Selection of suitable IoT-based End-devices, tools, and technologies for implementing Smart Farming: Issues and Challenges

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Abstract

Purpose of Study: In the contemporary world, Internet-of-Things have become an indispensable part of our lives. The present era is of sensor-based electronic gadgets. Nowadays, more or less, every aspect of human life, from Home Automation, Healthcare, and Fitness, Agriculture, Education, Entertainment, Locomotive, Smart Farming, Smart Digital Cities, towards Industrial IoT, each one is redesigned from statistical to qualitative mechanisms. With the growing trends and technological transformations, the reality is that Internet-of-Things play a vital role. Currently, the agriculture industry is precise, and data-centered than traditional farming. Such revolutionary changes in the smart farming in the last decades are shaking the existing agriculture methods and creating new opportunities in the specific agriculture domains like crop status, insect and pest detection, and removal, irrigation, soil preparation, crop surveillance along with a range of unfolded issues and challenges. This study highlights the potential unfolded issues and challenges in the domain specific and precise selection of Internet-of-Thing based devices with supportive technologies and tools for instigating Smart Farming.

Methodology: a systematic data processing approach with literature search and screening to review is used in this study to identify selection of suitable iot-based end-devices, tools and technologies for implementing smart farming.

Main Findings: This study discussed the various IoT end-devices, tools and technologies in a well-organized manner. This study also highlights the foremost outspread challenges during selection of IoT-based resources for smart farming.

Implications: This article is beneficial to all concerned stakeholders involved in agricultural activities like farmers, agricultural institutions, professional decision makers, who are passionate for enhancing the smart farming.

Novelty/Originality of the study: Various scholars/researchers have been making efforts for smart farming by using IoT concepts in agriculture. This study make some efforts to discussed past research on IoT tools and Technology and challenges in selection of IoT devices for implementing an Iot based infrastructure for smart farming.

INTRODUCTION

Smart Agriculture refers to an agriculture management mechanism that depicts the proper utilization of Internet-of-Things (IoT) based devices with supportive technologies and tools to increase the crops' quality and agricultural product quantity (Singh, G. and Yogi, K.K. (2022a), (Singh, G et al, 2019)). Smart farming comprises the lots of mechanisms for improving the growth of crops via IoT-based end-devices, tools, and supportive technologies. It manages the crops regular logs, soil monitoring, precise cultivation, irrigation management, crop sowing, and preparation, etc. Everyone knows that the world's economy and growth of human beings majorly depend upon the agriculture. The most important source of human survival is agriculture and it fulfills their regular life needs. Smart farming permits farmers for growing harvests by properly using advanced tools and technologies.

With the concern towards Internet-of-Things, our day-to-day life is purely moving around IoT technology. To count calories, we are using our Smart Watch or asking Siri or Alexa to forecast or make predictions of the current weather. By deploying Internet-of-Things based end-devices, tools, and technologies like robotics, drones, and sensors with other hardware resources, farmers can identify the status of their harvest systematically and also keep the available resources (Bhatnagar, V., et al, 2020). This concept also reduces the futuristic impact on the environment. After deploying IoT-based devices, farmers are able to accurately map their crop fields. Internet-of-Things based farming, also known as Smart farming is a trending system to increase the productivity of crops smartly. It is the most awaited domain of today's digital world to take a step ahead for farmers.

In January 2022, the world's current total population touched 7.9 billion according to the most recent United Nations estimates elaborated by WorldMeter. According to the United Nation's Population Division Projections, the population is projected to grow to 10.46 billion by 2070. Figure 1 shows the World's population projection by the United Nation from

2020 to 2070. Therefore, it is a demandable step towards increasing the productivity of crops on the limited agricultural land.

Smart Farming introduces Internet-of-Things concepts via proper utilization of agricultural robots, agricultural drones, suitable integrated sensors, high-density cameras for digital satellite crops imagery with other analytical technologies and tools for fetching and managing the insights of the agricultural land. Launching of IoT-based end-devices on or near-by farming land getting the information and related logs of farming land for further investigation (Sales, N., Remédios, O and Arsenio, A.(2015), Singh, G. and Yogi, K.K. (2020).

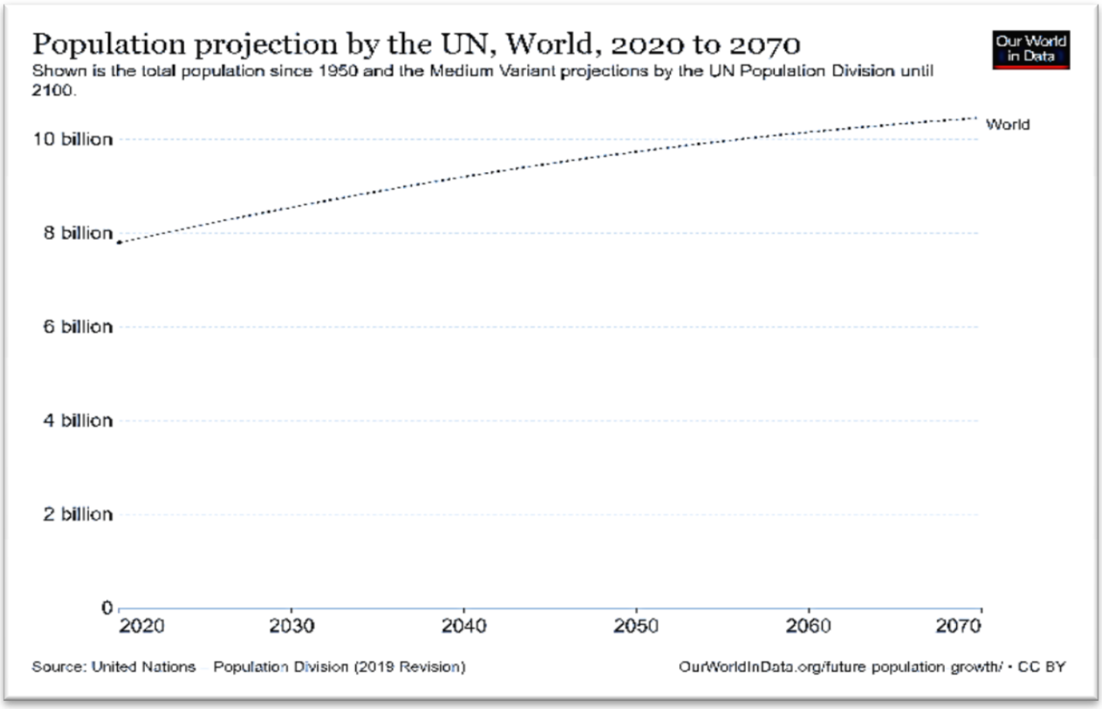

Figure 1: World Population projection by the UN from 2020 to 2070

According to various case studies,

- 75-80% of the farmers use some kind of Internet-of-Things based end-device and tools for smart farming.
- 90-96% of farmers agreed on the popularity of "Smart Farming".
- 65-70% of farmers adopted to improve their farming culture by the practice of "Internet-of-Things based end-devices, tools and technologies" for Smart farming.

RESEARCH METHODOLOGY

A. Methodology

To discuss the various Internet-of-Things based resources like physical end-devices, tools, and their supportive technology stacks available for Agro-industry. The motive of this study is to highlight the unfolded issues and provide the selection criteria of these agricultural resources for improving the quality of service in smart farming.

B. Main Findings, Novelty/Originality of the study

This study discussed the various agriculture applications and Internet-of-Things based end-devices like agricultural drones, robots, sensors, and supportive tools and technologies in an efficient manner. This study also highlights the major unfolded challenges during the selection of IoT-based resources for smart farming. Finally, the mentioned research provides the efficient selection criteria for improving the quality of service in smart farming.

C. Implications

This study is advantageous to all concerned stakeholders like farmers, agricultural institutions, and professional decision-makers, who are passionate about enhancing the smart farming.

SMART FARMING – THE IMPACT OF IOT ON AGRICULTURE

A. Applications

Imparting the knowledge and implementation of Internet-of-Things based end-devices, tools, and supportive technologies in agriculture, transformed the old-fashioned way of farming towards today's digitized Smart farming. Smart farming resolves the various issues of the regular traditional farming. Some major applications of Smart farming are as follows

(Shuwen, W. and Changli, Z.(2015), Cozzolino, D., Porker, K. and Laws, M. (2015), Kim, S., Lee, M. and Shin, C. (2018), Zujevs, A., Osadcuks, V. and Ahrendt, P. (2015):

- Soil Monitoring
- Farm Irrigation
- Fertilizers Spraying
- Pest Disease Management
- Harvesting Monitoring
- Yield Monitoring
- Forecasting Management
- Pesticides Monitoring
- Crop Disease Management

Figure 2 illustrates popular applications of Internet-of-Things based Smart Farming.

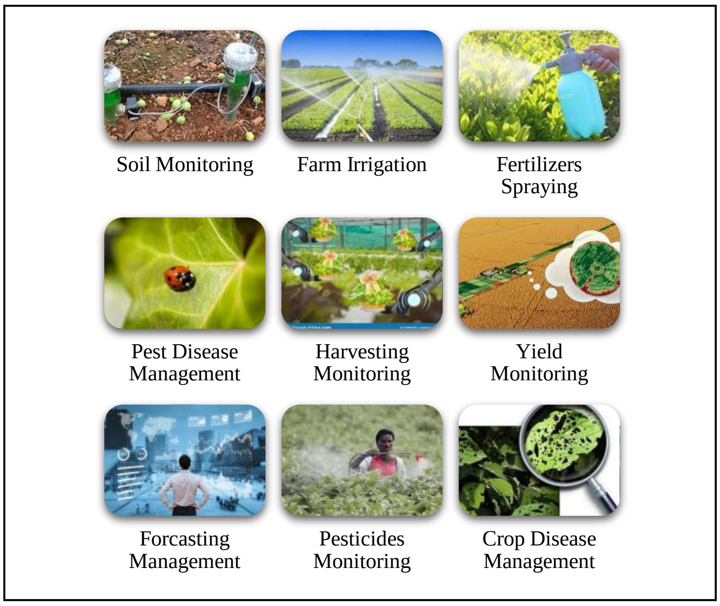

Figure 2: Major Applications of Internet-of-Things based Smart Farming

B. IoT-based End-Devices, Tools, and Technologies

1. Agriculture Sensors:

An agriculture sensor is a device that can sense the crops and their surrounding environment and convert the fetched information into the digital form for further processing. Some important features of agriculture sensors are as follows:

- The usage of agriculture sensors makes a remarkable impact in smart farming.
- Such type of sensors provides data and information related to water level, environment temperature, infrared temperature, and humidity to monitor and optimize environmental conditions.
- These sensors are also installed for analyzing the soil and air quality of the agriculture industry.
- With the help of drones and robots, specific sensors improve the quality of crops.
- Sensors can be managed and controlled via smart web, desktop, and mobile-based applications.
- Sensors can also be controlled by directly wireless connectivity like Wi-Fi, Bluetooth, or other cellular methodologies with the help of IoT-based end-devices.

Figure 3 lists some agriculture sensors used in Smart Farming.

Figure 3: Agricultural Sensors used in Smart Farming

2. Agriculture Robots

For agricultural-related activities, an agricultural robot has been introduced. The major functionality of agricultural robots is to manage the various farming activities on farming land at the harvesting stage (Manocha, N. and Gupta, R. (2020)). Challenging activities of the agricultural robot are Cloud seeding, Environment monitoring, Weed Control, Planting seeds in proper synchronization, and Soil testing and analysis. According to eminent research, the popularity of agricultural robots and their demand is projected to spread to $15.58 billion by 2035. Figure 4 lists some agriculture robots used in Smart Farming.

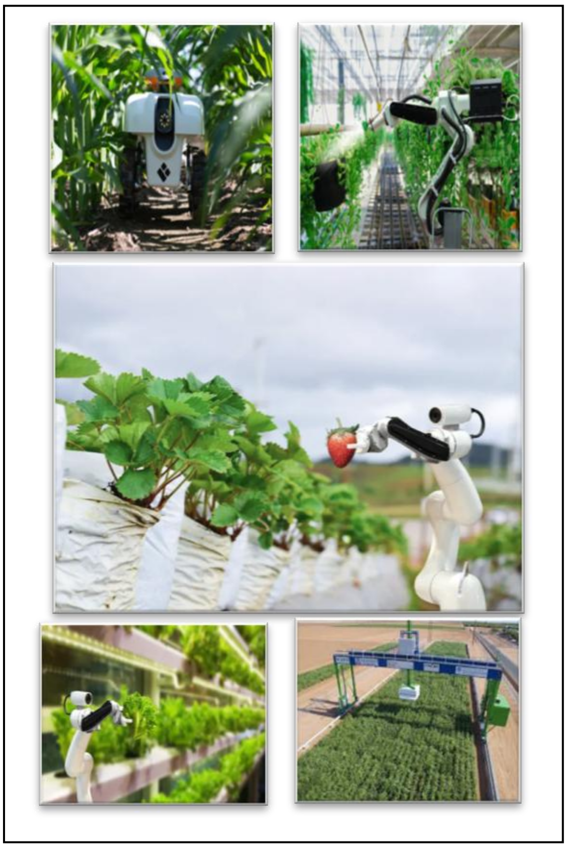

Figure 4: Agricultural Robots used in Smart Farming

3. Agriculture Drones

The agricultural drone is played a vital role to perform agricultural activities like Harvest optimization, Analysis of crop growth, etc. It is an Unmanned Aerial Vehicle (UAV) figure 5, which supports the process of capturing crops-related logs. With the help of agricultural drones, a farmer can observe the crop's growth stages and also analyze the soil variations (Postolache, O., Pereira, M. and Gir ao, A. (2013), Gadre, M. and Deoskar, A. (2020)).

With the tremendous growth in the today's digital world, the usage of agricultural drones in smart farming improves the harvest growth. With the help of data availability captured by drones, a farmer can take decisions wisely towards the right direction of crops growth (Nejkovic, V., et al, 2020), Singh, G. and Yogi, K.K. (2022b). Lots of applications, tools, and other technologies are available, which are helpful to identify the issues available in the specific farming land. Agricultural drones are also additionally providing the support in Plant pathogens monitoring, Livestock tracking, and surveying fences.

Figure 5: Agricultural Drones used in Smart Farming

According to a recent study, "agricultural drones are no different than other types of drones. The application of the UAV simply changes to fit the needs of the farmer. There are, however, several drones specifically made for agricultural use."

- Agras-T16, a product of DJI
- EA-2021, a product of EAVision
- eBee SQ, a product of senseFly
- Quantix Mapper, a product of Draganfly
- Drone4Agro V3

4. IoT-based other End-devices for Smart Farming:

There are numerous other IoT-based end-devices available for Smart Farming examples that show how to use IoT in agriculture from versatile to performing the Crop monitoring and other data analytics (Singh, G., Dubey, O. P., & Kumar, G. (2018)). Ag Vehicles, Concept Cars, and Tractors, Agri-Coolers, Agri-Heaters, Smart Sprinklers, Lights, Autonomous Greenhouses, and Urban Agriculture are used in agriculture to reduce the workload on labor and for precision farming (figure 6).

Figure 6: Agricultural Concept Cars and Tractors, Autonomous Greenhouses and Urban Agriculture, Smart Sprinklers used in Smart Farming

C. IoT-based Tools and Technologies

With the growth of the digital market, the agriculture domain has witnessed a huge impact of technological transformation on traditional farming (Putjaika, N. (2016)). Today, old-fashioned farming is completely converted into technology-driven and industrialized farming. With the usage of smart farming digital gadgets, a farmer is capable to control the crops growth and livestock monitoring wisely. The farmer is also efficient to decide the prediction and further improvement in the growth of harvest. Some popular tools and technologies available for Smart farming are discussed in Table 1.

Table 1: IoT-based Tools and Technologies

Tools and Technologies	Description
Tessel-2	This tool is basically used to build IoT prototypes and applications with the support of Node.JS libraries. Tessel-2 architecture also provides the facility of Wi-Fi or Ethernet features to an application development team for further implementation in a real-life scenario.
Eclipse-IoT Technologies	The eclipse-IoT community provides production-ready open-source technologies to the development team for building IoT-enabled applications, and managing cloud platforms and other IoT-enabled applications.
Arduino IoT	It is a cloud-based application that helps the development team to design and develop end-to-end connected objects in a very secure, easy, and quick way.
Platform-IoT	It is a hybrid cross-platform Internet-of-Things based integrated development environment (IDE) for managing the mobile app development.
M2M-Labs Mainspring	It is an IoT-based open-source application framework for developing machine-to-machine applications especially smart farming drone tracking, and remotely monitoring of harvest. J2EE, NoSQL, Apache, and Cassandra, are such technology stacks that are used for application development.
KinomaJS and KinomaConnect	KinomaConnect is used to develop Android and iOS-based applications for Mobile development. KinomaJS is a globally and cross-platform-based JavaScript API.
DeviceHive	It is an open-source platform for end-to-end communication system development. It provides a robust cloud-based API and other supportive libraries for smart device communication.
Kaax	KaaX is another open-source cloud-based framework that provides machine-to-machine (M2M) support.
Net	It is an IoT-enabled integrated development environment that supports the desktop, web, mobile, microservices, machine learning, game development, business intelligence, and cloud integration development.
Raspberry Pi OS	It is a rapid-application operating system that supports the Raspberry Pi board. More than 40000 packages and APIs are available for IoT technocrats.

ISSUES AND CHALLENGES

Numerous distinguished researchers have discussed the usage of IoT-based tools, technologies, and other supportive end devices in the operations of agriculture. But there are lots of unfolded challenges derived from the domain-specific end-devices, tools, and supportive technologies selection. This study explored major and common unfolded issues that arise during the implementation of various technology stacks in smart farming. Some of the highlighted issues are as follows:

- High investment for pre-installation of Agricultural Sensors, Robots, Drones, and other tools and technologies on agricultural land for operating and monitoring
- High-skilled manpower is required for managing and implementing the tools and technologies
- Heavy Maintenance Costs for end devices, tools, and technologies
- High-bandwidth continuous Internet connectivity required
- HD Cameras installation for Crop Satellite Imagery via sensors and drones
- A huge capacity server is required to store regular logs info related to crops and other activities
- Consistent energy-efficient environment setup in a reliable manner.
- Secured transmission of agricultural related information to concerned stakeholders
- Disaster-responsive IoT-based environment setup for further protection of digital devices from natural disasters
- Optimized utilization of agricultural resources
- Accurate Cost-analysis
- Accurate decision-making system to handle the natural disaster
- Crop residue for a clean environment
- Scalable configured environment setup for Smart Farming
- Risk of energy exhaustion

- Mobility and portability of environment setup.

Apart from mentioned issues, there are other lots of challenges like fertilizer and soil study, plant disease detection and diagnosis, Water study, fuel, and energy consumption to reduce Carbon Dioxide emissions, reducing Chemical reactions on crops, controlling soil compaction, and eliminating nutrient depletion are exists for the right selection of end-devices, tools, and technologies.

SELECTION CRITERIA FOR QUALITY OF SERVICE

This section covers the different parametric selection criteria, which can be adopted by stakeholders for smart farming to enhance the productivity of crops.

- Cost and Budgeting
- Domain Specific
- Infrastructure Mobility
- Remote Location compatibility.
- Confidentiality of Agricultural Data
- Privacy Preservation
- Mutual Authentication
- Resist Insertion Attacks
- Energy Efficiency and Utilization
- Skilled Manpower
- Response Time
- Disaster-responsive, etc.

By adopting these mentioned matrices for improving the Quality of Service (QoS) in Smart Farming, a farmer can monitor the field conditions and uplift other growing or common trends in agriculture.

CONCLUSION

This study discussed the various agriculture applications and Internet-of-Things based end-devices like agricultural drones, robots, sensors, and supportive tools and technologies in an efficient manner. This study also highlights the major unfolded challenges during the selection of IoT-based resources for smart farming. Finally, the mentioned research provides the efficient selection criteria for improving the quality of service in smart farming. This study is advantageous to all concerned stakeholders like farmers, agricultural institutions, and professional decision-makers, who are passionate about enhancing the smart farming.

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