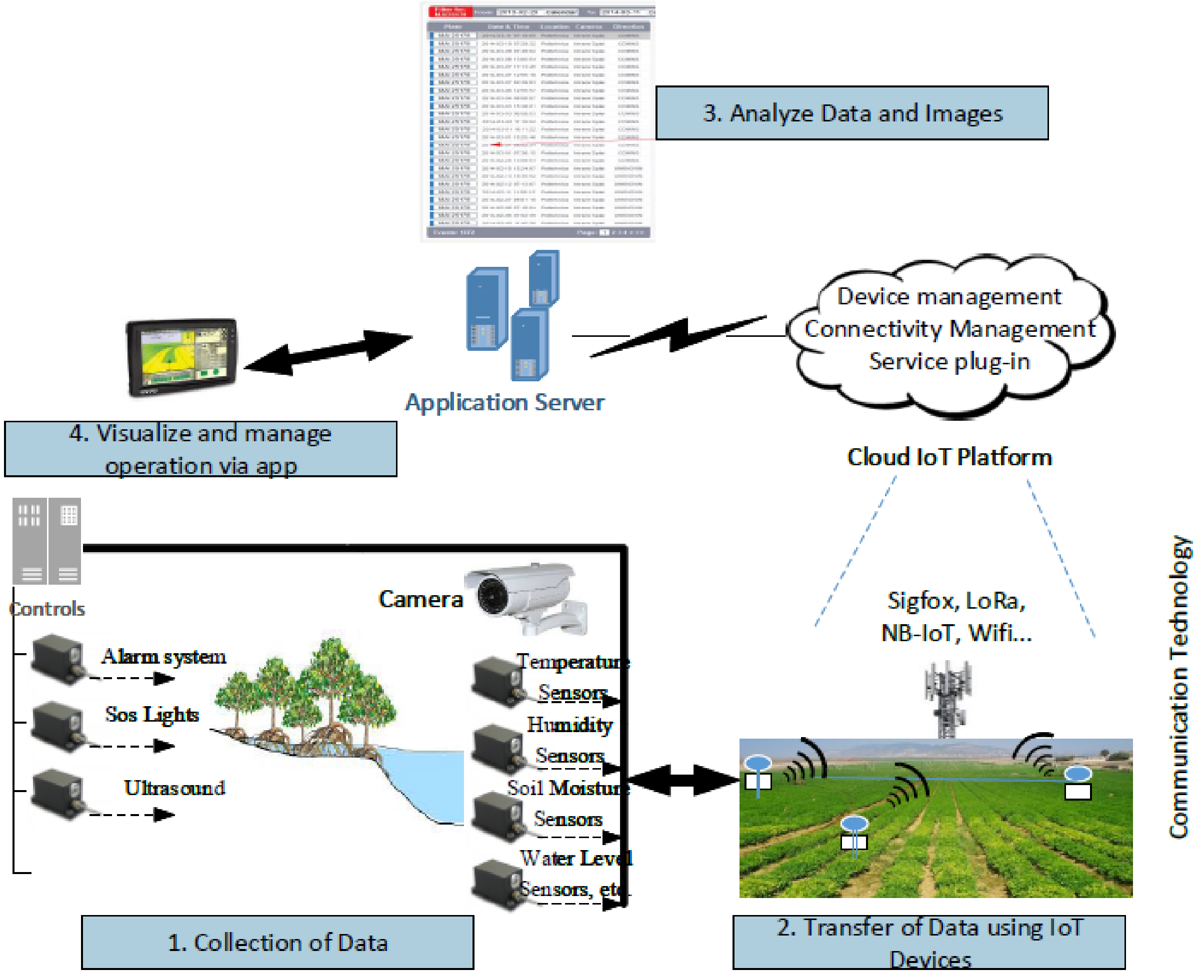

Figure 1: Illustration of IoT Application in Agriculture (Warwick 2015)

Figure 1 consists of four major components and these are: IoT devices, communication technology, internet, data storage and processing as shown in the illustration. These components ensure the creation of smart farms in greenhouse agricultural setting. The IoT network must necessarily have these component units in order to give the desired result.

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Methodology

To characterize and model tomato yield in normal weather condition with respect to temperature, humidity, soil moisture and quantity

Metric or parameter	Greenhouse	Normal Weather
Temperature (^{O}F)	76 (Standard 75 to 85)	62
Relative humidity (%)	70 (Standard 65 to 85)	75
Soil moisture(%)	75 (Standard 50 to 90)	50
Quantity(Tons)	35	30

Table 1: Characterized tomato yield in normal weather condition with respect to temperature, humidity, soil moisture and quantity

To establish the effect of temperature, humidity and soil moisture in tomato yield

Metric or parameter	Greenhouse	Effects of temperature and humidity in tomato yield
Temperature (^{O}F)	76^{O}F (75 to 85)	Temperatures below 75 degrees Fahrenheit are too low to grow a healthy tomato plant, and above 85 degrees Fahrenheit, increases the maximum tomato growth but is for a shorter period which affects the fruit weight says The University of Arizona Cooperative Extension. The low temperatures interfere with normal pollination of the blossoms, which drops off the plants.
Relative Humidity (%)	70 (65 to 85)	Tomato planting will not survive below 65 percent of relative humidity. Higher relative humidity levels negatively influence pollen release and distribution on the stigma.
Soil moisture (%)	75 (50 and above)	Below 50 percent, it retards the growth and production capacity of tomatoes.
Quantity (Tons)	35	Below 35 tons, the production capacity is reduced.

Table 2: Established effects of temperature, humidity and soil moisture in tomato yield.

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To develop an IoT rule base for monitoring and improving temperature, humidity and soil moisture in optimizing tomato yield

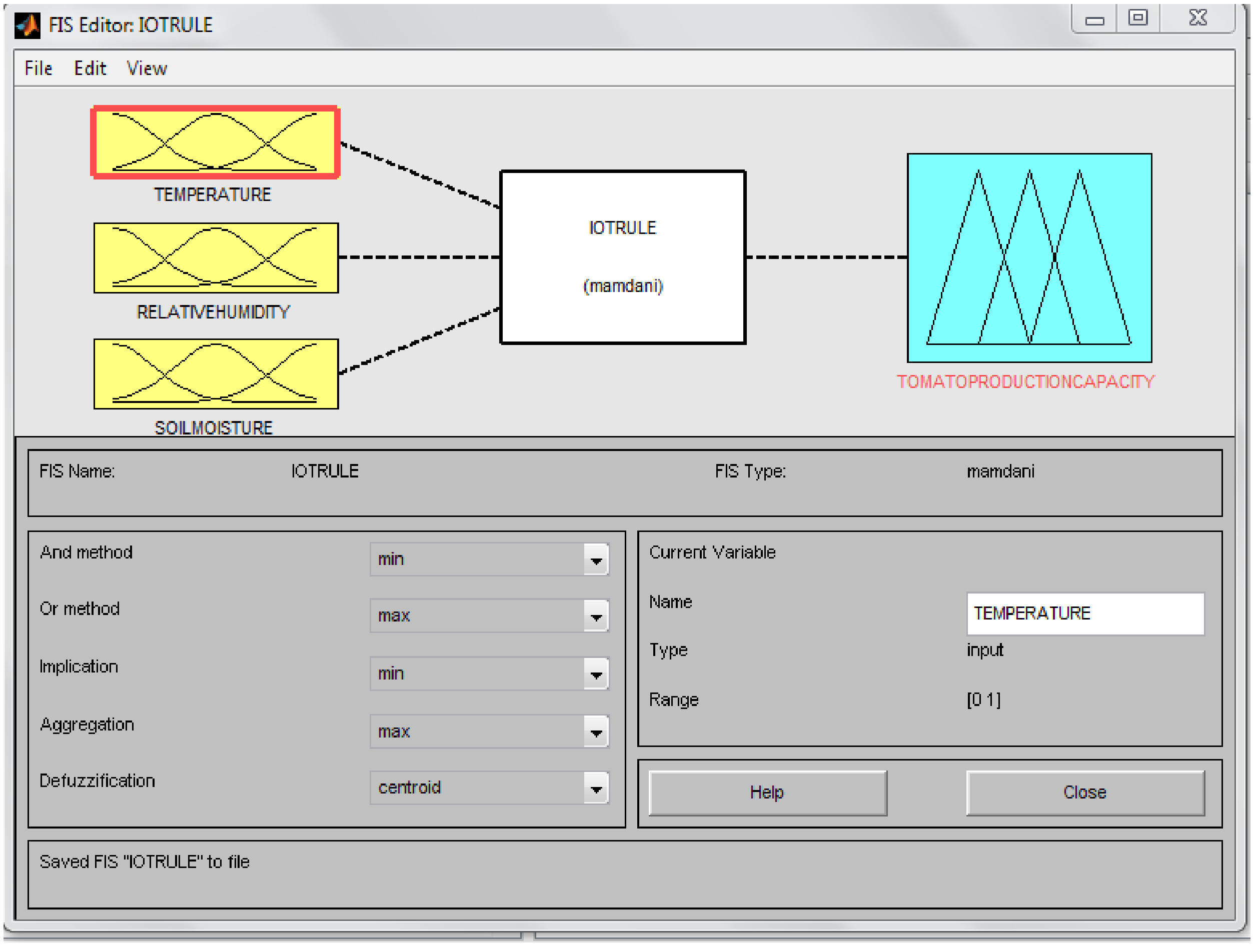

Figure 2: Developed IoT fuzzy inference system for monitoring and improving temperature and humidity in optimizing tomato yield. It also has an output of tomato production capacity.

Figure 2 has three inputs of temperature, relative humidity and soil moisture. It also has an output of tomato production capacity.

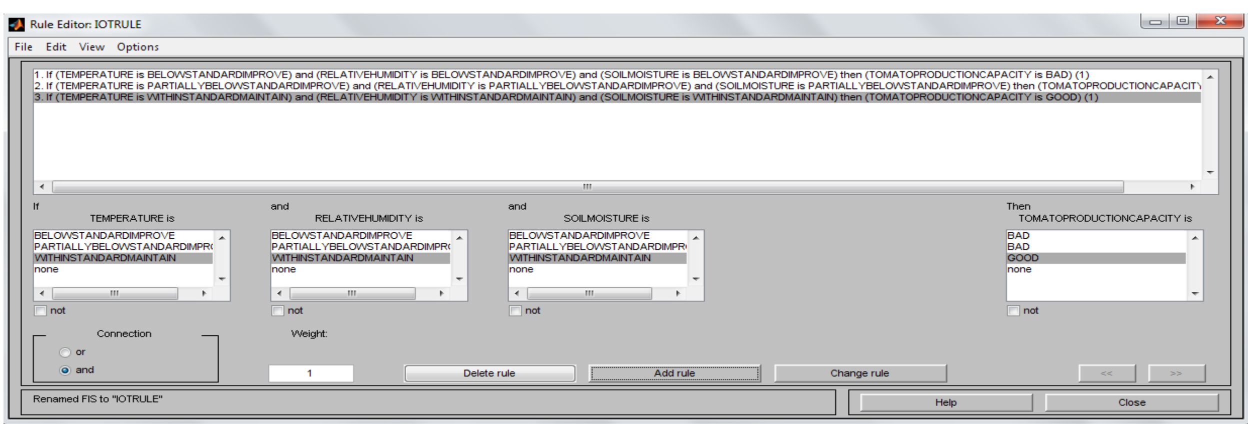

Figure 3: Developed IoT rule base for monitoring and improving temperature and humidity in optimizing tomato yield

Figure 3 has three rules that are comprehensively detailed in table 3.3. When rule base is expanded, a set of IF…THEN rules that will guide the activities precision monitoring will be executed as expected in the greenhouse smart farm.

To design an IoT based SIMULINK model for precision monitoring and improving tomato yield in green house agriculture.

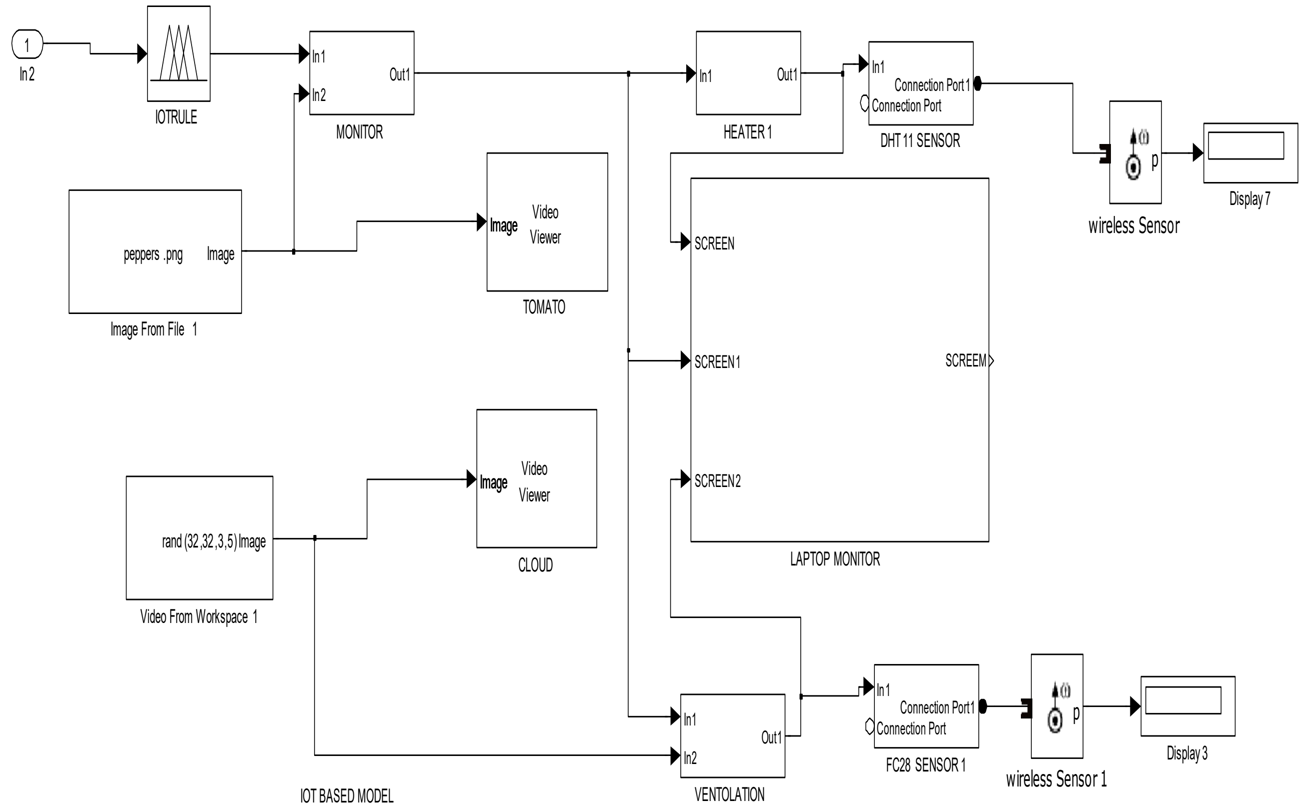

Figure 4: Designed IoT-based SIMULINK model for precision monitoring and improving tomato yield in greenhouse agriculture.

The results obtained after the simulation are as shown in figures 8 through 10.

To Develop an Algorithm that will Implement the Process

1. Identify if the temperature of the tomato plantation is out of the standard range of (Std 75^{0}F to 85^{0}F).
2. Identify if the relative humidity of the tomato plantation is out of the standard range of (Std 65% to 85%).
3. Identify if the soil moisture of the tomato plantation is out of the standard range of (Std50% to 90%).
4. Identify if the production capacity of tomato plantations in the greenhouse is reduced.
5. Design a Conventional SIMULINK model of development of an internet of things (IoT) based precision monitoring model and integrate 1, 2, 3 and 4
6. Develop an IoT rule base for monitoring and improving temperature, humidity, and moisture in optimizing tomato yield
7. Design an IoT-based SIMULINK model for precision monitoring and improving tomato yield in greenhouse agriculture
8. Integrate 6, and 7.
9. Apply 8in 5.
10. Do temperature, relative humidity, and soil moisture normalized and tomato production capacity improved when 8 is applied in 5?
11. If NO go to 9.

12. If YES go to 13.
13. Improved tomato yield in greenhouse agriculture.
14. Stop.
15. End.

To integrate conventional and IoT-based models and simulate the resulting model to validate and justify the research to show the percentage of improvement in precision monitoring of temperature, humidity, soil moisture, and yield of tomato with and without IoT-based model

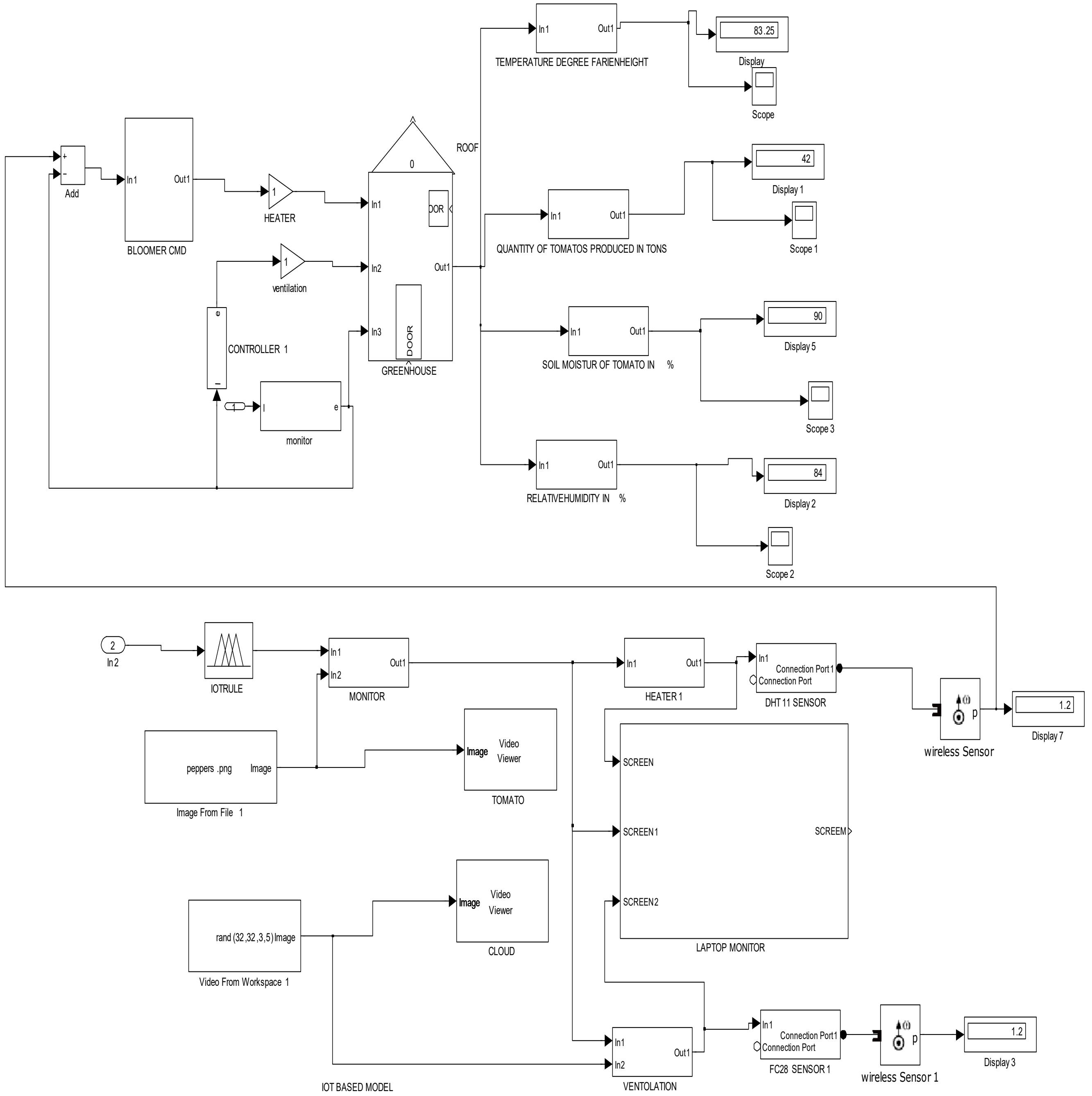

Figure 5: Integrated model to validate and justify the research to show the percentage of improvement in precision monitoring of temperature, humidity, soil moisture, and yield of tomato with and without IOT-based model.

The results obtained after the simulation are shown in Figures 6, 7 and 8

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Discussion of Result

Time (days)	conventional Greenhouse tomato plantation temperature(^{0}F)	IoT-based model Greenhouse tomato plantation temperature(^{0}F)
0	0	0
1	48	50
2	65	70
3	72	80
4	76	83.25
10	76	83.25

Table 3: Comparison Conventional and IoT-based model Greenhouse Tomato Farm Temperatures

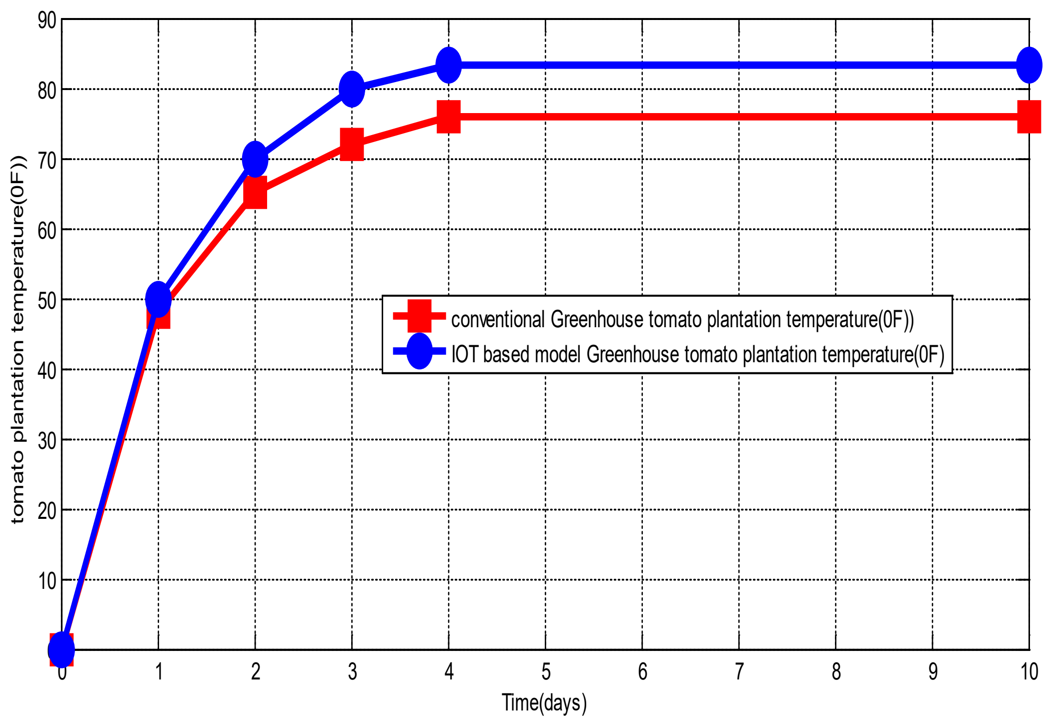

Figure 6: Comparison of Conventional and IOT based model Greenhouse Tomato Farm Temperatures

The highest conventional Greenhouse tomato farm temperature is 76(^{0}F) which automatically made tomato farms unhealthy. On the other hand, when IoT based model is incorporated into the system, its temperature increased to 83.25^{0}F thereby enhancing its growth ability and yielding quantity. Meanwhile, the percentage improvement in temperature when IOT based model is incorporated into the system over its conventional approach is 9.5%.

Time (days)	Conventional Greenhouse tomato plantation relative humidity (%).	IOT-based model Greenhouse tomato plantation relative humidity (%)
0	0	0
1	45	50
2	60	70
3	69	80
4	70	84
10	70	84

Table 4: Comparison of Conventional and IOT based Model Greenhouse Tomato Farm Relative Humidity.

Table 4 showed the simulation results of conventional and greenhouse tomato farm relative humidity. A graph plotted from the table gives a comparison of the between the two scenarios as shown in Figure 7.

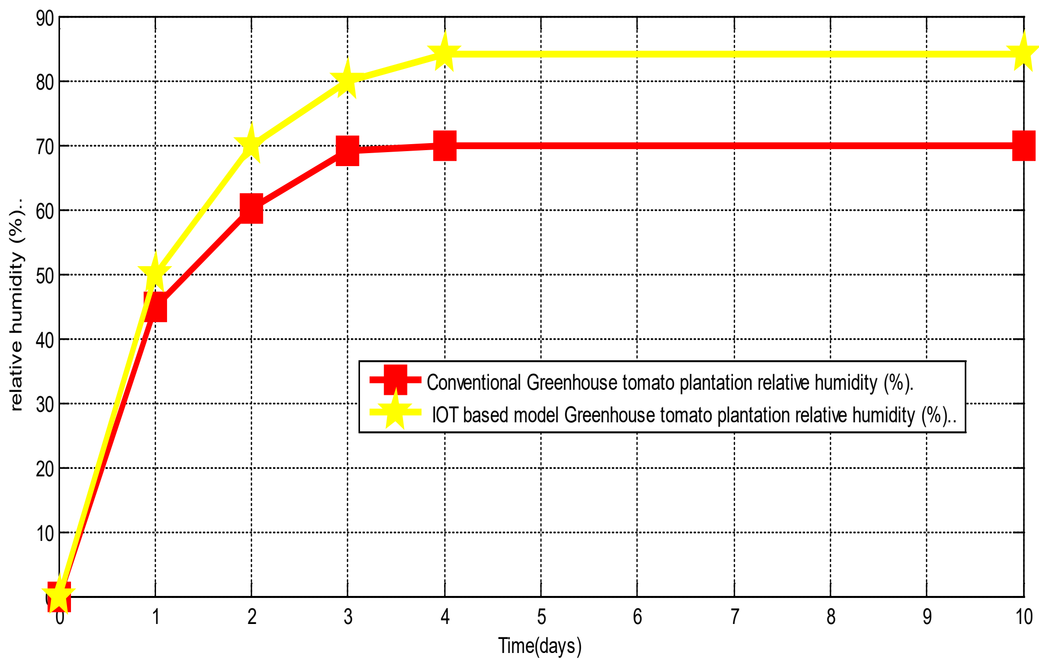

Figure 7: Comparison of Conventional and IOT based Model Greenhouse Tomato Farm Relative Humidity

In Figure 7, the highest conventional Greenhouse tomato plantation relative humidity is 70% thereby causing low production capacity in greenhouse tomato plantations. However, when IoT based model is incorporated into the system, it improved the relative humidity in the greenhouse tomato plantation to 84%. The percentage improvement in relative humidity when IoT based model is imbibed in the system over the conventional approach is 14%.

Time (days)	Conventional Greenhouse tomato plantation production capacity (Tons)	IOT-based model Greenhouse tomato plantation production capacity (Tons)
0	0	0
1	20	26
2	30	36
3	32	40
4	35	42
10	35	42

Table 5: Comparison of Conventional and IOT-based Model Greenhouse Tomato Farm production capacity

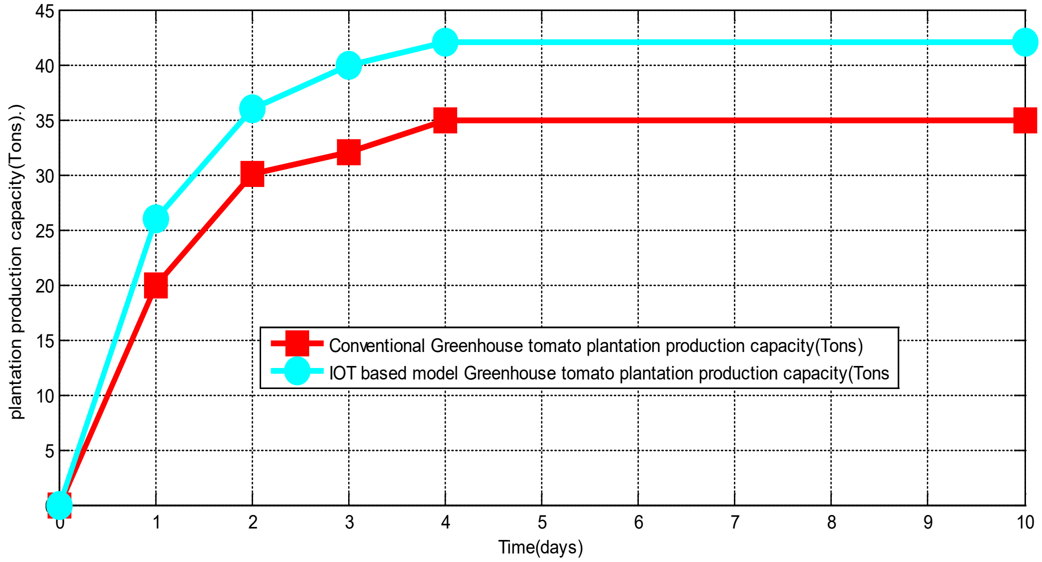

Figure 8: Comparison of Conventional and IoT-based Model Greenhouse Tomato Farm Production Capacity

In Figure 8 the conventional highest capacity of tomato plant plantation is 35 tons but when the IoT-based model Greenhouse is incorporated into the system it is 42 tons. The percentage improvement in tomato plantation when IoT based model is incorporated in the system over the conventional aspect is 20%.

Conclusion

The poor production of tomato in the world and Nigeria in particular has reduced the financial strength of agriculturists who primarily depends on tomato plantations for their daily income. This poor production capacity is overcome by improving tomato yield in a greenhouse using IoT. To realize it, the researcher tried characterizing and modeling tomato yield in normal weather conditions, establishing the effect of temperature and humidity in tomato yield, developing an IoT rule base for monitoring and improving temperature and humidity in optimizing tomato yield, designing an IoT-based SIMULINK model for precision monitoring and improving tomato yield in greenhouse agriculture, developing an algorithm that will implement the process and simulating the resulting model to validate and justify the research to show the percentage of improvement in precision monitoring of temperature, humidity and yield of tomato with and without IoT based model. The results obtained are the highest conventional Greenhouse tomato plantation temperature is 76(0F) which automatically made tomato plantations unhealthy. On the other hand, when IoT based model is incorporated into the system, its temperature increased to 83.250F thereby enhancing its growth ability and yielding quantity. Meanwhile, the percentage improvement in temperature when IoT based model is incorporated into the system over its conventional approach is 9.5%., the highest conventional Greenhouse tomato plantation relative humidity is 70% thereby causing low production capacity in greenhouse tomato plantations. However, when IoT based model is incorporated into the system, it improves the relative humidity in the greenhouse tomato plantation to 84%. The percentage improvement in relative humidity when IoT based model is imbibed in the system over the conventional approach is 14% and the conventional tomato plantation production soil moisture is 75%. while when IoT based model Greenhouse is imbibed in the system is 90% thereby enhancing the production capacity to the peak. The percentage improvement in soil moisture level when IoT based model is incorporated into the system is 15%. Finally, the conventional highest capacity of tomato plant plantation is 35 tons but when the IoT-based model Greenhouse is incorporated into the system is 42 tons. The percentage improvement in tomato plantation when IoT based model is incorporated in the system over the conventional aspect is 20%.

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