IOT-Based Smart Agriculture in Bangladesh: An Overview

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Abstract

The agricultural sector plays a critical role in Bangladesh's rapid economic growth, as 50% of the population directly depends on the industry for their livelihood. This article provides an overview of the global state of IoT-based smart agriculture today, with a focus on how control activities and powering the entire cultivation and irrigation process are carried out. We also looked at the various tools and technology employed in IoT-based smart agriculture and their potential to advance Bangladesh's agricultural industry. More than 70% of the country's land is used for agricultural production. Bangladesh is regarded as a nation particularly vulnerable to climate change, with its agricultural sector frequently being devastated by natural calamities. IoT-based smart agriculture has the potential to drastically alter Bangladesh's agricultural industry by lowering risks, increasing productivity, and boosting resistance to climate change. The bulk of people working in the agricultural industry should raise their level of life by embracing the era of Internet of Things (IoT)-based smart agriculture. To do this, the electricity needed for the monitoring and management of IoT-based smart agriculture will need to be supplied by renewable energy sources. Given that agriculture plays a significant part in Bangladesh's economy and that this technology is being embraced globally in this sector, it is imperative that Bangladesh address its issues and make the necessary preparations to ensure that it is going forward in a sustainable manner.

Keywords: IoT; Smart Agriculture; Prospects; Challenges. Bangladesh.

Introduction

The amount of food required to feed everyone in 2050 and what we produce today differ significantly. By 2050, there will be around 10 billion people on the planet, which is roughly 3 billion more mouths to feed than in 2010 (Kuddus et al., 2021). Bangladesh is the eighth most densely populated country in the world, home to 163 million people on a land area of just 147,570 km^2 (2.88k people/km^2) (Sunny, Mithun, et al., 2021). We know that Bangladesh is a developing country. A significant portion of the Gross Domestic Product (GDP) of rising nations comes from the agriculture sector (Sunny, Prodhan, et al., 2021). Bangladesh has made significant strides in agriculture to meet the demands of its enormous population in recent years which has also contributed in providing proper nutrition for children

Significance | IoT-based smart agriculture can revolutionize Bangladesh's farming sector, mitigating climate risks, increasing productivity, and improving livelihoods sustainably.

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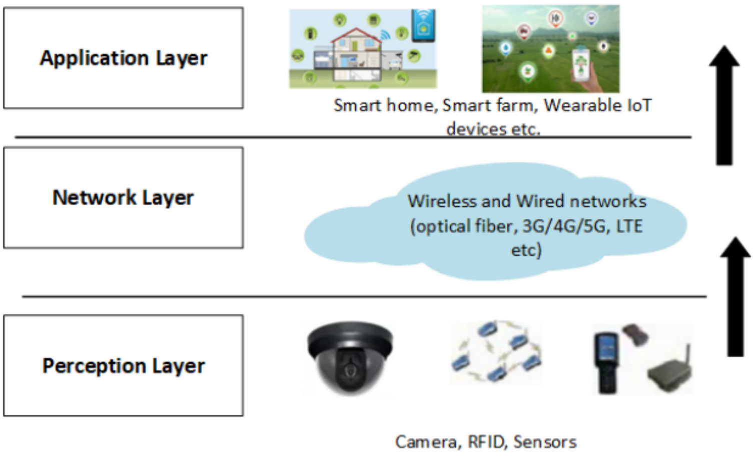

Figure 1. 3-layer Architecture of IoT (Islam et al., 2022)

Table 1. Potential of IoT in Agriculture (Ping Hua et al., 2018).

Agricultural Steps	Field of Application	Method of Application
Production Observation	Vineyards	RFID chips were utilized to remotely monitor vineyards, manage plant data, and generate a vineyard information map (Luvisi et al., 2010).
	Cotton field	A wireless smart sensor array was used to assess soil moisture and temperature for irrigation scheduling in cotton (Vellidis et al., 2008).
	Greenhouse	WSN was used to monitor microclimates in potatoes, such as humidity and temperature, and revealed the risk of fungal attack (Morais et al., 2013).
Controlling Processing	Facility agriculture	IoT-RFID, GPS, and smart sensors are used to monitor and transfer data from the field (Hu & Qian, 2011).
	Fruit	Dragon fruit pre-cooling and packing using RFID and sensor technology to track environmental data and package information (Hua et al., 2018).
	Meat	A collaborative network was used to communicate information on the precise order of animals entering the slaughterhouse using an RFID identification device (Barge et al., 2013).
Transportation	Fish	RFID sensors with temperature and humidity detection were employed for transporting fresh fish from South Africa to Europe (Abad et al., 2009).
	Frozen Aquatics	A WSN combined with Compressed Sending was utilized to track real-time temperature changes during the shipping of frozen and chilled aquatic items (XinQing et al., 2016).
	Fruit	RFID tags with probes were utilized to simultaneously record ambient and pulp temperatures in the pineapple supply chain (Amador et al., 2009).
	Fruit	Real-time monitoring of fruit storage and transport conditions in chambers was achieved using ZigBee-based wireless sensor nodes (Ruiz-Garcia et al., 2007).
	Meat	An EPCIS-based online system and RFID tags were utilized to monitor temperature in the cold meat chain (Thakur & Forås, 2015).
	Fish	RFID tags, GPS, and mobile communication were used to control the temperature of chilled fish. (Jian et al., 2009).
Tracing Origin and Monitoring Sales	Cheese	An RFID-based web-based info-tracing system was created to link and gather fundamental cheese information, including producer, origin, and quality attributes (Papetti et al., 2012).
	Meat	To obtain precise beef food traceability information, cell phones, GIS systems, and RFID technology were combined (Meng et al., 2015).
	Wine	To improve white wine traceability from the vineyard to the customers' wine glasses, RFID technology and WSN were combined (Catarinucci et al., 2011).
	Wheat	To guarantee flour quality and safety, a system utilizing RFID and 2D barcode technology was created for wheat flour (JianPing et al., 2012).
	Product Origin	To identify the origin of agricultural products, an anti-counterfeit system based on GPS and encrypted Chinese-sensible coding was developed (ChuanHeng et al., 2013).
	Fruit	To track and record fruit data, an RFID-based traceability system was created (Gandino et al., 2007).

(Kuddus et al., 2022) but many of its sectors still use antiquated and human-centric agricultural methods are still being practiced (Sultana et al., 2014). Human-intensive agricultural practices result in more labor, higher production costs, and waste of valuable resources including water, electricity, and fertilizer (Madushanki et al., 2019). That is why, adoption of technology in the field of agriculture in a country like Bangladesh is essential for having increased yield and to lessen the human labor as well as to reduce waste, resulting in sustainable development of smart farming and food security (Kuddus et al., 2020).

Therefore, implementing technologies like AI, IoT, wireless networks along with accountable leadership in Bangladesh's agriculture industry can enhance smart farming efficacy and efficiency (Haque et al., 2021). From the beginning of history, farms relied on seasonal labor to boost profitability. But now, concepts like Agri-Food 4.0 are aiming to achieve reduced human effort and greater yield. Agri-Food 4.0 is a digitalized method to improve productivity and land management, promoting agricultural sustainability, farmer well-being, and sector competitiveness with the help of 5G wireless communication technology to the field (Panetto et al., 2020).

The needs described above can be addressed by making effective use of IoT design concepts and technology assistance, resulting in a highly distributed communication network with optimum resource consumption (Xia et al., 2012). The Internet of Things (IoT) is a fast growing mechanism that includes a wide range of networked cloud applications, including as electrical, digital, mechanical, and unique ID systems, allowing data to be transmitted without the need for human contact. IoT sensors and big data analytics can revolutionize farming techniques, resulting in cost-effective and resource-efficient production. The goal is to increase yields, minimize water use, and transform traditional agriculture to smart and precision agriculture by leveraging automation and IoT technologies (Abu et al., 2022; Alam et al., 2023; Ferdous et al., 2023). Nevertheless, it can also play a crucial role in implementing Smart Bangladesh by 2041, an initiative taken by the government of Bangladesh.

2. Motivation: Needs of IoT based Agriculture in Bangladesh

Farmers and agriculture have a crucial role in ensuring food security and reducing poverty, contributing to Bangladesh's economic growth (Eastwood et al., 2019). According to scholars, traditional farming remains prevalent in distant villages in Bangladesh, making achieving the United Nations' 2030 Sustainable Development Goal (SDG: 2.4.1) for sustainable agriculture problematic (Abu et al., 2022). Several authors proposed the use of IoT for smart farming (Ahmed et al., 2018). Though AI and IoT-based smart farming poses challenges for alignment with traditional agriculture, there are scopes where these technologies can be applied to obtain sustainability in the field of agriculture in Bangladesh. The needs can be described as such:

1. Managing Effective Energy with Low Energy Intensity
2. Managing irrigation
3. Managing fertilizer
4. Controlling pests detecting diseases
5. Precision Agriculture (PA)

Energy intensity is a criterion used to assess a country's economic efficiency (Khosruzzaman et al., 2010). The lower the intensity, the better the performance. Despite its low energy requirements, Bangladesh faces challenges in achieving sustainable growth through efficient energy consumption (Philibert et al., 2002). Irrigation system consumes the most energy when it comes to agriculture. In Bangladesh, most irrigation setups rely on diesel or electricity-powered pumps to draw subsurface water for irrigation, with just 30% of the water efficiently used by crops and the remainder squandered (Mondal, 2010). Using IoT devices and sensors can ensure the proper use of water in the field for various types of crops differently. Alongside, maintaining soil quality and minerals is crucial for improving agricultural production (Sultana et al., 2014). As different types of crops need different soil conditions, IoT sensors can be calibrated and implemented to ensure optimal conditions for a variety of crops. Nevertheless, proper use of fertilizers is crucial for desired plant growth. In Bangladesh, the usage of inorganic fertilizers such as urea, TSP, and MoP since the 1950's has resulted in nutrient imbalance, affecting 75% of soil-plant systems due to adverse effects (Sultana et al., 2014) and IoT devices can help to indicate the sufficient usage of fertilizers which will be sustainable both in terms of cost and environment. Also, managing pests and diseases of the corps leads to better yield. A wireless sensor network-connected imaging equipment may take high-resolution crop field photographs and send them to a central cloud server for AI analysis to detect plant conditions and provide treatments (Patil et al., 2012). Moreover, Precision agriculture (PA) is a promising breakthrough in smart agricultural systems that aims to optimize and improve procedures within agricultural segments to promote long-term growth in output, management, and monitoring (Tzounis et al., 2017). The PA platform utilizes modern technologies, including NB-IoT, remote sensing, communication protocols, mobile network infrastructure, and AI/ML, to meet the requirements (Patil et al., 2012).

According to the Global ICT Standardization Forum for India, the potential benefits of IOT include improved performance, visibility, and scalability, better and more cost-effective services, transparency of physical flows and status information, and increased efficiency, accuracy, mobility, and automation (Patil et al., 2012). To ensure sustainable development of Bangladesh in the long run, these benefits must be put to use in the field of Agriculture.

3. Related Works

Adoption of IoT in agriculture is not yet widely popular in Bangladesh where most of the farmers still depend on traditional methods for production. However, there are several IoT solutions available currently which are utilized in agriculture for pesticide/fertilizer management, plant health, disease prevention, irrigation monitoring, soil conservation, distribution network traceability, vehicle control, and machine and equipment maintenance (Abu et al., 2022). It's important to note that the strategies given in the studied publications for IoT systems can be used in various scenarios.

Currently, a trend of ongoing research and developments has been observed in this field. For instance, IoT devices are being used to enhance agricultural water consumption by detecting soil moisture, monitoring irrigation sources, and incorporating meteorological and humidity data (Fernández-Ahumada et al., 2019). IoT disease control systems detect and prevent plant disorders by gathering environmental data such as photos, noises, temperature, and humidity and evaluating it with image processing and artificial intelligence (Gayathri Devi et al., 2019). Moreover, IoT technology effectively identifies crop zones that require fertilizer or pesticide treatment, whereas aerial photos measure nitrogen concentration in huge plantations, potentially pinpointing individual fertilizer-required fields (Cao et al., 2018). IoT soil science platforms calculate planting parameters, assess water usage patterns, identify soil nutrients, and function as weather stations for measuring air quality (Backman et al., 2019). Another system (Prathibha et al., 2017) intends to leverage IoT in agriculture to detect environmental elements like temperature and humidity. For integrated IoT development, temperature and humidity sensors are used, together with a CC3200 processor. If the sensor detects abnormal readings, it sends information to farmers, who can then take appropriate action. An author offers a new IoT-based stick with temperature and moisture sensors that provides real-time data to farmers via a handheld device which is powered by a solar panel and battery, transmits live data to the cloud and shares it with experts remotely and provides an efficiency of 99% (Nayyar & Puri, 2017). With the references given, it is high time that Bangladesh adopted these technologies to increase the chances of high food security for the future.

4. Methodologies

By using IoT-enabled sensors on the farm, farmers can measure soil moisture levels, temperature changes, nutrient availability, pH levels, and more. This information can then be used to make informed decisions about when to irrigate or fertilize fields for optimal growth. This is entirely a review article and, therefore, relies on secondary sources of information. The review draws from various published reports and articles sourced from books, journals, proceedings, and online platforms. Through the synthesis and analysis of these sources, this review aims to present a comprehensive overview of the topic and identify key findings, trends, and gaps and how to implement them in our country effectively in the current knowledge base. When gathering data on IoT Based Smart Agriculture in Bangladesh from different sources, these are the websites that should be highlighted in particular like Google Scholar https://scholar.google.com/, ResearchGate https://www.researchgate.net/, Google www.google.com, BioOne https://bioone.org/, GetCITED http://www.getcited.org/, Academia https://www.academia.edu/. At the same time, inquiring some other search engines like goggle and others for gathering local information regarding IoT Based Smart Agriculture in Bangladesh without facing any restriction in connection to year of publication. Owning to some limitation of the number of published studies, we included partial matches, scientific reports, conference papers, reviews, unpublished reports, opinion papers (no field-data), thesis and other publications in the grey literature.

5. Architecture of IoT

The best architectural choice for developing Internet of Things systems is layered architecture, sometimes known as n-tier architecture, in which n is the number of tyres/layers. This architecture distributes system components horizontally, with each layer executing coherent functions without overlap and communication limited to adjacent layers (Syeed, et al., 2022). Three layers make up the foundation of the Internet of Things: the *perception layer*, which is used for sensing, the *network layer*, which handles data transfer, and the *application layer*, which is used for data storage and manipulation (Villa-Henriksen et al., 2020).

5.1 Perception Layer

The perception layer includes terminal devices, sensors, WSN, RFID, and NFC devices (Tzounis et al., 2017). These devices and sensors collect data on temperature, wind speed, humidity, nutrient levels, plant diseases, and insect pests, processed by embedded devices, and uploaded to a network layer for analysis. This layer is responsible for monitoring, control and communication through *Interface Core, Sensor Unit (Plug and Play), and Local Monitoring and Controlling applications* (Syeed, et al., 2022). The Interface Core is the micro-kernel in a system, providing the necessary components for plug-in modules or

Sensor units to function. These modules are designed for specific agricultural services like fertilization, paste control, environment monitoring, irrigation, and power management. They only function when connected to the Interface Core and cannot be used independently. Web or mobile applications are used for local monitoring and controlling, allowing farmers to configure, control, and monitor the Sensor Units (Syeed, et al., 2022).

5.2 Network Layer

In this layer, Sensor nodes communicate with other nodes and gateways to send data to a remote infrastructure for storage, analysis, processing, and transmission of important information (Gubbi et al., 2013). The Network Layer is the middle layer of this architecture, connecting the Perception and Application Layers. Its architecture is impacted by the communication protocols used, such as MQTT, which stresses performance, security, and dependability. MQTT is a secure, lightweight, and energy-efficient communication protocol, as per studies (Aziz, 2014). The MQTT protocol necessitates the use of a message broker and numerous clients, with the Application Layer serving as the message broker and the Perception Layer's Controller Unit as the MQTT client. MQTT safeguards connections with transport layer security encryption with a username and password. To address security issues, a lightweight encryption technique is presented for encrypting data in the perception layer prior to transmission to the network layer. This method provides quick, encrypted authentication, real-time communication, and no data loss (Syeed, et al., 2022). Moreover, Wireless protocols and standards, such as IEEE 802.15.4, ZigBee, Sigfox, ONE-NET, WirelessHART, ISA100.11a, LoRaWAN, Bluetooth Low Energy (BLE), and DASH7, facilitate interconnection between internet enabled gateways and end-nodes (Suhohen et al., 2012).

5.3 Application Layer

This is the final layer of the architecture where the benefits and conveniences of IoT are most noticeable (Islam et al., 2022). This layer is typically a cloud server with high processing capabilities, large storage unit, rich Input/Output subsystem, and extensive PCI Express-based expansion capabilities, supporting large data volumes (Syeed, et al., 2022). There are several components of this layer which may include Database, Data Processing Engine, AI Engine, Data Analytics Engine, API Engine etc. To elaborate, The Data Preprocessing Engine, which carries out operations including data cleansing, outlier detection, and inconsistency resolving, provides preprocessed data to the database. The AI Engine functions as a central point for intelligent assistance systems, providing advanced artificial intelligence technology, such as machine learning algorithms and the Expert System, to enable decision support systems. The interface engine uses this knowledge base to support reasoning, and the expert system stores domain information in a particular format. Modern web development includes the Application Programming Interface (API) to provide optimal results (Syeed, et al., 2022).

6. IoT: Technologies and Devices

The underlying technologies of IoT typically include wireless connectivity, sensors, embedded systems and cloud computing. For instance, Wifi, Bluetooth, Zigbee, Cellular are some examples of wireless connectivity used based on the range and power requirements. There are many sensors which can collect data like Temperature, Humidity, Motion, Gas, Proximity etc from the respective environment. Moreover, embedded systems like Arduino, ESPs, Raspberry Pi, SoC (System-on-Chip) make the core of an IoT system. For cloud computing, platforms like Thinger.io, Microsoft Azure IoT, and Google Cloud IoT Core, ThingSpeak play a crucial role. Some of the commonly used technologies in the field IoT namely, *RFID technology, WSN technology, Sensors technology, GPS technology* are discussed in this section.

6.1. RFID technology for IoT

RFID technology, also known as automated identification and data capture (AIDC), is considered by experts to be at the foundation of IoT (Wamba et al., 2008). RFID (Radio Frequency Identification) technology utilizes electromagnetic fields to automatically detect and track tags attached to things. These tags include electronically recorded data that may be read wirelessly with RFID scanners. RFID provides the seamless integration of physical things into digital systems in IoT applications, allowing for real-time asset visibility and control.

An RFID system consists of *RFID tags, RFID Readers, Middlewire,* and *IoT platform.* When an RFID tag gets within range of an RFID reader, the device sends out radio waves. The RFID tag accepts radio waves, powers up, and transmits its unique identity (ID) and other data to the reader. The RFID scanner grabs the tag ID and sends it to the middleware or straight to the IoT platform. The IoT platform processes the tag data, correlates it with other sensor data as needed, and takes actions depending on established rules or user requests. There are four frequency bands now depending on the application: low frequency system at 125 kHz, high frequency system at 13.56 MHz, ultra-high frequency system at 433 MHz or 868 MHz in Europe, and microwave RFID tags using the 2.4 GHz or 5.8 GHz range (Brandl et al., 2016). RFID enables real-time asset tracking, more automation, higher data accuracy, better inventory management, and easy interaction with current IoT infrastructure.

6.2. WSN technology for IoT

A wireless sensor network (WSN) is a network of self-contained sensors that connect wirelessly and collect data on physical or environmental factors for real-time monitoring and analysis in IoT applications. WSN's hardware architecture included four components: *sensor, processor, transceiver, and power units* (Warrier & Kumar, 2016). WSN combines MEMS (Micro electro mechanical Systems), embedded computing, and wireless communication to monitor and process network objects in real-time, providing detailed and accurate information (Ping Hua et al., 2018).

Sensor nodes are low-power devices that collect environmental data and communicate with the network architecture via a gateway or base station. These devices use a variety of communication protocols, including Zigbee, Bluetooth Low Energy (BLE), IEEE 802.15.4, and LoRaWAN. Because of the battery's limited life, power management is critical. Sensor nodes transform physical environments or events into digital data while performing early processing to save energy. Data from many nodes is pooled at intermediate nodes or gateways before being sent to a central server or cloud platform. Aggregated data is saved, evaluated, and acted upon. WSN in IoT provides real-time monitoring, cost-effective deployment, wireless connectivity, energy efficiency, data insights etc. There is a wide range of applications of these benefits of WSN technology which may include monitoring of environment, healthcare, infrastructure as well as industrial automation and smart grid implementation.

6.3. Sensors technology for IoT

Sensor technology, which includes sensitive components, conversion elements, conversion circuits, and auxiliary power, has been around for almost 150 years since the 1860s (Ping Hua et al., 2018). Sensors are devices that detect and measure physical qualities or environmental situations, then convert them to electrical impulses. These signals are subsequently processed, evaluated, and used to make sound decisions in IoT applications. Sensors can be classified as physical, chemical, or biosensors based on their basic effects (Ma & YB, 2017). Some examples of sensors can be made as:

Temperature Sensors: Measure the ambient temperature and provide data for climate control, weather monitoring, HVAC systems, and industrial applications.

Humidity Sensors: Air relative humidity levels are monitored for a variety of applications, including environmental monitoring, HVAC control, and agricultural applications.

Pressure Sensors: Measure pressure fluctuations in gasses or liquids for applications such as industrial automation, automotive systems, weather forecasting, and healthcare monitoring.

Proximity sensors: Detect the presence or absence of surrounding items without physical contact, which is widely utilized in industrial automation, object detection, and security applications.

Motion sensors: Detect the movement of objects or people and are used in security systems, lighting controls, occupancy monitoring, and gaming gadgets.

Light sensors: Measure ambient light levels or detect changes in light intensity; they are used in smart lighting systems, automatic street lights, and energy-saving applications.

Gas sensors: Detect the presence of specific gasses in the environment, which is critical for industrial safety, air quality monitoring, and environmental protection.

Acceleration Sensors (Accelerometers): These devices measure the acceleration forces exerted on objects along one or more axes and are widely employed in inertial navigation systems, motion detection, and vibration monitoring.

Infrared Sensors: Detect infrared radiation generated by objects to determine temperature, proximity, or motion, commonly used in temperature measurement, motion detection, and presence sensing applications.

Some important features of sensor technology that should be considered while using one are accuracy, precision, range, sensitivity, power consumption, interoperability. Sensor data from IoT devi processed locally before being transferred to a central hub or cloud platform for analysis and decision-making. This data is used in fields like smart cities, industrial automation, healthcare, and environmental monitoring. Moreover, In recent years, it has been widely employed in agricultural processing and detection, greenhouse environment monitoring, fruit and vegetable preservation, precision farming, and grain storage (Li et al., 2018).

6.4. GPS technology for IoT

Global Positioning System (GPS) technology is now an essential component of the Internet of Things (IoT), providing precise location data that improves the usefulness and value of many IoT applications. The GPS system consists of three components: the space satellite constellation, the ground control system, and user devices (Hofmann-Wellenhof et al., 2001). It is a satellite-based technology that determines a device's location and time. IoT devices with GPS receivers collect signals from numerous satellites and compute their distance over time. They then engage in trilateration, in which they cross spheres formed by the distances between each satellite. This triangulation pinpoints the device's exact location. GPS-derived position data is integrated into an IoT system and frequently sent to a central server or cloud platform for real-time tracking and analysis. GPS is a global system that provides 98% satellite coverage, allowing for continuous observation and measurement of at least four satellites at each location while offering high-precision 3D coordinates, 3D speed, and time data, with positioning accuracy of centimeters, speed error of less than 0.01 m/s, and timing accuracy of 20 ns (Ping Hua et al., 2018).

GPS technology enhances logistics, inventory management, and fleet management by tracking assets in real time. It helps farmers optimize crop yields, respond to emergencies, and use health and fitness apps. GPS-enabled IoT devices are critical for emergency response and monitoring the elderly or patients with special medical needs. In the perception layer of IoT technology, GPS is a rapidly expanding business with applications in traffic, navigation, agriculture, environment monitoring, industrial, and healthcare (Caldas et al., 2015).

7. Potential of IoT in Agriculture

Bangladesh's agricultural sector, contributing 14.79% to the country's GDP and accommodating 45.1% of the labor force, is the primary livelihood source for rural people (Bagchi et al., 2019). That is why it is important to implement technologies like IoT and AI in agriculture to ensure sustainable development of this sector. Smart agriculture, also known as precision agriculture, is the application of the Internet of Things in agriculture. It uses smart irrigation systems, weather stations, farm management software, livestock wearables for health monitoring, autonomous machinery and drones for precision farming, smart sensors to monitor soil conditions, and farm management software for decision-making. It also promotes sustainable systems and boosts productivity. Table-1 indicates how IoT can be significantly used in several steps of agriculture.

9. Challenges for the Future

As we know, IoT systems are data driven architecture. It collects, processes and analyses data, from the environment to the cloud storage. Artificial intelligence are systems that feed on data and can provide desired insight for the future similar condition. So further research to integrate these two technologies for smart farming will be a sustainable step for the future. Moreover, Bangladesh is facing negative environmental and climate change impacts as a result of intensive cultivation practices, in addition to its traditional farming culture. That is why it is important to implement these technologies while reducing or modifying current practices, in order to mitigate the adverse impacts of climate change with proper forecasting and precautions (Syeed, et al., 2022).

Another step towards sustainable agriculture can be the implementation of Precision Agriculture (PA). The approach optimizes profitability, sustainability, and environmental protection by utilizing data from soils, crops, nutrients, moisture, and yield. It involves observing, assessing, and responding to variations in agricultural production processes, using sensor technologies for applications like yield monitoring, soil sensing, and irrigation management (Lee et al., 2010). So, further development in this field can optimize cost and yield management in agriculture which is beneficial for a country like Bangladesh where overpopulation is a prominent problem.

Furthermore, to implement these technologies in agriculture of Bangladesh and to get actual benefits out of it, knowledge and responsible leadership can play a vital role. It is simultaneously an opportunity and a challenge for the people of Bangladesh. According to studies, responsible leadership originated as a response to leadership failures caused by ethical and socioeconomic demands that had not been addressed in previous literature, notably in agricultural and sustainable development. Effective leadership involves fostering inclusive connections with stakeholders to achieve ethical, socially desirable, and sustainable outcomes (Noor-E-Sabiha & Rahman, 2018). So, with the development of responsible leadership, Bangladesh is likely to see rapid growth in this field.

10. Conclusion

This study concludes the basic principles of IoT and its significance in the field of agriculture. Furthermore, it also indicates how Bangladesh can adopt and implement this technology to meet her current problems and to bring development in the field of economy, food security and management, and socio-cultural aspects. As the global population continues to rise and Bangladesh is at the forefront of the problem, implication of IoT in Agriculture, more specifically precision agriculture (PA) can ease the need of excessive food demand while fulfilling the SDG set by the United Nation. Because of the applications of the IoT technology, broadly monitoring and controlling, it is possible to to reach the desired end with the help of adequate knowledge and leadership development. Development and utilization of the underlying technologies like RFID, WSN, Sensors, GPS etc. can further help the agricultural growth in Bangladesh. As this technology is being adopted worldwide in the field of agriculture and agriculture holds a major role in the economy of Bangladesh, it is high time Bangladesh faced its challenges and made required arrangements to make sure it is moving towards the future with a sustainable approach.

Author Contribution

A.R.S. and all authors wrote and reviewed the manuscript.

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The authors have no conflict of interest.

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