Rethinking Food Sufficiency with Smart Agriculture using Internet of Things

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Abstract: The emergence of the internet of things spread across several sectors and the agricultural industry is not left out. The application of smart agriculture using IoT will improve productivity among stakeholders in the sector. It gives automation, control, and monitoring in agro-industry which leads to food sufficiency. This project was designed to address food sufficiency through smart agriculture using IoT. A methodic literature assessment (MLA) was adopted for this research where some research questions that we believe if addressed properly will increase food sufficiency were asked and answer with from literature. This project address the IoT sensor or devices and their application to achieve robust farming.

Keywords: Internet of things (IoT), Methodic literature assessment (MLA), Smart agriculture; Food sufficiency

1. Introduction

With the current growth rate of the world population, there is an ever-increasing need for food. The quality and quantity of food available must be such that can sustain the growing population. On the other hand, there is a shortage of arable land as available lands are gradually been used up for development purposes. This fact coupled with the unpredictability of climatic and weather elements continually makes agriculture a futile adventure (Donepudi et al., 2020a).

Agriculture provides food for man, raw materials for industries, hides, and skins for clothing and rugs. All of which are needed for the sustenance of the economy. Research has shown that agriculture is the mainstay of the economy not only in developing economies but also in well-developed economies.

The internet of things is a concept that involves the interconnection of computers and other devices, such that they can function optimally with little or no human interference. Internet of Things (IoT) is employed to enhance operational efficiency and productivity in the agriculture sector (Vadlamudi, 2021). There is a paradigm shift from the use of wireless sensor networks (WSN) as a major driver of smart agriculture to the use of IoT. The IoT integrates several existing technologies, such as WSN, radio frequency identification, cloud computing, middleware systems, and end-user applications (Elijah et al., 2018).

The internet of things has found its application in several areas. (Elijah et al., 2018). Some of such areas are; connected industry, smart city, smart-home (Park, Cho, Han, and Kwon 2017.) smart-energy, connected car (Husni et al 2016), smart-agriculture (Brewster, Roussaki, Kalatzis, Doolin, and Ellis, 2017), environmental monitoring (Sastra and Wiharta, 2016), supply chain, etc. the idea behind the internet of things is the use of the internet as a means of exchanging information between the virtual and the physical environment (Ahmed, 2020). This is accomplished by connecting related electronic gadgets, digital, and mechanical machines, animals, objects, or people that are providing with exclusive identifiers the capability to hand over information over a system without needing a human-to-computer, or human-to-human interface (Vadlamudi, 2017; Elijah et al., 2018).

The Food and Agricultural Organization of the United Nation (FAO) predicts that the global population will reach 8 billion people by 2025 and 9.6 billion people by 2050 (FAO, 2009). These figures only point us towards the direction of food scarcity by the latest 2050, if by all means there is no increase of 70% in food production by 2050 worldwide. The great upsurge in worldwide residents and the rising claim for high-quality foodstuffs produce the need for the strengthening and innovation of agronomic practices. Similarly, the necessity for high productivity in water usage and other assets is also needed (Tzounis et al., 2017; Zhu et al., 2021).

The application of IoT in agriculture is about empowering farmers with the decision tools and automation technologies that seamlessly integrate products, knowledge, and services for better productivity, quality, and profit (Elijah et al., 2018).

We must secure our food now, and for that to happen, there is an urgent need for the adoption of IoT into mainstream agriculture, Hence this article aimed at providing possible ways to rethinking food sufficiency through smart agriculture using IoT.

2. Literature Review

Internet of things (IoT) has various applications as earlier stated. But when it comes to agriculture, IoT is expected to optimize production by any means. Farmlands and greenhouses are about to move from precision to a micro-precision model of

Agricultural production (Tzounis et al., 2017). If accurate monitoring and evaluation are put in place, and IoT is properly utilized, then the result of optimal growing and living conditions for both animals and crops will be guaranteed. This in turn guarantees availability and sufficiency. But not just the growing or harvest stage will be monitored. The entire product lifecycle will be monitored; from the growing, harvesting, post-harvest, such as; storage, processing, distribution, packaging, and sales. Several challenges oppose the functioning of the IoT in smart agriculture and it is only essential to understudy these challenges to be properly guided on the adoption and usage of the technology. One major drawback that was listed is that of security, cost, and compatibility.

Several areas related to the deployment of IoT in agriculture have been discussed in detail in the various available literature. A survey of the literature shows that there are lots of work ongoing in the development of IoT technology that can be used to increase operational efficiency and productivity of plant and livestock. The benefits of IoT and open challenges have been identified and discussed in this literature. Internet of things is likely to bargain numerous paybacks to the food production sector. However, there are still several issues to be addressed to make it affordable for small and medium-scale farmers' mostly in rural areas and in developing and underdeveloped countries (Ahmed et al., 2020). The key issues are security and cost. It is expected that as competition increases in the agriculture sector and favorable policies are being implemented the adoption rate of IoT in agriculture will increase accordingly (Elijah et al., 2018)

Jayaraman et al. (2015) in their paper, presented SmartFarmNet, a pioneering effort in building a scalable sensor data acquisition, analysis, and visualization platform for smart farming applications, based on the Internet of Things. The architectural design of the platform presented shows that it aims at supporting virtually any IoT devices that allow rapid ingestion and visualization of IoT data using a simple do – it- yourself approach with little or no knowledge of complex programming. It also provides a virtual environment for sharing and visualization of collected data and results from the analysis. The proposed SmartFarmNet uses a unique and novel real-time statistical analysis approach that enables near real-time responses to user queries (validating the platform's ability to scale to handle high-velocity data streams). Through evaluation using actual farming data.

2.1 IoT Components

For adequate incorporation of IoT into the agricultural sector, the layers of operations and integration must be considered. These layers according to (Tzounis et al., 2017), are; the perception layer, the network layer, and the application layer. There have been several giant strides towards the improvement of IoT, yet, the technology has not gotten its final shape and this is simply because it is still in the process of evolution. However, food sufficiency depends heavily on the use for sustainable agriculture and more, due to the unpredictability of certain climatic factors that affects crop growth and yield.

To further understand smart agriculture using IoT, four major components were considered which are; 1) IoT devices; 2) communication technology; 3) Internet; and 4) data storage and processing (Elijah et al., 2018).

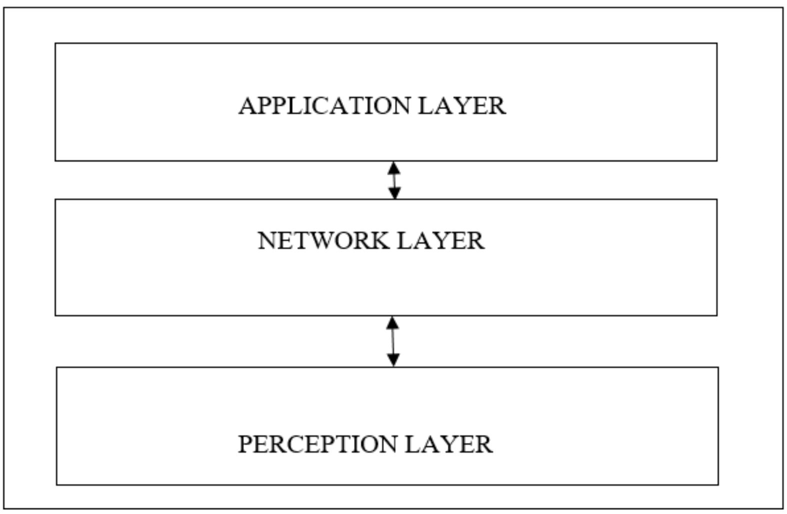

Figure 1: Layers of operations of IoT in Agriculture

The 4 main pieces of machinery are vital for any internet of things presentation. The description of the IoT components as thus; IoT devices – sensors, communication technology – communication, Internet, data storage and processing

At the perception layer, the use of wireless sensors to monitor the agricultural process is paramount. Such technologies as the near field connection (NFC), are being used here. Apart from monitoring and control during the production process, there is a need for identification and tracking of livestock products post-harvest (Tzounis et al., 2017). Summarily, at this level, the sensors are put in place to monitor and keep track of the processes. The sensors will adequately predict the weather and climatic factors such as rainfall, temperature, soil moisture contents, humidity, radiation, wind, soil pH, and fertility, and so on. Typical user scenarios include products or livestock monitoring, supply chain and quality control tracking, and lifecycle assessment of agricultural products. (Tzounis et al., 2017; Welbourne et al., 2009)

The network layer is the life wire of the configuration. Wireless sensor nodes interacting with physical objects and the environment. This layer is responsible for remote storage, further analysis. The data is further processed and disseminated as valuable information that can be extracted and used for decision-making. (Gubbi et al., 2013)

The last and most important layer is the application layer. It is the one that facilitates the realization of the IoT (Tzounis et al., 2017; Verma et al., 2021). This layer involves the hardware components interconnected in a manner that data can be stored, analyzed, synthesized, and presented for easy access, use and application. Several features of it make it suitable for agriculture; some of them are; power efficiency, memory, computational efficiency, portability, durability, coverage, reliability, and cost. These three layers described above work effectively because of the features of IoT listed.

2.2 Basic Sensors used in Smart Farming

Sensors are used to monitor and measure variables such as soil nutrients and weather data, heat, light, pollution levels, humidity, wind, and so on. They gather information such as air temperature, soil temperature at various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation, and atmospheric pressure (Elijah et al., 2018). The sensors can be classified into location sensors, optical sensors, mechanical sensors, electrochemical sensors, and airflow sensors (Li, 2012). The output of the sensor is in most cases an electrical signal that is transmitted to a microcontroller and, consequently, to a network for further processing. Before now this technology was immature, but thanks to the innovation and modernization that make it possible. The intelligent sensor is the essential component for the development of the internet of things system revolution (Ahmed et al., 2021). Figure 2 demonstrates the core components of the internet of things technology sensor. As shown in figure 2b, an intelligent sensor generally comprises of the following;

- A detecting gadget that measures detailed physical factors such as temperature, pollution levels, humidity, etc, from the real world.
- A signal preparing to change the indication into data that the intelligent detector can use.
- A computational block like a digital gesture computer, which pre-processes and analyses the measurements.
- A communication block like a wireless transmitter, which transfers data with the entry sensor node.

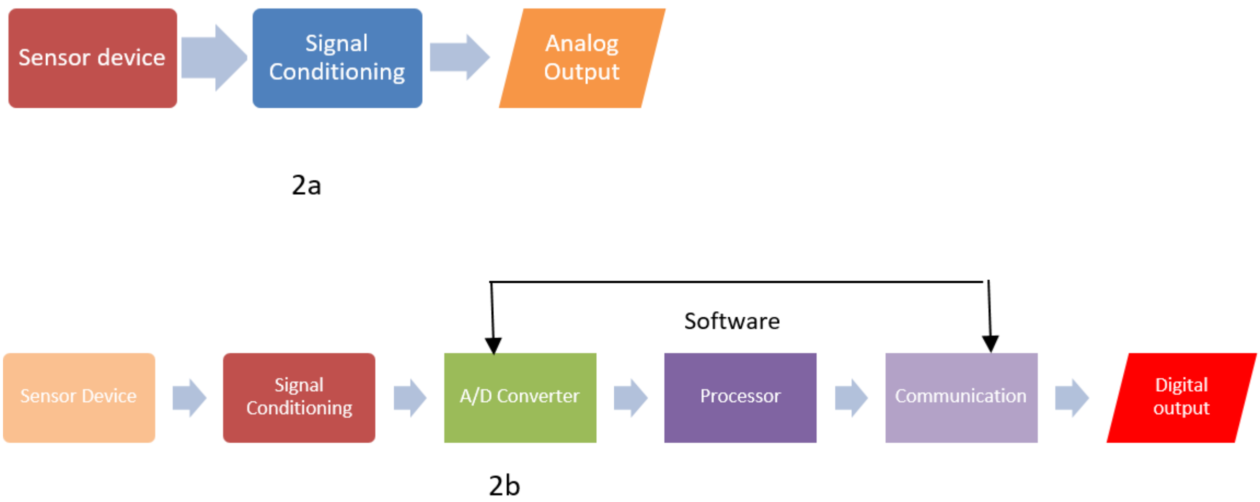

Figure 2: Block illustration of (2a) Basic device and (2b) intelligent device

2.3 Types of Sensor in Agriculture

Currently, technological inventions are transforming conventional farming practices. Uncultured satellite imagery, aerial systems, and sensor machinery are extraordinary changing the agronomic sector. Smart farming is the use of data and information systems in improving multi-factorial and complex farming practices (Elijah et al., 2018). Smart agriculture is not based on the accurate implementation of measurements, rather has access to data and the use of data. The principal goal of smart agriculture is to detect how the generated information will be relevant in an intelligent manner. Also, it is a model that needs all operatives on the farm (Donepudi et al., 2020b). Nowadays farmers can make use of smart mobile gadgets like tablets and smartphones, to contact real-time data such as irrigation, plant and soil condition, fertilization, climate, weeds, weather to mention a few. Owing to this innovation, farmers can perform some activities concerning the data accessed and then seek intervention when needed. Currently, there so many types of sensors in agriculture that can be employed to measure and compute the factors of a farm field. The simple functions of these devices and their associated stipulations or conditions are concisely summarized in Table 1 below.

Table 1: Types of IoT sensors and their simple functions in Agriculture

Types of Sensor	Sensor	Function	Uses in Agriculture
Optical	Photodiode	It uses a light ray to measure soil composition or properties.	It is used to distinguish between different soil types and moistures, example include clay or organic soil
Electromechanical	Ion-Selective Field Effect Transistor devices (ISFET) and Ion-Selective Electrodes (ISE) and	It makes use of an electrode to determine certain ion present in the soil	Farmers use this sensor to detect the presence of elements compositions such as Phosphorus, nitrogen, potassium, etc in the soil
Mechanical	Torsiometer or Tensiometer	It uses a probing method to detect and measure compact rate in the soil	Farmers use this type of sensor to discover the force the roots of the plant used to absorb water from the soil.
Dielectric soil Wetness	Time Domain Reflectom-etry (TDR) or Electrodes for Frequency Domain (FDR)	It uses electrodes to assess the level of wetness or moisture in the soil.	With this sensor, farmers can measure water content in the soil.
Location	Global positioning system (GPS)	This sensor measures the latitude, altitude, and longitude	With GPS sensors available now, farmers can detect the exact position of their farmland and crops.
Airflow	Here dimensions can be achieved at a dynamic or fixed location	It measures air permeability in the soil	It classifies different types of soil, moisture levels, compaction level of the soil structure.

3. Methods

To achieve the objective of this project, we choose a methodical literature assessment (MLA). The scope of this project includes how to increase food sufficiency through smart agriculture using IoT and this can be achieved by assessing and providing an evaluation of available internet of things oriented smart agricultural sensors, monitoring, and communication protocol as well as some challenges existing in implementation of smart agriculture. The method adopted in this research follows the methodology recommended by Keele (2016) and Bhatnagar et al. (2020).

Research Objectives

This study objective included the following:

RO1: To focus on the recent research on smart agriculture using IoT.

RO2: To distinguish the prevailing smart agriculture using IoT applications, devices/sensors as well as communication protocols.

RO3: To suggest a classification that highpoints the implementation of IoT agriculture approaches and processes.

RO4: To IoT-orient smart agriculture background that has been suggested that involves of simple IoT agriculture terminology to recognize the present IoT resolutions for the determination of smart agriculture.

RO5: To find the research lag concerning challenges as well as trending issues.

Research Questions

To achieve the fore mentioned research objectives of this study, we designed three chair questions that will help to address the goal of this project by searching literature that provides answers to these questions. The question is presented in Table 2 below.

Table 2: Research Questions

1.	What are the major application fields of smart agriculture using IoT?
2.	What is the role of the internet of things oriented sensor/device in smart agriculture?
3.	What is the role of smart agriculture using the internet of things standard and communication protocols?
4.	What methods are employed to tackle issues related to smart agriculture using IoT?

All the literature used for this study was selected based on the relevant and in line with the research objectives of this project. For us to achieve this we adopted the search method recommended by Dyba and Dingsoyr (2008) for screening relevant literature that leads to a solid conclusion. Also, key wording articles using abstract was another way to select relevant literature according to Petersen et al., (2006). This was done using two stages. In the first one, we assessed the abstract to recognize the models while the last stage was to use the keywords to check the quality and relevance of the literature. Thus, 29 pieces of literature were selected for this project.

4. Results and Discussion

The results in this study are presented according to the research questions stated in the methodology. Also, the research addresses issues that are directly proportional to food sufficiency if carefully follow.

4.1 Research Question One

What are the major Application Fields of smart agriculture using IoT?

Rethinking food sufficiency through smart agriculture using IoT solutions contains multiple controlling, monitoring, and tracking applications, which measure different types of parameters such as temperature monitoring, air monitoring, soil monitoring, humidity monitoring, water monitoring, pest control, fertilization, location tracking, and illumination control. The selected kinds of literature address the major field of smart agriculture using IoT in this methodical literature assessment (MLA) to include monitoring, controlling, and tracking as shown in Figure 3. The majority of the researches have fixated on monitoring (70%), tracking (5%), and controlling (25%) as presented in Figure 3.

However, the main priority of smart agriculture using IoT applications in major fields as presented in Figure 3 is discussed here. The major ordering of these applications is accurate farming (16%), irrigation controlling and monitoring (16%), soil (13%), temperature (12%), tracking and animal monitoring (11%), humidity (11%), controlling water and monitoring (7%), air monitoring (5%), disease monitoring (5%) and fertilization monitoring (4%) as presented in Figure 4. Most of the pieces of literature selected focus on irrigation control and monitoring, precision farming (Watthanawisuth et al., 2009; Thorat et al., 2017; Jayaraman et al., 2015; Postolache et al., 2014; Xijun et al., 2009; Fourati et al., 2014).

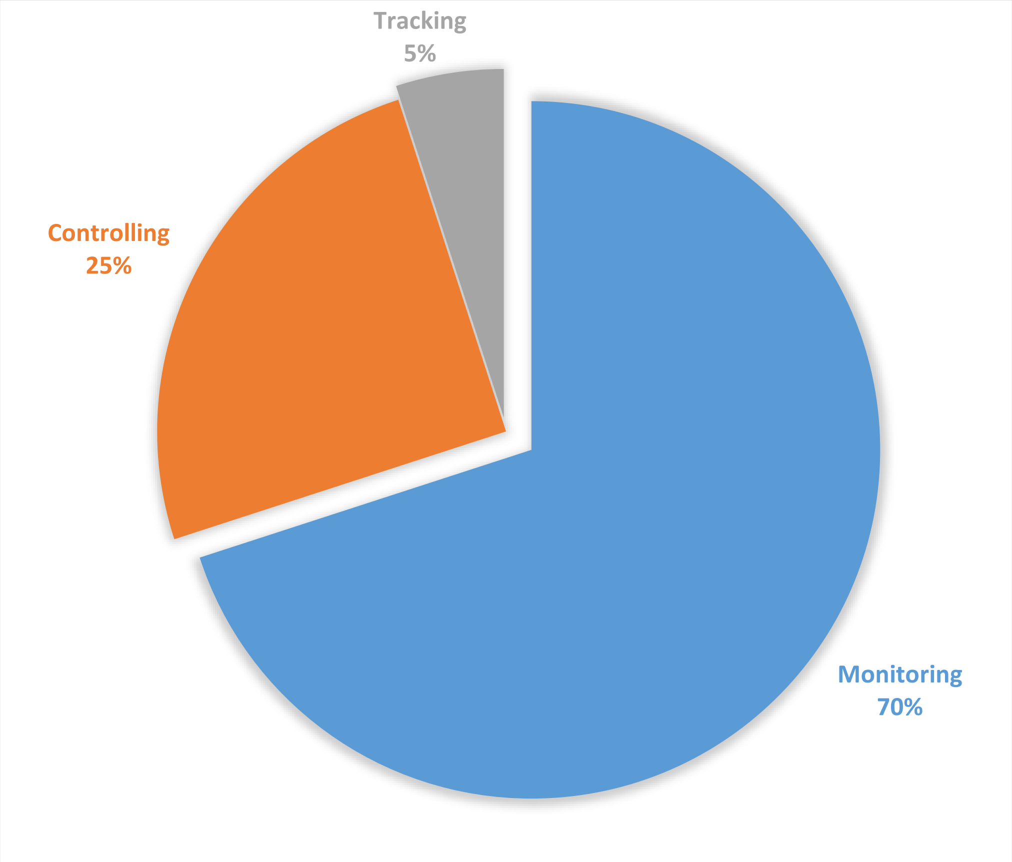

Figure 3: Major Application Fields of smart agriculture using IoT

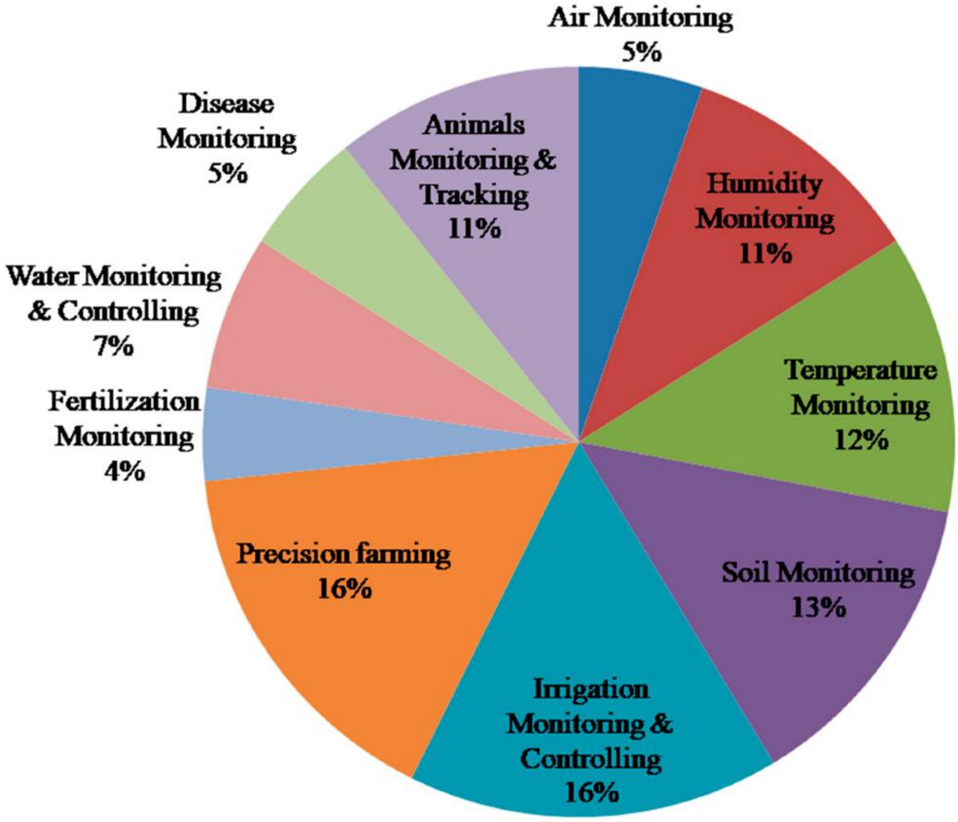

Figure 4: Smart Agriculture Using IoT Application

4.2 Research Question Two:

What is the role of the internet of things oriented sensor/device in smart agriculture?

For decades now, so many firms and industries have been using numerous types of sensor or devices, but the resolution of internet of things have broadened IT applications to agriculture sector now making to live up to the current food security the world is going through at the moment. The internet of things sensors or device involves an embedded structure that works together with sensors, actuators, and necessary WSN. The embedded structures contain memory, microprocessor, and communication modules, and output/input modules. Sensor screen numerous environmental factors, and farm parameters in smart agriculture, and dynamic information that is acquired using amenities interference.

Generally, sensors or devices used in smart agriculture include humidity sensors, temperature sensors, and soil configuration monitoring sensors, CO_2 sensors, airflow sensors, pressure sensors, and moisture sensors. The important features of the internet of things sensors or devices that enable them to fit for agriculture include reliability, portability, memory, overage, durability. This methodic project exhibits that most investigators have been concentrated on temperature monitoring (19%), moistness (17%), and soil dryness (14%). Twenty types of data have been collected using diverse viewing and sensing devices, as shown in Figure 6. Hence, if this farm parameter is addressed, food sufficiency will be attained, because these parameters monitored or controlled with the use of IoT sensors are the major factors that affect food production across the world.

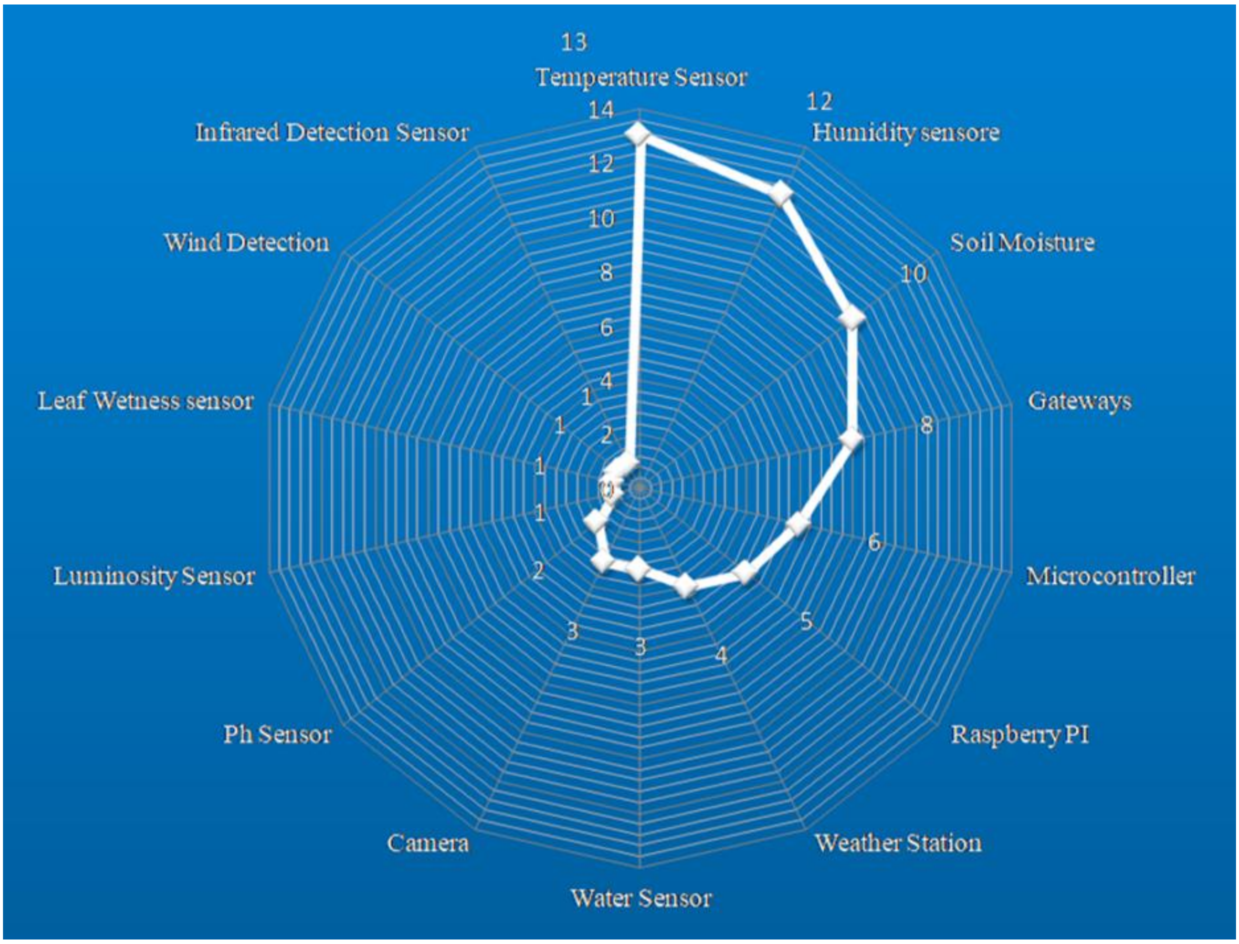

Figure 5: Internet of things Devices

4.3 Research Question Three:

What is the role of smart agriculture using the internet of things standard and communication protocols?

A good number of internet of things communication protocols are usually applied within the internet of things networks because they are cost-effective, wide coverage area, little energy required as matched to others' wide range communication protocols. Nonetheless, WSN is recognized as utmost used technology (35%), ZigBee (10%) and WIFI (20%),

Worldwide Interoperability for Microwave Access (WiMAX)

WiMAX, a wireless network that is centered on an IEEE 802.16 usual whose communication variety is 50 km and the data rate is 0.4–1 Gbps (IEEE Standard for Local and metropolitan area methods, 2011). WiMAX is suitable for lights, controlling diverse and checking agricultural performances such as crop region margin monitoring, observing farming schemes, and water pumps, controlling entries, and the remote examination of the farming schemes.

4.4 Research Question Four:

What methods are employed to tackle issues related to smart agriculture using IoT?

There are numerous research methods in the ground of IoT and smart agriculture, as presented below.

(a) Projected method and solution: There are single or numerous schemes, and resolutions have been suggested to scrutinize the process in its real setting. In Krishna et al., (2017) a wireless mechanical scheme has been projected to monitor and control the diverse agricultural work. Also, several IoT-oriented structures have been projected to observe the animals' actions such as observing health situations and climate factors (Chen et al., 2013; Huang et al., 2015; Noda et al 2017; Vadlamudi, 2016). IoT skills have been used to deliver diverse agricultural resolutions such as observing the grains quality, soil quality, and capacity in the soil (Jayaraman et al., 2015; Agrawal et al., 2016; Gill et al., 2017).

(b) Review/Survey: A technique that assembles measurable information pertinent to the internet of things agriculture (Lakshmi Narayana et al., 2012). The pieces of literature presented a review on numerous internet of things agricultural uses and communication procedures (Ojha et al., 2015). According to Singels and Smith (2006), an analysis has been presented on IoT-oriented exactness irrigation and seeding.

(c) Platforms: Diverse IoT-oriented podiums have been established under the measured environment to scrutinize its impact on agriculture. A smart system podium has been established to observe the conservational situations, soil settings, and fertilization (Pallavi et al., 2017). Additionally, diverse temperature, water, moisture monitoring, and irrigation platforms have been premeditated (Ruiz-Garcia et al., 2009).

(d) Architecture: Several IoT-oriented agricultural architectures planned to bring together the information from sensors or devices and store the organized data for appropriate analysis (Mazon-Olivo et al., 2018; Muangprathub et al., 2019).

(e) Application: Portable apps deliver a linking for numerous IoT sensors or devices and enable the agronomist to have healthier control over diverse agricultural presentations. Several uses have been established to observe the crop output and disease findings at early phases (Foughali et al., 2018; Mohanrai et al., 2016). According to Dholu, M., and Ghodinde (2018), a cloud-oriented IoT use has been established to control the farm factors such as humidity, light, pesticides. And water.

(f) Method: A sequence of phases taken to obtain facts about IoT-oriented agriculture. Numerous approaches have been considered to assimilate the communication technologies like WiMAX, WiFi, etc., and get the degree of the field factors such as soil humidity, temperature, and water quantity (Jain et al., 2008; Pahuja et al., 2013).

(g) Framework: A theoretical system that is planned to monitor or maintain for building approximately that walk around the strategies and theoretical assembly in useful etiquettes in IoT-oriented agriculture (Ujwala et al., 2012; Rao et al., 2018; Liu et al., 2019).

However, implementation issues and problems of smart agriculture using IoT might be a result of any of the following:

- Security,
- Cost,
- Lack of technological know-how,
- Localization,
- Scalability

5. Conclusion

The project follows an MLA that helps us to achieve the objectives of this project. The project reviewed 29 pieces of works of literature. Thus, from the pieces of literature, rethinking food sufficiency is feasible if smart agriculture using IoT is adopted by all and sundry. Hence, smart agriculture using IoT is recommended for all the stakeholders in the sector as a way to improve the food supply.

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