Food Security through Smart Agriculture and the Internet of Things

Dr. Sara Jeza Alotaibi
alotaibisar@ipa.edu.sa
Associate Professor in Web Technologies, Institute of Public Administration, Saudi Arabia

Abstract
One of the most pressing socioeconomic problems confronting humanity on a worldwide scale is food security, particularly in light of the expanding population and declining land productivity. These causes have increased the number of people in the world who are at risk of starving and have caused the natural ecosystems to degrade at previously unheard-of speeds. Happily, the Internet of Things (IoT) development provides a glimmer of light for those worried about food security through smart agriculture—a development that is particularly relevant to automating food production operations in order to reduce labor expenses. When compared to conventional farming techniques, smart agriculture has the benefit of maximizing resource use through precise chemical input application and regulation of environmental factors like temperature and humidity. Farmers may make data-driven choices about the possibility of insect invasion, natural disasters, anticipated yields, and even prospective market shifts with the use of smart farming tools. The technical foundation of smart agriculture serves as a potential response to worries about food security. It is made up of wireless sensor networks and integrated cloud computing modules inside IoT.

Keywords:
Internet of Things (IoT); Smart Agriculture; Wireless Sensor Networks; Precision Agriculture; Real-Time Analytics; Remote Monitoring; Artificial Intelligence.

1. Introduction

The global agricultural systems are under considerable pressure to meet the food security demands of the rapidly growing population, especially when considering the negative impacts of climate change and depletion of natural resources. According to the latest reports by the Food and Agriculture Organisation (FAO), the world population could increase to about 9.6 billion people by 2025, the current population growth rate currently standing at three people per second—equivalent to 250,000 people each day. With the projected explosive increase in the global population, there are now serious concerns regarding the ability of the existing factors of production to meet the demand and achieve food security goals for the global population. Indeed, urban areas are documented as being the worst affected by food shortages, which is responsible for the progressive increase in living standards across major cities in the world [1], [34].

Furthermore, the exacerbating destruction of natural ecosystems by climate change, soil and water pollution, and the depletion of oil resources pose significant strains to the preservation efforts for arable lands. Scientists consider smart agriculture as a potentially reliable solution to addressing the food crisis in rapidly developing urban areas; however, a multidisciplinary approach is necessary in order to develop an integrated solution to create a sustainable balance between optimal agricultural productivity and conservation of natural resources.

Technological advancement plays a key role in ensuring global food security and providing effective solutions for emerging needs, especially with regards climate change—and, indeed, the agricultural sector is keen to preserve the environment by rationalising natural resources for increased food productivity [2], [35]. However, the traditional agricultural methods do not provide stakeholders in the agricultural sector with the required resources to combat the emerging threats to food security; however, the adoption of advanced techniques such as remote control, data management, analysis systems, value addition, and process automation, in addition to the Fourth Industrial Revolution technologies (e.g., the Internet of Things; robotics; artificial intelligence) is critical when it comes to increasing the productivity and profitability of agricultural practices whilst making food production more environmentally friendly [3], [36]. The IoT systems and devices used in smart agriculture deliver seamless communication across a highly complex, multi-layered network infrastructure facilitating the collection and analysis of data to generate valuable insights for increased agricultural productivity [4], [37]. The figure below illustrates the flow of data across the IoT's network layers in a smart farm.

Manuscript received November 5, 2022
Manuscript revised November 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.11.5

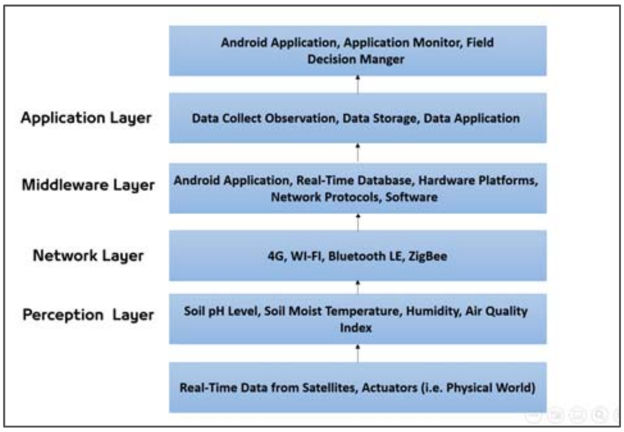

Figure 1 : The Flow of Data across the IoT Network Layers in a Smart Farm [4]

The perception layer comprises connected systems of detectors and sensors that collect real-time data concerning the groundwater level, air quality, humidity, temperature variations, and soil moisture [4]; these detectors and sensors are embedded with high-speed processors, which perform error analysis to ensure that only precise data is sent to the cloud-based server [4].

The network layer is relied upon by smart agriculture for the transmission of real-time data on the crop environment to the cloud servers. This layer has a processing component that performs abstraction functions for all sensitive data before sharing the connected system components such as databases and actuators [4]. In addition, here, sensors and monitors utilise wireless networks in order to communicate with information management systems so as to analyse important variable data.

Similarly, the middleware layer's role is to link the application layer to the network layer for seamless communication between the hardware and software components. It controls the network protocols used in the operating systems and sensors in order to manage resource sharing, perform predictive analytics of the expected crop yield, and to allow remote monitoring [4]. In precision agriculture, the middleware network layer performs functions such as climate control and automated irrigation so as to ensure optimal resource utilisation.

Finally, the application layer is the last network interface composed of the communication protocols that link the connected devices to the middleware layer. It performs functions such as data encryption and provides intelligent insights into the changes in environmental variables during crop growth [4], which enables farmers to take relevant actions so as to ensure maximum yields.

2. LITERATURE REVIEW

2.1 The concept of Smart Agriculture

Agriculture plays a critical role in ensuring food security and global economic growth—and yet in recent years, agricultural productivity has been significantly constrained by environmental issues such as climate change and global warming, despite the increased demand for food supply due to population growth [5]. In light of this, modern technology provides a framework for integrating advanced techniques and systems in agricultural processes through smart agriculture to boost production and minimise the destruction of natural resources such as soil. The concept of smart agriculture is based on automation technology so as to allow for the real-time monitoring of the crop environment using specialised sensors, which also regulate productivity constraints such as temperature, moisture, humidity, and chemical inputs [6]. Furthermore, smart agriculture leverages cloud-computing technology so as to store and analyse the garnered real-time data as a source of valuable insights on the expected quality of products, the precise harvesting time, and the likelihood of incidents such as pest invasion. Indeed, applying the latest IoT and sensor technologies in smart agriculture has fundamentally changed the effectiveness of the responses to the impacts of climate change and the influence of crop optimisation and soil suitability on the quality and quantity of outputs [6]. Advanced concepts such as precision farming in smart agriculture are vital in automated irrigation systems and weed control whilst minimising labour costs.

The idea behind smart farming is to provide the agricultural sector the infrastructure it needs to exploit cutting-edge technologies, such as big data, the cloud, and the internet of things (IoT), for automating, tracking, and analyzing activities. Smart farming, sometimes referred to as precision agriculture, is software-managed and sensor-monitored. The need for climate-smart agriculture, the rising demand for higher crop yields, the need to use natural resources more effectively, the growing use and sophistication of information and communication technology, and the expanding global population all contribute to the growing importance of smart farming.

2.2 The Concept of the Internet of Things

As it develops to support the fundamental tenets of society, the Internet of Things phenomenon has continued to draw attention from the general public. However, in order to comprehend this phenomenon fully, it is important to recognize that its definition changes depending on the context in which it is used. However, they are all connected via a network or the internet. Suraki & Jahanshahi define the Internet of Things based on two concepts: "internet" and "thing," defining the former as "The worldwide network of interconnected computer networks, based on a standard communication protocol," and the latter as "an object not a person" [24]. Chopra et al. define the Internet of Things as "the internet of the future that will allow communication amongst anyone and at any place, and will enable machine-to-machine (M2M). The Internet of Things is further described as a self-configured global network infrastructure that includes standards and comprehensible communication protocols that allow both virtual and physical objects to recognize physical characteristics and fictional personalities that are seamlessly incorporated into the information structure. The Internet of Things, according to Hu et al., is the linking of all objects to the internet using Radio Frequency Identification (RFID) and other information, by detecting various types of equipment to accomplish intelligent identification and administration [25].

There are several examples of the Internet of Things' use in the public sector, as should be expected given its broad adoption. The use of numerous technologies to enhance patient care delivery via IoT in the healthcare industry is one prominent example of this. One such application is the fuzzy-based fog computing for real-time health data transmission in Saudi Arabia, which addressed the issue of the network bottleneck's high traffic volume as well as the overburdening of the cloud with more data [26]. Indeed, high data production and internet connectivity variables, such as high network latency, huge data transfer, and high service latency, have a substantial influence on the delay. All of these problems prevent the cloud from offering a real-time mode for processing and delivering patient data. Contrarily, utilizing fog services with the Fuzzy Data Packet Allocation (FDPA) algorithm, fuzzy-based fog computing enables the integration of healthcare IoT devices with the cloud, transferring patient data to agencies and physicians in real-time mode [26].

IoT monitoring systems have been incorporated into the healthcare system on a worldwide scale [27] and, in fact, the capacity to monitor the patient 24 hours a day can only be accomplished by the IoT-configured system. This is another example of how IoT is being used in the health sector. The use of non-intrusive biological sensors that can measure a variety of parameters, such as heartbeat, ECG, temperature, blood pressure, and respiration, would serve as an illustration of this [28]. A key component of such a system is the Arduino Mega Controller, to which non-invasive biomedical sensors are linked. The output from the Arduino Mega Controller is then shown on any digital monitoring system. The information gathered by the sensors is subsequently transferred to the ThingSpeak cloud, where it is accessible by doctors and other interested parties for real-time follow-ups and storage of patient information.

Similar to this, Myers et al. suggested an Internet of Things-integrated Structural Health Monitoring system (SHM), which would enable it to avoid operational concerns by acquiring fast reaction times, offloading processing resources, data storage, and high remote monitoring capabilities [29]. In Thailand, IoT has been combined with the Health Level 7 protocol for cloud-based real-time healthcare monitoring. This framework is now used to assist and keep an eye on the elderly. Here, the information is given in real-time and is based on data saved in the cloud using the JSON language [30], which is also directly related to hospitals and public health. In accordance with the Health Level 7 standard, this enables clinicians to use the data collected by the monitoring system for the patient's treatment or to offer advise via web services. In fact, Ranjana & Alexander use the same idea to describe how IoT serves as an ongoing medical reminder for elderly persons [31].

Additionally, the Internet of Things has been widely used in the area of security. IoT has aided in reducing public mass shootings in the United States, which needed to be stopped by a citizen reaction. The current Homeland Security Department recommendation for a civilian to prevent shootings is to flee, hide, and fight—a tactic that, in most cases, may not be helpful in saving lives. Therefore, a decentralized and intelligent Internet of Things-based decision has been implemented in the majority of US buildings to avoid citizens from becoming targets [32]. This effectively manages civilian evacuation while identifying and monitoring the situation to significantly boost public safety. Such a technology is also used in other emergency situations, alerting people to the safest exits and helping them leave. Such a system is dynamic, avoids the attacker or the emergency source, eliminates congestion during evacuation, and lessens evacuee terror.

IoT has also been used in China's intense aquaculture business using IoT-based monitoring devices that track water quality. This is vital because in China, the growth of agriculture is thought to depend on the quality of the water. As a result, the modernization of aquaculture has become simpler with the introduction of a water monitoring quality system based on IoT [33].

The Internet of Things (IoT) refers to the connection of objects and devices through an embedded network composed of sensors, software, and electronic circuits so as to allow data storage, sharing, and exchange [7]. IoT relies on pervasive computing and ambient intelligence technologies in order to execute tasks remotely using portable devices and unmanned aerial vehicles (drones), especially when covering large physical distances [7]. Agricultural production is one area in which IoT technology is applied in smart farming so as to increase crop yield and reduce the depletion of natural resources through the controlled utilisation of farm inputs. Notably, the connected devices in the IoT rely on embedded computer systems in order to communicate with monitoring devices such as the sensors used in smart agriculture so as to relay data on humidity, temperature, and soil moisture in the crop environment [7].

2.3 Applications of Technologies for Smart Agriculture and the Internet of Things

Precision agriculture is one area in farming in which the Internet of Things (IoT) is widely adopted with the aim of solving the environmental variations which harm crop productivity [8]. Precision agriculture is considered to be an effective technology when it comes to reducing the negative impacts of agricultural processes on the environment. Interestingly, integrating this IoT technology with advanced systems such as cloud computing and wireless sensor networks to smart agriculture increases safety in the utilisation of farm inputs such as pesticides and fertilisers [8]. Moreover, smart agriculture based on IoT technologies increases the effectiveness and efficiency of practices such as monitoring the balance of nutrients in crops, making accurate predictions on the outbreak of animal diseases and crop pests, and soil testing, all with the aim of planting crops with maximum yield. Notably, precision agriculture relies on the Wireless Sensor Networks (WSN) in order to increase agricultural processes such as pesticide application and climate control for environmental conservation and optimal crop production. The common application of WSNs in precision farming includes automatic water pumps, pressure sensors, passive infrared sensors, humidity sensors, temperature sensors, soil moisture sensors, and monitoring cameras connected to integrated server systems and cloud computing infrastructure for optimal functioning. The diagram below illustrates the applications of wireless sensor networks in precision farming:

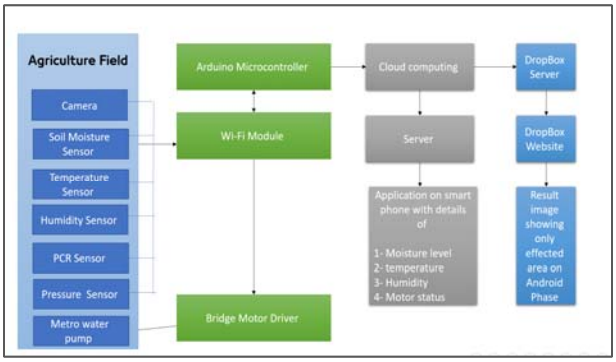

Figure 2: Applications of WSNs in Precision Agriculture [8]

Real-time monitoring of the agricultural environment through the Message Queuing Telemetry Tracking (MQTT) IoT technique is applied so as to increase crop productivity through smart agriculture—and notably, this relies on remote monitoring systems, which collect real-time data of the atmosphere in agricultural production systems so as to enable farmers to adopt the appropriate maintenance practices for optimal yields and reduced rate of natural resource depletion [9]. Furthermore, MQTT technology is highly reliable and efficient in mitigating the negative impacts of climate change on agricultural production by adopting relevant measures so as to maintain soil fertility, reduce water wastage, and control the light intensity on crops [9]. The Message Queuing Telemetry Tracking (MQTT) system is comprised of wireless sensors, channel relay modules for different sensors, and light water pumps, which regulate the agricultural environment by increasing or reducing the supply of variable inputs on demand [9].

IoT applications such as bio raisers are designed with the aim of minimising the usage of fertilisers in crop production. This relies on real-time data analytics from the agricultural environment so as to perform automated balances that provide the exact nutrient requirements in a crop, as well as conserve natural resources, such as water and soil [1]. This system is comprised of integrated wireless sensors that measure soil moisture, which helps farmers to precisely control the number of inputs drawing insights from a cloud-computing platform from which changes in crop environment can be monitored as shown in the figure below.

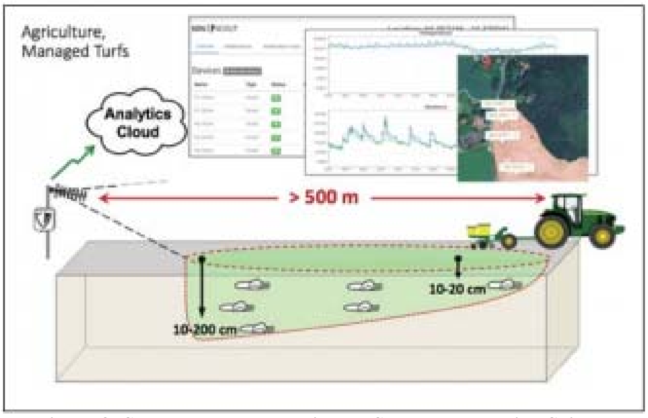

Figure 3: System-Integrated Wireless Sensors Measuring Soil Moisture [9]

According to [1], a combination of IoT systems (such as the soil scout sensors with bio raiser technology in the production of blueberries) creates a precision agriculture environment, which saves up to 70% of the water footprint. Notably, the sensors used in bio raisers have 927.700 MHz transmission power, making them highly efficient in detecting slight changes in soil moisture, possessing a mean accuracy of 98% and temperature with 99.2% accuracy [1]. This solution is highly relevant in urban areas in which agricultural production resources (such as water) are scarce.

2.4 The Advantages and Disadvantages of Smart Applications and Technologies in Agriculture

The application of technology in agriculture, horticulture, and aquaculture with the aim of enhancing productivity, efficiency, and profitability is known as agricultural technology, or agrotechnology. Any items, services, or applications that enhance various agriculturally produced goods are referred to as agricultural technology.

Agriculture science, agronomy, and agricultural engineering advancements have led to changes in agricultural technology. Historians have highlighted a number of agricultural revolutions as significant shifts in agricultural practice and productivity, and these revolutions were closely related to technological development [5-16].

The following lists the benefits and drawbacks of smart agricultural technologies and applications:

2.4.1 Benefits

- **Automation.** Smart agriculture and IoT technologies utilise sensor mechanisms so as to detect changes in the crop environment and automatically relay the data to a cloud-computing platform for analytics [11], which plays a fundamental role in generating valuable insights on the necessary adjustments for crops to thrive and produce quality yields; for example, in precision farming, automation helps farmers to know the exact amount of chemical inputs and water required by the crops on a real-time basis [12]. Furthermore, IoT and smart agriculture technologies support wireless sensor networks, hence creating the possibility for remote monitoring. This would enable farmers to focus on multiple agricultural activities, including crop management, value addition, and marketing simultaneously from integrated devices [11].
- **Cost Reduction.** Automated agricultural processes reduce labour requirements for food production significantly: fewer system operators are needed in order to monitor the

crop environment, regulate inputs, and perform tasks such as spraying, weeding, and harvesting [13]. This reduces the risk of crop damage and labour costs, hence enabling farmers to reap optimal profits.

- **Increased Yields.** The fundamental basis of IoT and smart agriculture technologies in food production is to increase yields through precision farming: here, real-time data collection and analysis capabilities enable farmers to make accurate predictions concerning weather patterns, pest invasion, and soil nutrients and inputs. The systems are designed with AI-driven sensor and analytics mechanisms that detect the exact crop requirements for moisture, temperature, pest control, and chemical inputs through automated functions [14], thus creating an optimal environment for agricultural productivity—especially with regards the lower risk of crop damage by natural occurrences or pests.

2.4.2 Disadvantages

- **Cybersecurity Threats.** Sensor systems rely on wireless networks in order to transmit data across connected devices, servers, databases, and analytics systems, which in turn exposes sensitive crop data to hacking threats, thus increasing the risk of privacy breaches significantly. Furthermore, the intercepted data may be manipulated to produce inaccurate analytics of the crop environment, causing farmers to incur losses [15]. In addition, distributed denial of service attacks on the network infrastructure may potentially disrupt agricultural processes, leading to crop damage, leading to delayed responses to the vital requirements for optimal growth [16].
- **High Initial Costs.** The acquisition of agricultural systems, monitoring devices, and subscription fees for cloud-computing infrastructure is generally expensive, especially for small-scale farmers—and these costs are further escalated by the implementation of custom-designed software and hardware to suit the specific needs of the agricultural environment in which a farmer operates [17]. In addition, farmers and their workers require specialised training in order to equip them with the relevant knowledge and skills so as to operate the equipment efficiently [17]. As a result, the cumulative costs of setting up a smart farm are considerably high.

3. IMPORTANT REQUIREMENTS AND ATTRIBUTES FOR INTERNET OF THINGS IMPLEMENTATION IN SMART AGRICULTURE

The effective utilisation of the Internet of Things in smart agriculture to achieve optimal productivity for food security relies on the following critical technology requirements and attributes for the collection and analysis of data.

- **Cloud Service-Oriented Architecture**. IoT devices and sensors used in smart agriculture communicate through cloud service-oriented architecture, which performs critical functions such as monitoring farming operations and market-oriented services such as value addition [18]. IoT systems increase the efficiency of these processes by reducing labour requirements, ensuring the optimal utilisation of farm inputs, pest control, and soil management for increased production. The required cloud-computing system for precision agriculture must automatically perform functions such as collecting and filling crop data, utilising sensors so as to monitor the crop environment, performing predictive analytics of the expected yields, controlling water pumps, and managing agricultural data efficiently [18]. The figure below illustrates the additional functions of a cloud service-oriented architecture in smart agriculture.

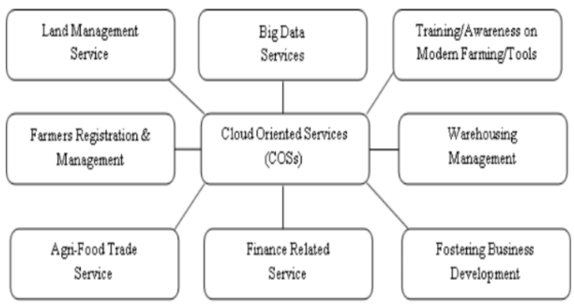

Figure 4: The Additional Functions of a Cloud Service-Oriented Architecture in Smart Agriculture [18]

The cloud service-oriented architecture for smart agriculture offers farmers a unified multichannel platform so as to allow for a two-way flow of information across the monitoring devices through web portals, voice and text services, Internet-based systems, and other interactive systems [18]. Seamless access to real-time data concerning the crop environment conditions helps farmers to make informed choices, which leads to optimal yields for food security.

- Specialised monitoring devices are used in smart agriculture to detect, gather, and transmit variable data on the environmental conditions in the crop field to a cloud server. The basic structure of IoT monitoring devices for smart agriculture is composed of broadcasting processing modules, ARM embedded board, and a communication module, as shown in the figure below [19].

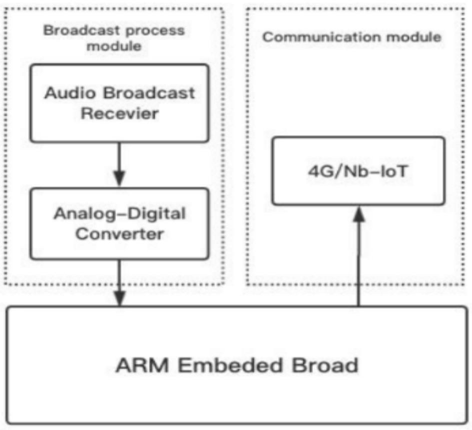

Figure 5: The Basic Structure of IoT Monitoring Devices for Smart Agriculture [19]

The role of a broadcasting-processing module is to receive open-circuit data from the ADC component, then converting it from an analog to a digital format that a user can easily understand. The arm-embedded board serves an operating system's role by processing and transmitting data across the network layers through a frequency module [19]. Data from the sensors is then relayed to remote monitoring devices via the wireless communication module, which provides a robust connection for seamless data transmission across the connected devices.

- **Data Exchange System.** The IoT systems used in smart agriculture rely on a data exchange system in the communication across sensors, monitoring devices, and analytics systems. The data from monitoring devices are processed on different protocols depending on the nature of its deployment environment [19]. This data exchange system interprets various inputs from the monitoring devices and transforms them into a unified format to provide readable outputs on the device monitors. Other functions of the data exchange system include queuing input data before the transmission to the database and monitoring centre systems [19]—important when it comes to monitoring connected devices through a management-oriented platform, which analyses input and generates status reports with the relevant statistical data so as to enable users to make accurate decisions concerning the necessary adjustments so as to achieve optimal yield [19].

4. RECOMMENDATIONS FOR USING SMART AGRICULTURE AND THE INTERNET OF THINGS

In the light of the applications, advantages, and disadvantages of smart agriculture and the Internet of Things when it comes to addressing the problem of food security. The Internet of Things (IoT) development provides a glimmer of light for those worried about food security through smart agriculture—a development that is particularly relevant to automating food production operations in order to reduce labor expenses. When compared to conventional farming techniques, smart agriculture has the benefit of maximizing resource use through precise chemical input application and regulation of environmental factors like temperature and humidity. Farmers may make data-driven choices about the possibility of insect invasion, natural disasters, anticipated yields, and even prospective market shifts with the use of smart farming tools. The technical foundation of smart agriculture serves as a potential response to worries about food security. It is made up of wireless sensor networks and integrated cloud computing modules inside IoT. The following recommendations have been made with the aim of increasing agricultural productivity.

- **Adopting Sustainable Resource-Utilisation Solutions.** Smart agriculture and IoT solutions are fundamentally vital when it comes to increasing crop yield through efficient monitoring and data-driven decision processes. However, the question of sustainability the of the production processes (especially concerning adaptability to the changing scope of technological advancement) is a noteworthy one, and so in order to address this concern, farmers need to adopt sustainable resource utilisation strategies (e.g., developing IoT systems for water recycling, leakage monitoring, and automated irrigation) in order to keep wastage at a minimum [20]. Furthermore, farming technologies such as hydroponics are recommended when it comes to conserving soil resources for sustainable production, especially when considering the negative impacts of climate change on soil fertility [20]. Therefore, the efficient utilisation of natural resources is a key prerequisite for continued production.
- **Home-Based Automation.** Adopting home-based automation IoT technology based on high-speed wireless networks is recommended when the process of monitoring in smart agriculture is looking to be improved. The availability of secure and cheap Long-Term Evolution (LTE) network infrastructures compatible with smartphones and other portable devices used in agriculture is a promising future for global food security [23]. Notably, home-based automation systems running on Arduino micro-controllers and artificial intelligence are recommended as effective, reliable solutions for the remote control of the physical infrastructure in a farm [21]. Moreover, the integration of home-based automation offers increased efficiency in monitoring and analysing real-time data through intelligent systems, which collect and relay only relevant data to cloud computing servers. [21] recommends the integration of a generic IoT framework in smart agriculture so as to leverage cloud-computing technology in order to manage wireless devices and sensor networks from remote locations effectively.
- **Solar-Based Smart Agriculture.** Rural areas contribute significantly to global food security due to huge land tracks, which are ideal for agricultural production. However, smart agriculture and IoT adoption in such areas are faced with serious challenges, especially when it comes to the limited access to networking infrastructure and the inadequate knowledge of automation and sensor technologies [22]. In order to address the growing concerns of global food security, [22] recommends adopting solar-driven smart agriculture and IoT technologies for a sustainable response to the loss of soil fertility and other implications of climate change on crop productivity. Solar-driven wireless sensor systems are embedded with integrated devices, which collect and relay data on the environmental conditions to a centralised server for analytics and the generation of improvement insights. Furthermore, solar-based smart agriculture technologies are relatively affordable and easy to use, hence increasing food productivity in rural areas [23].

5. CONCLUSION

This paper shows that there has been a lot of recent research on the application of IoT technology in agriculture, with the majority of that research concentrating on IoT-enabled smart monitoring and control. Despite the fact that IoT is now being used in agriculture, there are still a number of limitations that need to be solved in further study. Nevertheless, a lot of research has been done on using IoT to many aspects of agriculture.

The Internet of Things (IoT) is a potential technological application in the area of smart agriculture that could improve crop productivity as a sustainable solution to global food security concerns. Relevant studies show that the world population is currently increasing by three people every second, and is expected to increase considerably by 2025—and when considering this in combination with the adverse impacts of climate change, the current agricultural resources cannot address the global food security requirements. In light of this, IoT technologies (e.g., wireless sensor networks; artificial intelligence; cloud-computing to the automation of agricultural processes) have contributed significantly to crop yield. Notably, automated systems gather real-time data, transmit to the servers through wireless networks, and perform analytics so as to generate important insights for regulating production constraints. This is to ensure optimal yield, disaster preparedness, and optimal resource utilisation.

In mind of all of the above, this paper recommends applying IoT in smart agriculture so as to foster the adoption of sustainable resource utilisation and home-based automation with the overall aim of improving agricultural productivity for food security.

Acknowledgement

This work was supported by the institute of public administration, Riyadh, Saudi Arabia. Author is thankful for the support.

Declaration of Conflicting Interests

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

Data Availability

All data generated during this study are included in this published article.

RERERENCES

[1] V. Larios, R. Michaelson, A. Virtanen, J. Talola, R. Maciel, and R. Bertran, “Best practices to develop smart agriculture to support food demand with the rapid urbanization trends in Latin America,”, pp. 555–558, 2019. Article (CrossRef Link).

[2] M. Ur Rahman, F. Baiardi, and L. Ricci, “Blockchain Smart Contract for Scalable Data Sharing in IoT: A Case Study of Smart Agriculture,” *2020 IEEE Global Conference on Artificial Intelligence and Internet of Things (GCAIoT)*, 2020. Doi:10.1109/GCAIoT51063.2020.9345874

[3] R. Chaudhary, J. R. Pandey, P. Pandey, and P. Chaudhary, “Case study of Internet of Things in area of Agriculture, ‘AGCO's Fuse Technology's’ ‘Connected Farm Services’," *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)*, 2015, pp. 148-153, Doi: 10.1109/ICGCIoT.2015.7380447

[4] S. Verma, R. Gala, S. Madhavan, S. Burkule, S. Chauhan, and C. Prakash, "An Internet of Things (IoT) Architecture for Smart Agriculture," *2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, 2018, pp. 1-4, doi: 10.1109/ICCUBEA.2018.8697707

[5] M. Hasan, K. N. Uddin, A. Sayeed, and T. Tasneem, "Smart Agriculture Robotic System Based on Internet of Things to Boost Crop Production," *2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)*, 2021, pp. 157-162, doi: 10.1109/ICREST51555.2021.9331091

[6] O. Friha, M. A. Ferrag, L. Shu, L. Maglaras, and X. Wang, "Internet of Things for the Future of Smart Agriculture: A Comprehensive Survey of Emerging Technologies," in *IEEE/CAA Journal of Automatica Sinica*, vol. 8, no. 4, pp. 718-752, April 2021, doi: 10.1109/JAS.2021.1003925.

[7] S. Meadthaisong and T. Meadthaisong, "Smart Farming Using Internet of Thing(IoT) in Agriculture by Tangible Programming for Children," *2020 17th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2020, pp. 611-614, doi: 10.1109/ECTI-CON49241.2020.9158083

[8] R. K. Patil and S. S. Patil, "Cognitive Intelligence of Internet of Things in Smart Agriculture Applications," *2020 IEEE Pune Section International Conference (PuneCon)*, 2020, pp. 129-132, doi: 10.1109/PuneCon50868.2020.9362449

[9] S. V. Mukherji, R. Sinha, S. Basak, and S. P. Kar, "Smart Agriculture using Internet of Things and MQTT Protocol," *2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon)*, 2019, pp. 14-16, doi: 10.1109/COMITCon.2019.8862233 .

[11] D. C. Bogatinoska, R. Malekian, J. Trengoska, and W. A. Nyako, "Advanced sensing and internet of things in smart cities," *2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 2016, pp. 632-637, doi: 10.1109/MIPRO.2016.7522218 .

[12] M. Dholu and K. A. Ghodinde, "Internet of Things (IoT) for Precision Agriculture Application," *2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI)*, 2018, pp. 339-342, doi: 10.1109/ICOEI.2018.8553720 .

[13] O. Elijah, T. A. Rahman, I. Orikumhi, C. Y. Leow, and M. H. D. N. Hindia, "An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges," in *IEEE Internet of Things Journal*, vol. 5, no. 5, pp. 3758-3773, Oct. 2018, doi: 10.1109/JIOT.2018.2844296 .

[14] A. Salam and S. Shah, "Internet of Things in Smart Agriculture: Enabling Technologies," *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, 2019, pp. 692-695, doi: 10.1109/WF-IoT.2019.8767306 .

[15] M. R. Kassim, "IoT Applications in Smart Agriculture: Issues and Challenges," *2020 IEEE Conference on Open Systems (ICOS)*, 2020, pp. 19-24, doi: 10.1109/ICOS50156.2020.9293672 .

[16] G. Suciu, C.-I. Istrate, and M.-C. Ditu, G. Suciu, C. Istrate and M. Dițu, "Secure smart agriculture monitoring technique

through isolation," *2019 Global IoT Summit (GIoTS)*, 2019, pp. 1-5, doi: 10.1109/GIOTS.2019.8766433 .

[17] K. Grgic, D. Zagar, J. Balen, and J. Vlaovic, "Internet of Things in Smart Agriculture — Possibilities and Challenges," *2020 International Conference on Smart Systems and Technologies (SST)*, 2020, pp. 239-244, doi: 10.1109/SST49455.2020.9264043 .

[18] P. Srinivasulu, M. S. Babu, R. Venkat, and K. Rajesh, "Cloud service oriented architecture (CSoA) for agriculture through internet of things (IoT) and big data," *2017 IEEE International Conference on Electrical, Instrumentation and Communication Engineering (ICEICE)*, 2017, pp. 1-6, doi: 10.1109/ICEICE.2017.8191906 .

[19] H. Huang, "Architecture of Audio Broadcasting Coverage Monitoring System Based on Internet of Things," *2019 IEEE International Conference on Smart Internet of Things (SmartIoT)*, 2019, pp. 320-324, doi: 10.1109/SmartIoT.2019.00055 .

[20] H. H. Kadar, S. S. Sameon, and P. A. A. Rafee, "Sustainable Water Resource Management Using IOT Solution for Agriculture," *2019 9th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2019, pp. 121-125, doi: 10.1109/ICCSCE47578.2019.9068592 .

[21] K. Mandula, R. Parupalli, C. H. A. S. Murty, E. Magesh, and R. Lunagariya, "Mobile based home automation using Internet of Things(IoT)," *2015 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)*, 2015, pp. 340-343, doi: 10.1109/ICCICCT.2015.7475301 .

[22] R. Maheswari, H. Azath, P. Sharmila, and S. R. Gnanamalar, "Smart Village: Solar Based Smart Agriculture with IoT Enabled for Climatic Change and Fertilization of Soil," *2019 IEEE 5th International Conference on Mechatronics System and Robots (ICMSR)*, 2019, pp. 102-105, doi: 10.1109/ICMSR.2019.8835454

[23] S. Namani and B. Gonen, "Smart Agriculture Based on IoT and Cloud Computing," *2020 3rd International Conference on Information and Computer Technologies (ICICT)*, 2020. DOI:10.1109/ICICT50521.2020.00094

[24] Chopra, K., Gupta, K., and Lambora, A., "Future Internet: The Internet of Things-A Literature Review," *2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon)*, 2019, pp. 135-139, doi: 10.1109/COMITCon.2019.8862269.

[25] Hu, F., Xie, D., Shen, S. (2013). 2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing. *IEEE*. DOI 10.1109/Greencom/iThings/CPS31688.2013

[26] Shukla,S., Hassan, M., Jung, L., and Awang, A., "Fuzzy-based Fog Computing for Real-Time Data Transmission in Healthcare Internet-of-Things," *2018 Second International Conference on Green Computing and Internet of Things (ICGCIoT)*, 2018, pp. 104-108, doi: 10.1109/ICGCIoT.2018.8753057 .

[27] Ahmed,Z., Mortuza, M., Uddin, M. , Kabir, M., Mahiuddin, M., and Hoque, M., "Internet of Things Based Patient Health Monitoring System Using Wearable Biomedical Device," *2018 International Conference on Innovation in Engineering and Technology (ICIET)*, 2018, pp. 1-5, doi: 10.1109/CIET.2018.8660846 .

[28] Zholdas,N., Postolache, O., and Mansurova, M., "Health Monitoring System Using Internet of Things," *2021 IEEE International Conference on Smart Information Systems and Technologies (SIST)*, 2021, pp. 1-4, doi: 10.1109/SIST50301.2021.9465928 .

[29] Myers, A., Mahmud, M., Abdelgawad, A., and Yelamarthi,K., "Toward integrating Structural Health Monitoring with Internet of Things (IoT)," *2016 IEEE International Conference on Electro Information Technology (EIT)*, 2016, pp. 0438-0441, doi: 10.1109/EIT.2016.7535280.

[30] Plathong, K., and Surakratanasakul,B., "A study of integration Internet of Things with health level 7 protocol for real-time healthcare monitoring by using cloud computing," *2017 10th Biomedical Engineering International Conference (BMEiCON)*, 2017, pp. 1-5, doi: 10.1109/BMEiCON.2017.8229134.

[31] Ranjana, P. and Alexander, E., "Health Alert and Medicine Remainder using Internet of Things," *2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, 2018, pp. 1-4, doi: 10.1109/ICCIC.2018.8782349 .

[32] Gao. I., "Using the Social Network Internet of Things to Mitigate Public Mass Shootings," *2016 IEEE 2nd International Conference on Collaboration and Internet Computing (CIC)*, 2016, pp. 486-489, doi: 10.1109/CIC.2016.073 .

[33] Sun, P., & Chen, Y. (2019). "Aquiculture Remote Monitoring System Based on Internet of Things," *2019 International Conference on Robots & Intelligent System (ICRIS)*, 2019, pp. 187-190, doi: 10.1109/ICRIS.2019.00056 .

[34] Ostad-Ali-Askari, K. Management of risks substances and sustainable development. Appl Water Sci 12, 65 (2022). https://doi.org/10.1007/s13201-021-01562-7

[35] Ghashghaie et al., Applications of time series analysis to investigate components of Madiyan-rood river water quality. Appl Water Sci 12, 202 (2022). https://doi.org/10.1007/s13201-022-01693-5

[36] Ostad-Ali-Askari et al., Quantity and quality modelling of groundwater to manage water resources in Isfahan-Borkhar Aquifer. Environ Dev Sustain 23, 15943–15959 (2021). https://doi.org/10.1007/s10668-021-01323-1

[37] Talebmorad et al., Hydro geo-sphere integrated hydrologic model in modeling of wide basins. Sustain. Water Resour. Manag. 8, 118 (2022). https://doi.org/10.1007/s40899-022-00689-y