IoT Applications in Agriculture: Impacts and Challenges (A Review)

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Abstract
In this era, it can never be argued the benefits of technology to the daily life of the ordinary man. Modern technology which was once viewed as western propaganda by many in the African sub-Saharan has now come to be seen as an inextricable part of the daily life of the common man. The versatility of modern technology is seen in the creation of computer application which has propagated knowledge and brought much ease to life. This is innovation. This is civilization. This paper, however, interests itself in a particular group of computer applications – the Internet of Things (IoT); with the view of exposing its impacts and challenges as it is applied to the agricultural sector, while taking the Abakiliki farmers of Ebonyi State, Nigeria, as a case study.

*Keywords***:** IoT applications, Sensors, Agricultural productivity, food quality and quantity

1.0 INTRODUCTION

The expression "Internet of Things" describes the idea that the Internet is now more than just a platform for people to use to communicate with one another online. It also refers to the idea that devices can use the Internet to electronically communicate with their surroundings. As a result, information is constantly flowing between devices, being exchanged, and being used for a variety of different purposes.

The Internet of Things (IoT) is based on the technologies that make up it, such as the usage of sensors, RFID chips, nanotechnologies, identity systems (chips, cards, SIMs), and others. The most accurate way to describe it is probably as a group of interconnected technologies that may be used to produce fascinating goals. Sriveni and Bilal [1], pointed out that the internet can be used to read,

recognize, locate, address, and/or operate objects, especially commonplace ones like household appliances, furniture, clothing, vehicles, roadways, and smart materials. In general, the Internet of Things (IoT) and numerously related technological advancements (such as By storing and analyzing data in a dispersed manner and improving productivity, convergence, cloud services, data analytics, and the proliferation of sensors) are revolutionizing different industries.

Cellular networks' extensive coverage makes it possible to transmit data often and, in certain situations, almost instantly. A server receives either individual or aggregated measurements, and this allows for querying, cleaning, and analysis. To guide decisions and motivate activities, pertinent insights are given back to an end user or other IoT devices. Each of these activities is becoming more straightforward and less expensive to implement thanks to a large selection of already-available products and services that are specialized for particular applications.

IoT in agriculture is a modern technique for turning farming into a data-driven sector that will grow the economy and business. The following are typical components of an IoT for an agricultural system: measurement tools, Data transfer, data storage, and analytics, implementation of feedback, project structure, and support (Figure 1). The device layer contains the electronics needed to enable its functions as well as an instrument that measures the desired parameter (such as soil moisture). The communication protocol of the data transmission layer is used to connect devices that are arranged in a topology to a gateway.

A sustainable food supply is becoming necessary due to the rapid growth in the global population. Fruits and vegetables, in the opinion of experts, form the foundation of a healthy diet. The productivity and quality of crops, particularly those for fruit, grain, and vegetables, have significantly decreased in recent years due to the global spread of deadly plant pests and diseases. The problem is made worse by climate change and increased international economic flaws. The agricultural sector now has new options to tackle these worldwide challenges; thanks to technological advancements. With the help of technologies like IoT, it is possible to reimagine outdated farming methods and develop more economical procedures that produce larger quantities of food while using fewer resources. The goal of an Internet of Things (IoT) based farming system is to automate irrigation and monitor the crop field using sensors.

It is, therefore, necessary to adopt cutting-edge technology and practices known as the Internet of Things to boost productivity, and efficiency, and to reduce the challenges that farmers experience in agriculture. Farmers may now use IoT to learn a lot about the most recent technological advancements and farming methods. Multiple sectors of the agricultural industry today rely on IoT technology for farming to boost productivity, for worldwide marketing, to enhance profit in less time and cost, and for other aspects such as the reduction of human intervention in farming.
The technology known as IoT, or the Internet of Things is useful and extensively adopted. The Internet of Things (IoT) consists of several types of sensors, electronics, network elements,

and software. The Internet of Things (IoT) enables users to share their data in networks. Numerous applications focused on crops, including those that monitor and select crop growth, help irrigation decision-making, etc., are made possible by IoT.

Every aspect of conventional farming processes can be drastically altered by incorporating the most recent sensing and IoT technologies. Smart agriculture may currently take agriculture to levels that were previously unthinkable because of the seamless integration of wireless sensors and the IoT. The growth of an agricultural nation today involves agriculture in a significant way. Agriculture-related issues impede a country's progress constantly. The only option to overcome the current problem is through updating the traditional agricultural practices that are still in use today.

According to Syeda *et. al.* [2], the globe is moving toward IoT agricultural systems since it has become more difficult over the past several decades to meet consumer demands. The researchers are concentrating on developing monitoring and operations systems to improve yields and provide healthier crops for use in agriculture. It is a major task to keep an eye on crops, identify stress areas and their levels of stress, and take appropriate action in response to the data.

It is therefore upon this ground that this paper proposes a critical review of the impacts of the adoption of these IoT applications both on the farmers and on the general economy, as well as the consequent challenges that therein accrue. But this is before reviewing the inputs of other researchers and professionals on this subject which has given reason for this research work. In the end, one would see that the contributions of the IoT to the farmers and the nation's agriculture sector as a whole are quite tremendous as they outweigh the challenges thereof. This paper also advocates measures for the management and control of the fallouts seen as the challenges inherent in the adoption of these IoT applications in the agrarian life of rural people.

2.0   LITERATURE REVIEW

IoT in agriculture is a contemporary method for transforming farming into a data-driven industry that will flourish the economy and industry. Funmilayo and Emmanuel [3] pointed out that Sustainable agriculture promotes the actualization of societal wishes and as well ensures protective measures are taken on our lands and resources for the upcoming generation. They, therefore, concluded that farmers should be trained and exposed to the use of IoT devices so that it will be easy for them to accept and use the technology.

Gokul *et. al.* [4] recommended a system built on the Internet of Things that makes it easier to manage water, monitor crops, and regulate pesticides. Making agriculture a smart system was one of their attempts to automate it. The system consists of two parts.

Gokul *et. al.* [4] also pointed out that IoT devices are connected to sensors that can be used by farmers for their agriculture development. This sensor will help farmers to collect, process, and store information (temperature and *pH humidity, etc) in a database server that is connected to the internet. Farmers can access the internet locally or remotely depending on the connection using a mobile device. This is shown in Figure 1.

Based on an actual agricultural system, Patil and Kale [6] researched and evaluated sensor technology and wireless network integration of IoT technology. The researchers presented the

Remote Monitoring System (RMS), which utilized both Internet and wireless connections. Using IoT, a Smart Agriculture Model was used. This aids in weather risk prediction and crop avoidance. The use of IoT in agriculture allows for the collection of real-time data on the production environment, enabling SMS-based quick access to agricultural facilities and providing advice on weather patterns for different crops.

A powerful deep learning-based detector for real-time pest and disease detection on tomato plants increased yield results from early diagnosis and treatment of plant diseases [7]. To detect various diseases and pests in a tomato field, a convolutional neural network (CNN) and single-shot multi-box detector (SSD) combination is used. This IoT method uses deep learning to find illnesses and pests in tomato plants.

In the year 2020, Kanimozhi, Pooja, Pavithra, and Saranya [8] argued that smarter farming is crucial in today's world. Being shrewd aids in increasing agricultural productivity with the aid of technology, this is achievable in today's modern world. GPS satellite is used to determine the area, longitude, and elevation in feet. The Arduino Uno R3 is used to construct the application that houses this sensor. The electrochemical sensor used to determine the PH and soil supplement levels provides the essential information needed in accurate horticulture. This sensor has been connected to the application and installed on the ground.
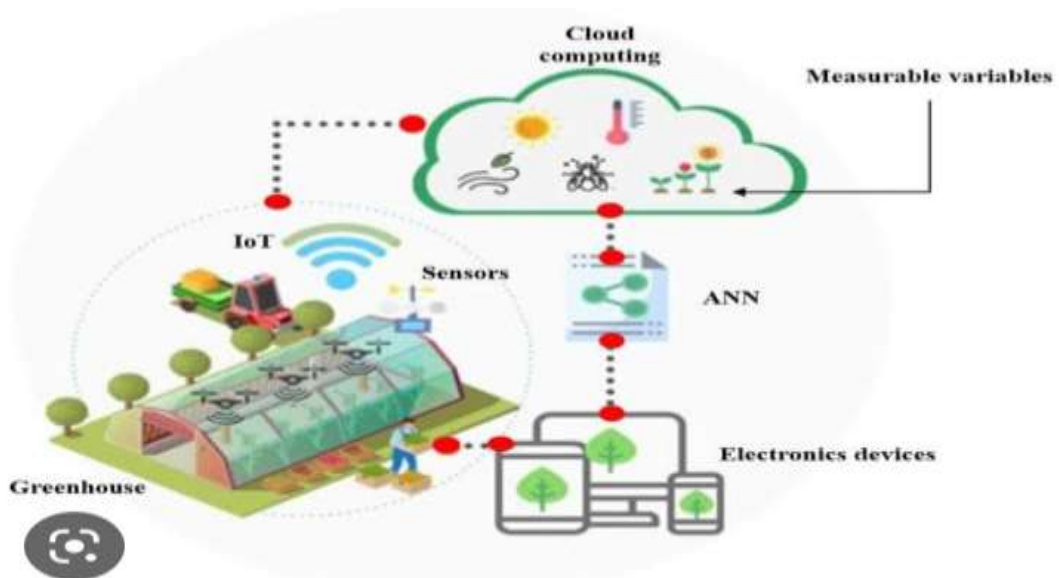
Figure 1: IoT Connection (Axel, Genaro, Manuel & Abraham [5])

With the help of this sensor, we can forecast the most productive crops that can be grown in that farm area as well as the soil's temperature, humidity, and PH level as well as the sort of fertilizer and pesticides that will be used. In Nigeria, Agriculture is one of the primary sources of income for some corporate and public organizations, as well as for people [9].

Although IoT-based solutions are being created to autonomously maintain and monitor crops with little or no human intervention, Nigerian agriculture, as to enterprise and a source of food security for her population, is still lagging in the use of IoT [10]. Dlodlo and Kalezhi 11] described how IoT may potentially help rural communities in South Africa and Zambia with their agricultural demands. These include the direct exchange of information between farmers and consumers and the application of IoT to agriculture.

Olakunle, *et. al.* [12] stated the inability of the Nigerian agriculture sector to meet local food demands and export at the required quality standards for market success. These are the two biggest problems the sector faces. The Internet of Things (IoT) can be utilized to assist a country's farming methods in adapting to adverse weather, a changing climate, and unfriendly locations (chemical compositions, floods, droughts, and soil erosion). The use of IoT technologies and Data Analytics in agriculture was covered in this study. The advantages and difficulties of implementing the IoT and DA were discussed. Finally, solutions to the issues Nigeria's agriculture sector is currently facing were also suggested.

Aamo, *et. al.* [13], in their work emphasized that due to the significant benefits it offers, the Internet of things (IoT) has grown in importance in practically every aspect of life. To reduce the challenges people experience executing their various activities, African nations, especially Nigeria are clamoring for the installation and deployment of IoT devices. Given how heavily the African continent depends on Agriculture, Nigeria, and Africa will gain from understanding and utilizing IoT for agriculture as they work to eradicate hunger.

In Africa and Nigeria, hunger and poverty will rise if IoT for agriculture is not adopted and implemented. Lessons from IoT applications in Agriculture include the fact that other nations particularly those in Europe, Asia, and South America are already utilizing IoT to address issues in agriculture. Recently, researchers concentrated more on the use of agricultural extension workers to address some of these issues while some farmers in the state heavily rely on the usage of fertilizers rather than implementing technology (IoT). In contrast to the expanding population, none of these efforts have produced very much. So, we advised incorporating IoT into our farm system. By identifying the numerous IoT applications in agriculture, this paper will therefore close the gap. Our study also highlights the benefits of IoT applications and in conclusion, this review provides a more comprehensive picture of IoT applications, impacts, and challenges.

3.0   METHODOLOGY

The goal that is striven in this case study reassessment is to summarize and analyze accurately the existing position of use of the internet of things (IoT) in agriculture with its strong influence and difficult tasks being recognized. To be able to achieve the aim of this study, the researchers carefully observed how farm practices are being done. Also, previous works from science direct, IEEE Xplore, and Scopus journals were reviewed. From our review, we, therefore, concluded that IoT has come to stay and there is a need to embrace it because it has the strength to rebrand rural agriculture to modern agriculture.

4.0 IoT APPLICATIONS IN AGRICULTURE

Due to the high level of unemployment and hardship, Nigerians have recognized agriculture as a good profession that will help us have economic stability. The government has launched some technological policies that motivate and support the youths and Nigerians to go into agriculture. Some of these technological (IoT) policies will reduce the obstacles faced by rural farmers. Some of these policies are as follows:

1. IoT E-wallet: This is known as Growth Enhancement Support system. It is one of the

benefits of IoT that the Nigerian government has introduced to ensure that government-subsidized inputs get to farmers at the right time. At the initial stage of this program, farmers received smartphones from the government which were configured as wallets. This program helped the government to have direct access to farmers at the rural level [3].

Statistics also reveal that in 2013, 1.2 million farmers received their free seeds and fertilizer via cellphone vouchers, increasing Nigeria's domestic food production by 8.1 million metric tons. As a result, Nigeria decreased its food imports by more than 40% by 2013, bringing the nation's agricultural self-sufficiency closer [14].
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2. Government in its effort to promote agriculture has created a platform called smart agro business through an agency called National Information Development Agency (NITDA). This platform will train graduates and provide the technology to manage their farms. Also, the platform is to make the economy a digital driving economy and also attain sustainable development goals (SDGs) which have the primary mandate to end hunger and have good food security by 2030.

3. To help farmers overcome some challenges, an IoT device called Zenvus was introduced. This is a smart device that provides farmers with the right information such as what, how, and when to farm. This is shown in Figure 3. This device has helped farmers to manage the problem of climate change which is a global problem as well.

The advantages that come with IoT are unquantifiable, however, most Nigerian farmers and youths have not embraced agriculture and the implementation of the Internet of Things into their farming profession due to inadequate awareness and the cost of implementing IoT. Farmers are encouraged to leverage IoT to ensure improved water conservation, improved livestock farming, reduced environmental stress, improved soil management, and erosion control.

Figure 2: Nigerian Farmers harvesting their crops [15]

Figure 3: Zenvus device

Technology does advance from time to time, claim Douglas, Cosmas, Augustine, and Ikenna [16], the appropriate technology must be used in the current scenario, and IoT is such technology at the moment. By utilizing IoT in agriculture, the conventional farming system will be replaced with a contemporary one. IoT can be used in the following agricultural sectors:

1. Irrigation System

Irrigation system ensures steady water and the health of livestock, crops, and harvest depends on water. It is therefore very certain that the irrigation system will help farmers to provide not only enough water but quality water to their farms meaning that crops and livestock will have water at the right time.

Introducing IoT into this practice will ensure that adequate measure is taken relating to the quantity of water which a farmer will apply to his crops. The water proportion/type of water that crops need varies from one crop to another. One good thing about the irrigation system is that farmers use it to overcome the problem of dust which most farmers face during the dry season. With IoT, agriculture must overcome growing water shortages and limited land availability while supplying a growing global population's rising consumption needs [17].

Application of IoT to an irrigation system commences once the soil moisture value is below an approved value or exceeds the approved temperature. When this happens, the system will send a signal through a wireless sensor which is placed on the crop field. The dataset generated for monitoring is analyzed using a machine-learning algorithm [18].

2. Control of Pests and Diseases

The rate at which diseases and pests spread from one place to another or from one crop or livestock to another is a serious concern to farmers. Farmers use pesticides and insecticides to control the spread of pests and diseases on the farm. Most of them do not have modern knowledge on how to handle such situations which sometimes are unexpected. Technology is the best solution to the modern-day problem of diseases and pesticides. This is

because we live in a technological age, which is altering our way of life and giving our society a new identity by improving human potential and facilitating adaptation to difficult life circumstances like pandemics, war, hunger, and natural disasters [16].

The technology that can revolutionize the agricultural sector and control the spread of diseases and pesticides in farming is the IoT. This type of technology will help farmers observe, predict and analyze the cause of these diseases and give a solution at an early stage.

Wireless sensors, robots and drones, and other portable smart devices that have access to the Internet are used to monitor the spread of diseases and pests in our farm using deep learning for image recognition and IoT technology. The use of these smart devices will help farmers to recognize crops and livestock that are infected and isolate them as soon as possible [19]. It is well known that the traditional system of detecting diseases and pests is error-prone and ineffective. In addition to the use of these smart devices, farmers make better decisions relating to pest and disease control as well as have quality and quantity yield.

3. Soil monitoring

A plant's life is mostly reliant on the soil. According to Muhammad and Mohammad [10], the soil is the stomach of plants, and sampling is the first step in an investigation to gather information particular to a given field, which is subsequently utilized to make additional important judgments at various stages.

The manual system is prone to error and encourages waste of time and erroneous assumptions on the part of the farmers. Soil monitoring is the process of evaluating soil moisture, soil humidity, soil temperature, soil pH, and other soil nutrients. Once this information is obtained, a farmer can decide which type of crops, and vegetables to plant and expect good yield during harvest [20]. The use of internet of things is an innovative technology that offers services to farmers at a reduced cost. Once the fertility of the soil is known using sensor technology and necessary

precautions taken, a farmer can predict the position of his farm before harvest.

4. Livestock monitoring

The steady increase in population is gradually becoming a problem in Nigeria because there is not enough food to care for this exponential growth in our population. Due to the increase in population, there is a need to increase our livestock production. An increase in livestock production means more meat, milk, money (GDP), and employment for the youths. To overcome this challenge, IoT for livestock should be used at all levels of livestock production. This is referred to as livestock monitoring. It is a system that will promote efficiency and reduce costs for livestock owners and buyers as well.

According to Abdullahi *et. al.* [21], the farmer can monitor the entire condition without their physical presence. In monitoring livestock, IoT sensors are placed at livestock, this will help to monitor their movement, health condition, and milk production and know when they are to reproduce. Also, the problem of cattle rustling in the country will be reduced or eliminated. In the same vein, information relating to livestock disease is detected on time and appropriate measures are taken to prevent the spread of a such pandemic.

5. Crop Monitoring

The use of IoT in agriculture is well-felt in crop monitoring. Some crops that are produced in Nigeria are bananas, beans, cashew nuts, cassava, cocoa, groundnuts, maize, palm oil, rice, rubber, sesame, sorghum, soybeans, and yams. Farmers have depended on traditional means over the years to monitor their crops but this system has not affected the production level of most farmers. It is very obvious that crop monitoring goes beyond crop, but includes soil, water, and disease /pest control.

Crop monitoring involves monitoring crop growth, diseases, or pests that can damage production. IoT in the area of crop monitoring has proven to give optimal yield thereby making agriculture less labor-intensive controlling cost, monitoring performance, and maintenance [1]. With the concept of IoT and Cloud computing, it is possible to have more accurate results.

Using IoT devices in monitoring crops will therefore ensure food sufficiency and reduce poverty in the country. According to Laxmi and Sanjay [22], to avoid the loss that farmers encounter in the agriculture sector, we come up with the idea of an IoT-based crop monitoring system.

6. Climate Change

This is a global problem and it has affected our existence on earth. Nigeria as part of the global community is also affected by climate change. Today, desertification and flooding are gradually becoming normal phenomena. Both lives and properties are lost due to flooding, and desertification has made some farmers migrate to other regions while other farmers have lost their livestock due to the total security of the food supply is significantly at stake due to poor weather conditions' considerable impact on agricultural production [23][24].

Utku and Enver [25] depicted that Climate change is a term used to describe the combined effects of rising temperatures on land and at sea, higher heat content in the oceans, more water vapor in the atmosphere, retreating glaciers and snow caps, diminishing sea ice, and rising sea levels. Agricultural production is under numerous stresses due to climate change.

Farmers adopting IoT in their operation will access the correct information at any point in time. This access to correct information will help farmers to make accurate predictions and also monitor the weather thereby helping them to know when to plant, weed, and harvest. Today, farmers still use the manual system in monitoring weather and this portends some negative effects on the crops and livestock. For example, inadequate or excess water supply in a farm affects the production of livestock and crops thereby leading to an increase or decrease in food production.

It is IoT that can solve this problem using real-time data which is obtained through remote sensing technology. Farmers today are facing the problem of desertification; meaning that some of them are living with a high inadequate water supply for their crops and livestock.

Some of them have migrated in search of water for their crops while others have lost their farm (crops) to flood. This problem also has caused some farmers to lose their lives in the process of migrating from one place to another. Samadi, [26] emphasized that Big data, IoT, and artificial intelligence have the potential to improve the accuracy of these severe event predictions. There are going to be major changes, transformations, and innovations because of the Internet of Things, the massive data it generates, and the capacity to harness it through artificial intelligence (AI) [27].

4.0 CHALLENGES OF IoT USAGE IN AGRICULTURE

We live in a technology age, and technology is reshaping society and altering our way of life by improving human potential and facilitating adaptation to challenging living circumstances including pandemics, war, starvation, natural disasters, and drought, among others [16]. IoT has significantly changed the environment for agriculture by examining the many difficulties and obstacles that farmers face [28]. The challenges of IoT that Nigerian farmers are facing are as follows:

1. **Shortage of skills:** Farming is well practiced at the rural level and most of the farmers are not well exposed to modern technological trends. IoT as a modern innovative technology will face this problem of skill shortage at the rural level. This is because farmers at the rural level are not well informed about IoT and its advantages while privately owned farms do not have the resource to employ IoT experts to help them in their farm or farms.

To overcome this, a government agency like National Information Technology Development Agency (NITDA) should provide a strategic third-party partnership. This will provide solutions to farmers at a very subsidized rate while the Ministry of Agriculture should from time to time organize training or sensitization programs to enlighten farmers on modern agricultural practices and the impact of technology on farming.

2. **Shortage of IoT facilities:** For the Internet of Things (IoT) to fully function, equipment such as software, hardware, and peopleware are needed. Some of these tools are not always readily available. In Nigeria, power (Electricity) is a serious concern to the people and internet services cannot transmit without a power supply. Also, an alternative power supply such as solar is not affordable to our rural farmers. So, for IoT to be enjoyed by our rural farmers, there is a need to make these tools affordable to them.

3. **Cost:** setting up a standard farm is a capital-intensive project. Introducing IoT is an additional cost, but the advantages of IoT are numerous. According to Ray [29], the implementation of an IoT system requires capital costs as well as operational costs. Applying IoT to our farms requires sensors, actuators, web technologies, and other IoT gadgets which attract a cost.

Also, the cost of buying data from mobile communication companies (MTN, Glo, Airtel, etc) from time to time to monitor our produce online may limit the success of IoT. It is, therefore, required for Nigeria Communication Commission (NCC) to enhance data rate and supply in the country and make internet services cheap and available to rural farmers.

4. **Security:** IoT generates data and these are large sets of data. These data are from soil nutrients and their pH, weather conditions, disease, pest and disease control, etc. There is, therefore, a need to secure these data because if an unauthorized user has access to these data, farmers would be vulnerable. There is, therefore, a need for a secure cloud for farmers and the information they generate.

5.0 IMPACTS

The introduction of IoT to agricultural applications brings numerous opportunities and potentials for smart farming [30][31], giving sufficient ability towards working together on assorted factors (and useful mechanisms) that allow opportunities to advance for improved comprehensive knowledge of the outlaying area. Hence, guaranteeing optimal profit through simple judicious use of limited resources. Also, the application of IoT in animal farming makes animal monitoring simple thereby keeping records of various

occurrences like feeding, vaccinating, and breeding. Therefore, with all this information available, a greater amount of cognizance about the farm and other industrial units with distinct existence is produced, giving room for better judgment of the entire system.

The advantages and uses of IoT in agriculture are:

i. **Production Efficiency:** Through correlation analysis between crop statistics data and agricultural environment data, the IoT-based agricultural production system has improved farmers, researchers, and government officials' capacity to assess the present situation and forecast the coming crop. Using this IoT-based decision support system, farmers can monitor the entire cycle from seeding to selling, which also helps to improve the quality of agricultural products.

ii. **Enhancement of yield and quality:** The efficient use of water and nutrients with disease discovery brings about output increment. The use of IoT therefore will help agriculturalists by getting live information from farmland to find a way to empower them to do shrew cultivating by likewise expanding their harvest yields and sustainable use of inputs.

iii. **Early disease identification** is possible because of sensor-based monitoring, information on the climate, and forecasts of crop diseases.

iv. **Lessens how the environment affects the crop:** Improved sensor-based monitoring will allow the system to learn how many environmental conditions impact crop development. Moreover, by employing this information, the effects of numerous environmental conditions on the crop might be mitigated.

v. **Effective management:** Farming can be made more efficient and accurate with the implementation of IoT devices applied in different domains of Agriculture. Hence, IoT-based system for agricultural applications offers a management system with greater production efficiency, yield, and profit.

6.0 DISCUSSION

As an innovative ideology that has changed the process of farming, IoT acts in the place of communication and computing in the time ahead. It is also used in smart traffic management, smart homes, and cities. Generally, IoT with its wide range of applications can almost be made the best use of in every sector. The topic of this article "IoT Applications in agriculture – Challenges and Impacts" acknowledges crop management, crop monitoring/field monitoring, resource management, cost-effective farming, and enhanced crop quality. Thus, with the help of the internet of things, the value and effectiveness of every practical front of increasing agricultural productivity are enhanced, making cropping systems intelligent and considerate. Equally, IoT has played a good role as a smart device in pest and crop disease detection and information transmission about them. This disease and pest detection ability of IoT technology at the early stage of crop farming enables high revenue generation for the farmers.

7.0 FUTURE RESEARCH

IoT-based farming has not yet fully embraced big data integration. A global solution to the issues of food security, by merging big data with the Internet of Things, sustainable resource management for water and other resources is extremely likely to be discovered.

As a result, this combination can create expert systems that can be used by both experienced and beginner users to yield the greatest quality results. It will also promote a community where people can easily use their expert models to discuss successful experiences, advancing farming. The purpose of this effort is to lay the groundwork for other scholars to develop the concept.

8.0 CONCLUSION

The agriculture industry has been transformed by IoT capturing the full potential of novel agricultural practices while facing the daily problems and difficulties in farming by offering clever solutions. IoT agriculture applications give ranchers and farmers the ability to gather

crucial and useful data, which can then be processed and used effectively. An IoT-enabled agricultural method can assist growers in successfully meeting the ever-increasing demands in light of the rapid population growth.

Acknowledgment

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