IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

A Comprehensive Survey on Internet of Things based Agriculture

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Abstract: *Agriculture is the source of food and livelihood of maximum population across the country. The traditional farming activities are time consuming and leads to wastage of resources such as water, seeds, fertilizers etc., The farmers are lagging in estimating the right amount of resources to be utilized efficiently for farming as well as failing to predict what crops to grow to meet current market needs. These challenges can be overcome with the help of modern internet technology. IoT is one of the emerging and promising internet technologies which can be applied in modern agriculture. IoT is the integration of devices and technologies such as Wireless sensor networks, sensors, cameras, moving vehicles, gateway devices, microcontrollers, solenoid valves, protocols, cloud etc., This technology automates the farming activities by reducing human intervention. By IoT, a famer can predict period of seed harvesting to cutting of crops. Also, earlier detection of crop diseases and status of crop growth is notified to the farmers periodically via mobile apps. In this paper we survey the different applications of IoT based agriculture.*

Keywords: IoT (Internet of Things), Precision Agriculture, Smart Agriculture, Agriculture, Food Security, IoT, Smart Farming

I. INTRODUCTION

In India, agriculture is one of the oldest livelihoods of many people. It is largely affecting to the Indian economy system as a major sector. The worldwide demand for Indian agriculture products is an ever increasing factor. Some of such products are spices, fiber, rice, wheat, medicinal plants etc. With this rapid growth in the demand of Indian agricultural products, there are some drawbacks in agricultural process which lowers the production of crops. A study [1] says that 65.2% of youth will not like to choose agriculture as a full time occupation because of inefficient use of resources and 52.8% of youth said that agriculture as an occupation cannot provide huge opportunities in building their carrier because of lack of technical upgradationin agriculture processes.

Also the traditional irrigation [2], market and transport setup lowers the crops yield. The advancement of IoT in agriculture is an emerging technology, which revolutionized the traditional agricultural processes. It has the potential to automate the manual processes without using the human intervention resulting in efficient outcome. Some of the agriculture processes where IoT can be applied are as follows:-.

IoT based Crop Health Monitoring
IoT based Pest Detection
IoT based Smart Irrigation
IoT based Precision Agriculture
IoT based Hydroponic system

The Figure 1 depicts the IoT in various applications.

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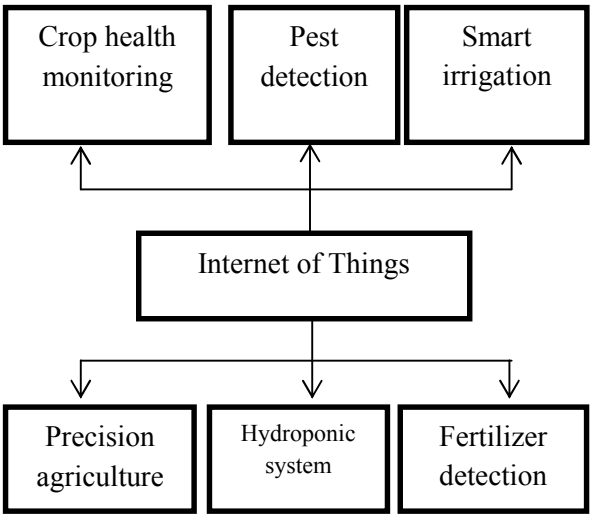

Figure 1: Applications of IoT in Agriculture

II. RELATED WORKS

The various surveys has shown the advances, emerging technologies and key challenges as determined by IoT based agriculture. The survey report Rubeena M M [3] has highlighted usage of smart GPS based Robot for specific agricultural activities. The usage of Wi-Fi/Zigbee camera, actuators is specified. However it does not discusses on pest management, soil health monitoring using IoT. As per the survey Muhammad Ayaz [4] discusses on potential of integrating IoT and Wireless sensors with traditional farming. The different kinds of sensors, communication technologies available for soil and crop health monitoring are mentioned. The importance of Unmanned Aerial Vehicles in crop surveillance and pest detection is also discussed. The survey in Muhammad Shoaib Farooq [5] specifies network technologies, sensors and smart phone based applications, the integration of IoT with big data storage and cloud computing is also discussed. The survey in Raquel Gómez-Chabla [6] reports various Iot based software applications and devices is discussed. However it does not discusses on resolving environmental issues for sustainable agriculture. The survey Vippon Preet Kour [7] shows recent IoT based technologies and role of sensor in agriculture sector is discussed. The development of hardware and software for agricultural activities is provided. The Table 1 describes the comparison of various surveys on recent advances and key challenges in IoT based agriculture

Table I: CAOMPARISION OF PAST SURVEYS

Authors	Year	Research findings	Research gap
Rubeena M M et al. [3]	2019	Performing agricultural activities using GPS based remote controlled Robot	Weather forecasting is not discussed. Pest detection and soil health monitoring is also discussed
Muhammad Ayaz et al. [4]	2019	The potential IoT and wireless sensor network with traditional farming practices. Use of Unmanned Aerial Vehicles and specific sensors and communication technologies for agricultural activities.	Improving quality of food. Real time monitoring of catastrophic events such as droughts, floods, ground water depletion etc.
Muhammad Ayaz et al. [5]	2019	Integration of Big data Analytics with IoT. Various Network architectures, communications for IoT based agriculture.	Optimal management of huge data. Power optimization Appropriate libraries and frameworks for agriculture application developer. Scalability and resource optimization

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Raquel Gómez-Chabla et al. [6]	2019	Various IoT based Software applications for agriculture and its benefits are discussed.	Resolving environmental issues for sustainable agriculture.
Vippon Preet Kour [7]	2020	Recent advances in IoT with development of hardware and software systems or agriculture. Sensors role in agriculture.	Monitoring of performance degradation Huge data management Designing of cost analytic models Power optimization Working with high speed communication network

A significant amount of work has been done on IoT technology in agricultural area [8]. Halil Durmu [9] proposed a interdisciplinary framework based on mobile agents such as robots or static sensors or sensor networks to collect, analyze and classify huge amount of data. This scheme uses WiFi or any other cellular communication for sharing the data. Also web based application is used for farmers visualization.A privacy preserving data aggregation scheme Jingcheng Song[10] for protecting agricultural sensitive data by using ElGamel Cryptosystem (public key encryption and signature scheme) is proposed for managing and securing agriculture data.A Cloud based Smart Farming Management Framework for data management is proposed by Amine Roukh [11]. This approach addresses the challenges of data acquisition, data processing, data storing and its visualization in smart farming. All these activities can be analyzed in both batch and real time basis. Since the process of mining large amount of data and extracting specific data is a challenge, the approach of managing large data is proposed by Chunling Li [12]. This approach optimizes the storage, processing of data generated in Agriculture process using K means algorithm and other hardware tools. The Table II depicts the survey of data management in smart farming

Table II: COMPARISON OF VARIOUS DATA MANAGEMENT TECHNIQUES IN SMART FARMING

Authors	Year	Hardware	Software	Advantages	Disadvantages
Halil Durmu [9]	2019	Robots Drones Environment Sensors Robot sensors Stereo Camera Auxillary Camera	HTML CSS Javascript Bootstrap library Python framework Django	Reliable communication of data.	More advancement in hardware configuration is required. Web page should be enhanced with more features to make user friendly.
Jingcheng Song [10]	2020	Environment sensors. Smart devices to support agriculture activities.	-	Secured and flexibility in managing and publishing data.	Replacing cloud with block chain framework.
Amine Roukh [11]	2020	MQTT Sensors	Googles V8 Javascript Engine. OpenStreetMap Graph QL	Robust Data Management	Scalability in adding more farm data needs to be improved. Improving User Interface.
Chunling Li [12]	2020	Sensors Eelay control unit, RFID Rapid testing equipment Video cameras.	MATLAB	Efficient data communication in real time. Leads to modernized agriculture.	Lacks in mining huge amount of data.

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Fanyu Bu [13] presented a smart agriculture IoT system based on deep reinforcement learning which comprises of four layers such as agricultural data collection layer, edge computing layer, agricultural data transmission layer, and cloud computing layer. This system integrates artificial intelligence with cloud computing. Special deep reinforcement models are designed which makes immediate smart designs to support agriculture processes. However the designed system does not provide accuracy up tohuman level performance in solving complex tasks in adoption to dynamic environments.

O. Koksal [14] discussedabout designing models for automating the major processes of IoT in agriculture called as FMISS (Farm management information systems), it is illustrated using 2 cases studies on smart farming in Kanya and Antalya. However only 2 case studies related to wheat and tomato crop production is discussed, so in future, the research can focus further on growing other crops by integrating various FMISS.Francisca Ogwueleka [15] discussed about implementing automated irrigation based information and communication technology (ICT) with the aid of network sensors and LAN. The literature reviews of technologies used in the area of smart agriculture and Arduino based novel architecture, process flow in automatic irrigation system is described. However it does not discusses with respect to large networks. So that future scope can be done on comparing reliability and efficiency in LAN and GSM. The use of Arduino can be extended to automate other agricultural processes such image processing for detecting plant diseases, pesticide detection etc.

Xue-Bo Jin [16] presented a Hybrid Deep Learning model for predicting natural conditions such as climate data, wind speed, humidity etc., which are essential for farming process. This model describes a special method called Empirical Mode Decomposition (EMD), which is used to decompose the climate data into fixed component groups with different frequency characteristics. The model also consists of GRU(Gated Recurrent Unit) which is a trained software program which acts like sub predictor for decomposing the climate data received from EMD. However in practical applications, the proposed predictor can be enhanced to get accurate predictions for the following 24 hours, based on the given input data.E. F. Amirova [17] discusses on growth rate and key problems associated with IoT in agriculture economy. The issues of agro-industrial process are addressed. Since the internal digital process is complex, our IoT must be prioritized with respect to development of business models for agricultural producers and agro-industrial process.The Table III represents various schemes of IoT based agriculture

Table III: VARIOUS SCHEMES OF IOT BASED AGRICULTURE.

Author	Year	Concept	Advantages	Disadvantages
Fanyu Bu et al., [13]	2020	Special deep reinforcement models for farming processes are designed by using AI and cloud computing.	Immediate smart decisions in adjusting farm environment for better crop growth can be taken.	Difficult to achieve the human-level performance in adapting to dynamic environments and difficult to solve complex tasks.
O.Koksal et al.,[14]	2020	Designing of architecture for various IoT based FMISs is discussed.	This study is useful for researchers on FMISs and designers who frame to architect different FMISs.	-
Francisca Ogwueleka et al., [15]	2020	Implementing a system based on information and communication technology (ICT) with the aid of network sensors and LAN for agriculture. It reviews on technologies used in smart agriculture, process flow in automatic irrigation using Aurdino based novel	The use of Arduino can be extended to processing of images to improve crop health.	It does not addresses for forming in large area.

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		architecture.		
Xue-Bo Jin et al. [16]	2020	Designing of hybrid deep learning predictor based on a self-learning EMD and GRU group model.	It is used to predict temperature, humidity and wind speed more accurately.	Predicting more environment factors needs to be addressed.
E.F. Amirova et al., [17]	2020	It discusses the importance of IoT in modern agricultural markets.Also describes the growth rate and key problems associated with IoT in agriculture economy.	The introduction of IoT in agricultural economy reduces the complexity involved in its internal process.	Transformation of business methodologies, internal business processes and the production, management culture of companies needs to be addressed.

Sergio Trilles [18] focuses on designing a middleware (software program), which is used to connect heterogeneous computing devices and application servers. An architecture called Agnostic, consisting of paradigms such as micro services architecture and server less computing is designed and also SEnviro Connect-a technological proposal is described. The entire work addresses the features like Scalability, Stability, Reusability, Interoperability & Reliability in IoT based agricultural environment. However mobility in IoT devices and adopting to IoT platform in dynamic circumstances can add as future enhancement.

As Supply Chain Management (SCM) is one of essential aspect of agriculture sector in India, the author Sanjeev Yadav [19] presented a research work on enhancing the coordinating mechanism in Agriculture Food Supply Chain Management (AFSCM) during natural outbreaks. A technique called DEMATEL is used to establish effective and casual relationships between all stakeholders of AFSCM. It also discusses on Top Management Support (TMS) by MICMAC analysis and based on (R-C) value, it is categorized in a cause group. Next the coordination index of the entire model is calculated based on the Cleveland theory. However only limited factors are addressed with respect to inter and intra organization. It does not consider social and environmental aspects in IoT with AFSCM.

Gaia Codeluppi [20] introduced a LoRaWAN-Based Smart Farming Modular IoT Architecture for managing the farms in a customized way. However an enhanced data analysis is required to predict the environmental factors to improve healthier crops production.Dinesh Manikandan [21] introduced a weather-aware IoT based architecture for Agro-gain where it collects data from various sensors like cameras, drones, images etc., this is also called data-driven architecture as it employs on collecting large amount of data. It address the problem of sending high bandwidth drone videos to the cloud by using Gateway based design where the data can be exchanged between farmer's PC and cloud.

Achilles D. Boursianis [22] given a comprehensive review on using IoT and Agricultural unmanned vehicles (UAV) in smart farming. The UAV's are used in various scenarios such as-irrigation, fertilization, weed management, crop growth monitoring, field-level phenotyping etc., However precise irrigation by minimizing salt contents in water, reducing of pollution aquifer, weed management, prevention of crop diseases and producing quality certified products to customers' needs to be addressed. The table IV depicts the comparison of various IoT based agriculture schemes

Table IV: COMPARISON OF VARIOUS IOT BASED AGRICULTURE SCHEMES

Author	Year	Concept	Advantages	Disadvantages
Sergio Trilles et al., [18]	2020	An effective solution to manage IoT Lifecycle in agriculture is presented.	Data management Scalability Event management Reliability Availability	Needs to be improved on IoT platform Interoperability.
Sanjeev Yadav et al., [19]	2020	An IoT based model for handling all AFSC activities is designed.	Provides efficient and supportive system for AFSC during natural outbreaks.	It does not consider social and environmental aspects in IoT with AFSCM. It did not show the calculation of CI for different

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				stakeholder's perspectives.
Gaia Codeluppi et al., [20]	2020	A "LoRaFarm"- IoT based platform for managing dynamic farms using heterogeneous technologies.	The farm is managed in a customized way.	Enhanced data analysis for predicting crop diseases needs to be addressed.
Dinesh Manikandan et al., [21]	2020	Weather-aware, solar powered IoT based architecture where it collects data from various sensors like cameras, drones, images etc., is designed. This is called Agro-gain architecture.	Low cost Highly available Supports high bandwidth sensors using TVWS.	Currently this architecture is deployed for only precision agriculture, animal and storage monitoring. So it can be enhanced further to use in other applications like weed management, crop health monitoring etc.,
Achilles D. Boursianis et al., [22]	2020	Comprehensive review on using IoT and Agricultural unmanned vehicles (UAV) in smart farming is presented.	High crop yield Low cost Smart monitoring of each plant individually.	_

Kaushik Sekaran [23] introduced a framework consisting of IoT in agriculture. It deals with theproduction and monitoring of crops using cloud computing. The data collected from various sensors is analyzed in real time and is intimated to farmers for making effective decisions.

Bhanu K N [24] proposed a Machine Learning based intelligent system for agriculture using IoT. It describes about integrating machine learning skills with modern information and communication technology to make data intensive prediction in agriculture farms. A review of different various machine learning technologies for IoT based agriculture is discussed. However fertility parameters can be considered as a future work.

Soumil Heble [25] introduced a low-power, low-cost IoT network for smart agriculture. In this architecture, IITH mote and low cost sensor nodes embedded with solar power are used. However remote monitoring of the farms in precision agriculture is not discussed.

Mobasshir Mahbub [26] presented a concept on smart farming based by integrating embedded electronics, IoT and wireless sensor network to increase the food production. It also makes use of special protocols and distance monitoring system. However it does not discusses with application of AI based robotics, Machine learning technologies for improving the results.

Amine Faid [27] presented an IoT-based low-cost architecture for smart farming based on wireless sensors network technology. It supports the plug-and-play nodes approach. The methodology used is the change point detection algorithm and leach protocol for network clustering. Heterogeneous wireless sensor nodes survey parameters are soil moisture, ambient temperature, air quality, etc. are periodically transmitted to the relevant cluster heads. The Base Station gathers data from the cluster heads for further processing and storing. However, the scalability and performance of the network depend on the size of the network. So the algorithms must be enhanced for network clustering and its life expansion.

N. Penchalaiah [28] proposed a new smart IoT based farming concept where it supports farmers in obtaining live data (temperature, soil humidity) so that the farming land monitoring can be done successfully which increases crops production with the rise in its value.

P. Salma Khatoon [29] introduced a framework for integrating IoT with heterogeneous devices in smart farming. A simple semantic annotation model is designed to annotate the data gathered from various sensors presented in a user-friendly manner. Semantic functionality is provided to the data using Resource Description Framework (RDF), so that interoperability is achieved for the heterogeneous data gathered from heterogeneous devices. However semantic interoperability is not discussed in this framework.

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Emre Özbilge [30] presented a model of smart agriculture using neural networks. a time-delay radial basis function (TDRBF) network approach is used to model weather condition in agricultural environment. So that farmers can make more accurate predictions on weather.However in large agricultural environment, developing a new region-based agricultural weather forecasting framework is essential. The Table V represents surveying of various schemesof IoT based agriculture

Table V: DIFFERENT SCHEMES OF IOT BASED AGRICULTURE

Author	Year	Concept	Advantages	Disadvantages
Kaushik Sekaran et al., [23]	2020	Proposes a base architecture for IoT based agriculture which consists of 3 layers to store, manage and monitor the crop growth details. This architecture provides opportunity for making efficient decisions on fertilizer utilization, water management, crop health monitoring based on data collected from sensors.	Crop quality can be improved.	This experimentation is carried out for only crops like groundnut and banana. So the architecture can be enhanced to yield other essential crops.
Bhanu K N et al., [24]	2020	Proposed a IoT based intelligent system for agriculture using Machine Learning technology is introduced.	Crop quality and productivity can be improved.	Different fertility factors needs to be considered in future work.
Soumil Heble et al., [25]	2020	Designing of low-power, low-cost IoT network for smart agriculture by using IITH mote, low cost sensor nodes with solar power is embedded.	It is a low cost architecture and uses less power consumption.	Remote farm monitoring is not addressed.
Mobasshir Mahbub [26]	2020	Presented a smart farming concept by integrating embedded electronics, IoT and wireless sensor network.	Crop production can be increased.	This architecture needs to be embedded with AI and ML for efficient outcome in agriculture.
Amine Faid et al., [27]	2020	IoT-based low-cost architecture for smart farming based on wireless sensors network technology.	Increases efficiency through process automation. Real-time monitoring of the crops can be made possible.	Designed for small, sized networks
N. Penchalaiah et al., [28]	2020	IoT based smart farming concept is introduced where it supports farmers in obtaining live data (temperature, soil humidity etc.) Aurdino technology, IoT's Thingspeaks's API and MATLAB R2019a is used.	Due to the collection of accurate and live data on farm land, the famers can take more efficient decisions for further processing.	_
P. Salma Khatoon et al., [29]	2020	A framework for achieving semantic interoperability in IoT based heterogeneous devices is introduced. Resource Description Framework (RDF) is used for providing semantic functionality to the data.	Interoperability between heterogeneous IoT devices can be achieved.	Syntactic interoperability amongst the heterogeneous devices of IoT needs to be addressed.

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Emre Özbilge et al., [30]	2020	Presented a model of smart agriculture using neural networks in which a time-delay radial basis function (TDRBF) network approach is used to model weather condition in agricultural environment.	Farmers can make more accurate predictions on weather.	In large agricultural environment, developing a new region-based agricultural weather forecasting framework is essential.

VI. CONCLUSION

In this paper, a systematic survey has been conducted on the various approaches for smart farming using Internet of Technology to improve the quantity and quality of food crops. A thorough analysis has been made on the security attributes, application areas, advantages, drawbacks, involved in the considered existing competing schemes. This study has provided the future directions for some open and challenging problems towards which the research is interested to continue.

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