Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: A Review

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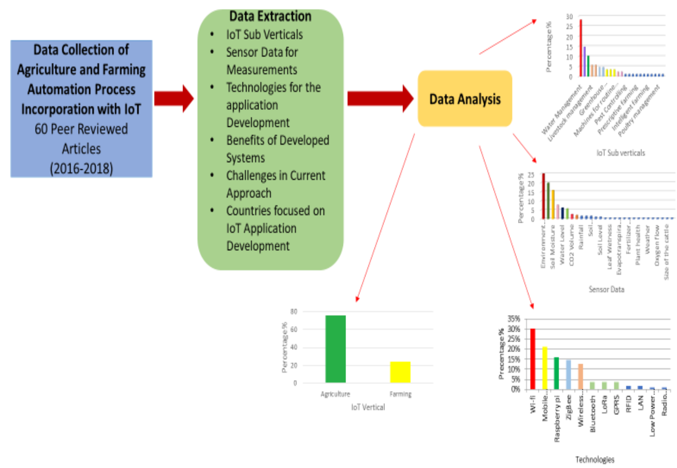
Abstract*—It is essential to increase the productivity of agricultural and farming processes to improve yields and cost-effectiveness with new technology such as the Internet of Things (IoT). In particular, IoT can make agricultural and farming industry processes more efficient by reducing human intervention through automation. In this study, the aim to analyze recently developed IoT applications in the agriculture and farming industries to provide an overview of sensor data collections, technologies, and sub-verticals such as water management and crop management. In this review, data is extracted from 60 peer-reviewed scientific publications (2016-2018) with a focus on IoT sub-verticals and sensor data collection for measurements to make accurate decisions. Our results from the reported studies show water management is the highest sub-vertical (28.08%) followed by crop management (14.60%) then smart farming (10.11%). From the data collection, livestock management and irrigation management resulted in the same percentage (5.61%). In regard to sensor data collection, the highest result was for the measurement of environmental temperature (24.87%) and environmental humidity (19.79%). There are also some other sensor data regarding soil moisture (15.73%) and soil pH (7.61%). Research indicates that of the technologies used in IoT application development, Wi-Fi is the most frequently used (30.27%) followed by mobile technology (21.10%). As per our review of the research, we can conclude that the agricultural sector (76.1%) is researched considerably more than compared to the farming sector (23.8%). This study should be used as a reference for members of the agricultural industry to improve and develop the use of IoT to enhance agricultural production efficiencies. This study also provides recommendations for future research to include IoT systems' scalability, heterogeneity aspects, IoT system architecture, data analysis methods, size or scale of the observed land or agricultural domain, IoT security and threat solutions/protocols, operational technology, data storage, cloud platform, and power supplies.

Keywords*—*Internet of Things; IoT; agricultural; smart farming; business; sensor data; automation



Graphical Abstract.

I. Introduction

IoT is a combination of worldwide data, web associated items or things, and is an integral component of the future Internet. IoT focuses on the automation of processes by lessening human interaction. In the process of automation, IoT collects data using sensors and processes the data using controllers and completing the automation processes by using actuators [1], [2]. IoT in agriculture and farming focus is on automating all the aspects of farming and agricultural methods to make the process more efficient and effective. Traditional approaches in livestock management (such as cattle detection) are not fully automated and have many inefficiencies such as higher human interaction, labour cost, power consumption, and water consumption [1], [3], [4], [5], [6]. The central concept of this review is to analyse the IoT sub-verticals, collected data for measurements and used technologies to develop applications. It is essential to identify the most researched sub-verticals, data collections and technologies to create new IoT applications in the future.

This review provides an overall picture of currently developed IoT applications in agriculture and farming between 2016 and 2018.

As a solution to the existing problems, researchers have focused on smart agricultural and farming automated systems with the help of IoT [7], [8], [9], [10]. IoT is the network of things which identifies elements clearly with the help of software intelligence, sensors and ubiquitous connectivity to the Internet. In IoT, the data that collects from Internet-connected items or things contains with gadgets, sensors and actuators [1]. Many researchers have focused on smart systems for monitoring and controlling agricultural parameters by enhancing productivity and efficiency. Smart systems collect data for measurements to get accurate results that can lead to appropriate actions. Current use of smart agricultural systems relates to collecting data on environmental parameters such as temperature, humidity, soil moisture and pH [11], [12], [13]. With accurate sensor data collection using a range of different sensors, researchers have implemented smart agricultural systems to make the farm process more effective [9], [14]. Research has mainly focused on sub-verticals such as water management, crop management and smart farming to make processes automated by reducing human intervention, costs, power consumption and water consumption.

The automation process of agricultural and farming reduced human interaction and improve the efficiency. The reason for that is every country population depends on agriculture thus consumers of these resources should use water and land resources optimally [19], [20]. Moreover, it is imperative to have good quality production and crop management in order to maximize profitability. Hence, IoT base agricultural management systems are integral for an agriculturally based country. The new systems developed using IoT technologies have reduced the drawbacks associated with traditional approaches and provided many advantages to farmers. For example, IoT-based water management systems collect environmental attributes such as temperature, water level and humidity through the sensors and provide accurate irrigation timing [19], [21]. In addition, crop management systems developed using IoT monitor the temperature, humidity and soil through sensors thus providing adequate information so that farmers can manage the crops appropriately [25]. Overall, these IoT-based systems help to reduce human interaction, power utilization and reduce cost in the field of agriculture. Moreover, IoT-based agricultural related applications have been used in the area of pest control, weather monitoring, nutrient management and greenhouse management.

IoT for agriculture uses sensors to collect big data on the agricultural environment. It discovers, analyses and deals with models built upon big data to make the development of agriculture more sustainable [34]. IoT can provide efficient and low-cost solutions to the collection of data. Weather, Water Scarcity, Soil fertility and Pesticides are the significant players in it. IoT will make agriculture beneficiary. Agriculture and farming depend on water [35]. Farmers depend on rainfall for all their agricultural needs.

Fertilizer also plays a very significant role in the field of agriculture by helping to increase the productivity of plants [36]. By using IoT, farmers can manage soil condition more effectively and at less expense by monitoring them from any location [37]. The primary objective of this study is how IoT and technologies are used in conserving water, fertiliser and energy in the agricultural industry by combining new technologies. This has benefits for the development of the economy of countries as well as the wealth of the people [38]. With the combination of both advanced technologies in hardware and software, IoT can track and count all relevant aspects of production which can reduce the waste, loss and cost [39]. The information needed to make smart decisions can be obtained merely by using electronic devices [40]. IoT transforms the agricultural industry and enables farmers to overcome different challenges. Innovative applications can address these issues and therefore increase the quality, quantity, sustainability and cost-effectiveness of crop production [41], [42], [43]. IoT provides more benefits to the farming industry by improving the health of animals through better food and environment, addressing the labour shortage issue as well cost savings through automation, increase in milk production, and increase in some animals during the breeding period through detection of estrus cycle and additional revenue streams from waste.

Our study has analyzed recently developed IoT applications in the fields of agriculture and farming to address current issues such as unnecessary human interaction leading to higher labour cost, unnecessary water consumption and water-saving measures for the future, higher energy consumption, energy-saving measures for the future and crop monitoring difficulties. According to our analysis, we can identify a focus on water and crop management as sub-verticals in the agriculture and farming sectors. This survey also focusses on other agriculture and farming sub-verticals to identify the gap between IoT application developments in the least researched areas. The IoT generates enormous data, so-called big data (high volume, at a different speed and different varieties of data) in varying data quality. Analysing the IoT system and its key attributes are the key to advancing smart IoT utilization. Therefore, the primary aim of our paper is to explore recently created IoT applications in the agriculture and farming industry to give the more profound understanding about sensor data collection, used technologies, and sub-verticals, for example, water and crop management. The secondary aim of this study is to analyse the current issues such as higher human interaction, high labour cost, higher water consumption and save water for future, higher energy consumption and save energy/electricity for future, crop monitoring difficulties in IoT for agriculture and farming.

The remainder of this paper is as follows: In Section II we include raw data collection methodology, data inclusion criteria, and data analysis methods. Finally, the results of Agriculture and Farming based on IoT Sub verticals, Sensor Data, and Technologies are presented in Section III, and in Section IV we discuss the results. Section V concludes the paper. The raw data collected from 60 peer-reviewed publications used in this paper are summarised in Table I.

II. Materials and Methods

Data collection involves identifying important criteria in research articles on the Internet of Things (IoT) in the agriculture and farming sectors.

As shown in Table I, these essential criteria were used to analyse relevant research papers. In particular, 60 peer-reviewed scientific publications on IoT in the agriculture and farming sectors published in scientific journals between 2016 and 2018 were used.

1) Collection of raw data: The data gathered for this review is from 60 peer-reviewed publications (2016-2018) that were collected from the IEEE database. All these publications have different data applications that have been studied and analyzed in this survey. The attributes compared were sub-verticals, data collection measurements, used technologies, challenges in current approach, benefits, countries and drivers of IoT.

2) Data inclusion criteria: To evaluate the data inclusion criteria a comparison table was drawn to include as the following attributes: Author, Sub vertical, Data collection measurements, Technologies, Benefits, Challenges, Solutions and Drivers of IoT. Nevertheless, in our study, articles were excluded when the selected attributes were not present. In our analysis, the number of sensors, amount of data collected, underlying technologies, sensor topology and other intermediate gateways were not included since no information can find with all the peer-reviewed publications (2016-2018).

3) Data analysis: We pooled and analyzed the reported studies based on data collected through peer reviewed articles and displaying emerging themes in a table. The data sets included attributes such as Sub vertical, Data collection measurements, Technologies, Benefits, Challenges, Solutions, Countries focused on automation of the agriculture proses and Drivers of IoT. The descriptive details of the study based on the publication year were analyzed to observe the results from 2016 to 2018.

III. Results

This review aims to analyse the incorporation of IoT for the development of applications in the agriculture and farming sectors. The study focuses on sub-verticals and collecting data for measurements and technologies in the field of agriculture and farming to increase productivity and efficiency with the help of the Internet of Things (IoT). This study of IoT in agriculture and farming focuses on developing a criterion approach with the help of agricultural environmental parameters and IoT measures and technologies. In the field of agriculture, there are many environmental parameters that need to be considered to enhance crops, reduce water consumption and human involvement [44]. Moreover, there are many sub-verticals that can be identified depending on the differences in approach.

In this review, we have gathered articles which have focused on agricultural and farming sub-verticals from 2016 to 2018. As shown in Fig. 1, 23 sub-verticals were found according to the results obtained and the topmost area was water management (28.08%).

As IoT depends on sensor data collections, a vast amount of data needs to be gathered to identify or predict accurate results. This study indicates that many researchers have focused on environmental temperature (24.87%), humidity (19.79%) and soil moisture (15.73%) as environmental measurements. As shown in Fig. 2, 28 types of data were collected for measurements with environmental temperature and humidity being considered the most critical parameters for agriculture and farming.

As shown in Fig. 3, we have categorised all technologies used in the articles. This study has identified Wi-Fi as the most used technology (30.27%) followed by Mobile Technology (21.10%) for both agriculture and farming. ZigBee, another data transfer technology, is also used but to a lesser extent.

According to Fig. 4, the use of IoT was more prominent in the agriculture industry than the farming industry (Agriculture – 76.1%, Farming – 23.8%).

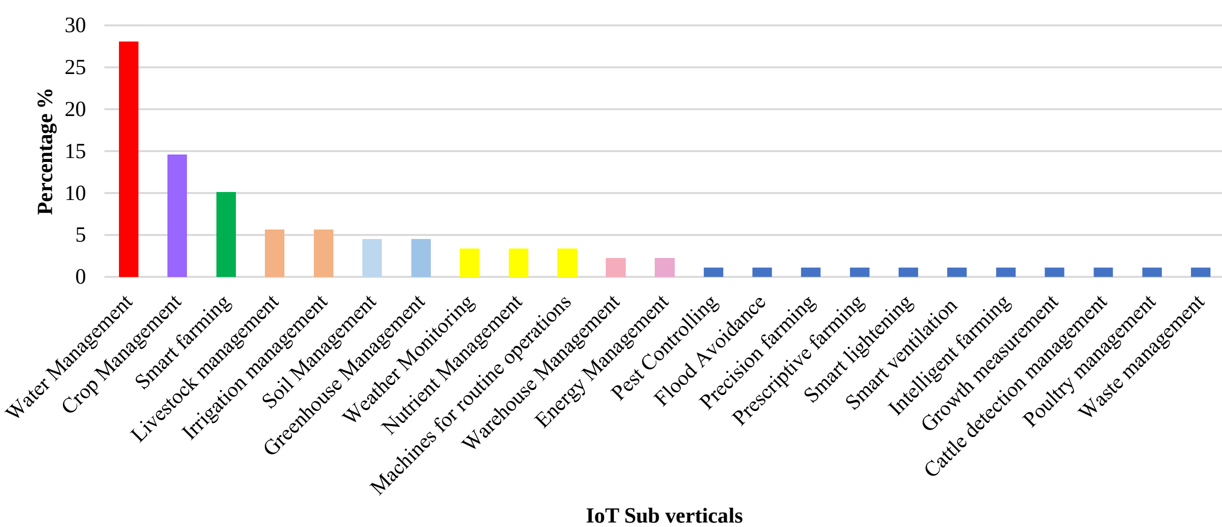


Fig. 1. Agriculture and Farming Sub Verticals: different Agricultural and Farming Sub Verticals Considered to Enhance Efficiency and Productivity–Pooling

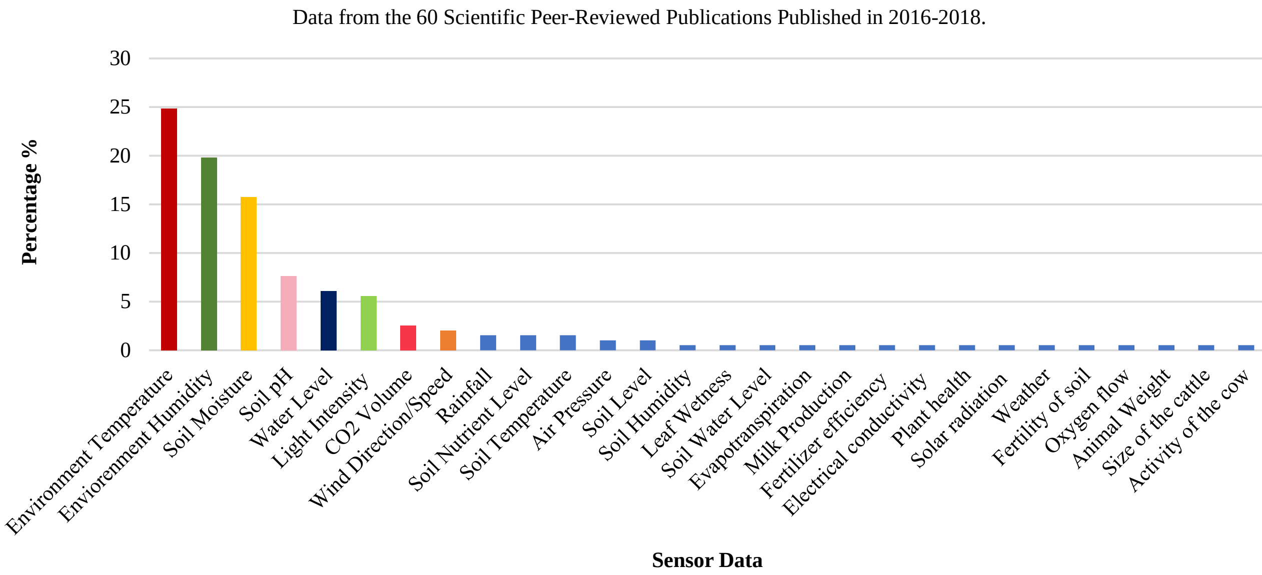


Fig. 2. Utilization of Sensor Data based on Farming Activities Referred to in the Data Pool of 60 Peer Reviewed Published Articles.

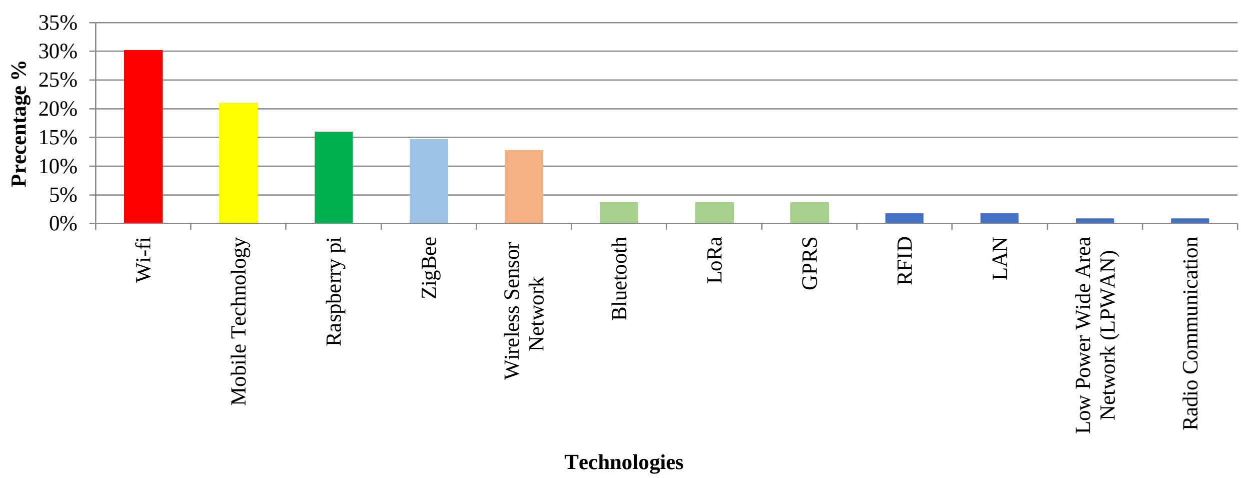


Fig. 3. Overview of different Technologies Referred to in the Data Pool of 60 Peer Reviewed Published Articles and Frequency of Mentions Shown in Order of High Frequency to Low.

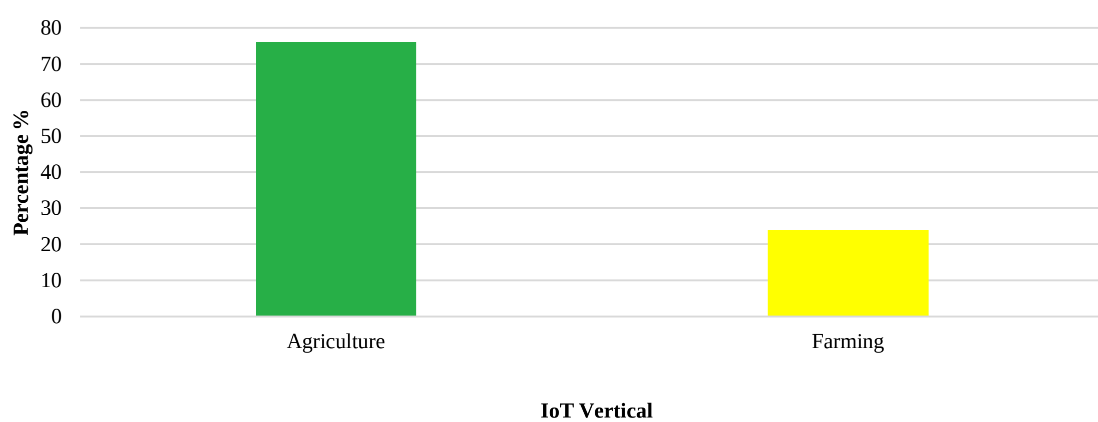


Fig. 4. Overview of Comparing the usage of Internet of Things in two Verticals as Agriculture and Farming in 60 Peer-Reviewed Research Articles to understand which is mostly used Internet of Things from Year 2016-2018.

TABLE I. IoT IN AGRICULTURE AND FARMING CRITERION-APPROACH-DATA EXTRACTED FROM 60 SCIENTIFIC ARTICLES IN 2016-2018

No	Year/Author	IoT Sub Verticals	Measures (Data collection)	Technologies Used	Benefits of Proposed System	Challenges in Current Approach	Solution for Current Issues	Drivers of IoT	Application
1	Venkate et al (2017) [1]	✓ Water Management	✓ Environmental temperature ✓ Humidity ✓ Soil ✓ moisture	✓ Raspberry pi ✓ Wi-Fi. ✓ RFID ✓ Bluetooth ✓ Zigbee	✓ Can detect the temperature, humidity and moisture. ✓ Continuous monitoring all the places including critical areas.	✓ Human interaction ✓ Labour cost ✓ Wastage of water ✓ Crop from abnormal irrigation.	✓ Detect temperature, humidity, moisture using sensors. ✓ Maximize the yield of crop by monitoring agricultural parameters.	✓ Can deploy it in any type of environment for, ✓ monitoring ✓ flexibility ✓ robust	✓ Agriculture
2	Athira et al (2017) [2]	✓ Pest controlling ✓ Weather monitoring	✓ Soil moisture ✓ Temperature ✓ Water level	✓ ZigBee	✓ Irrigation process is completely controlled by computer-based systems. ✓ System analyses the weather reports. ✓ Keep pest away from the crops. ✓ Help to faster the growth of plants. ✓ Power efficient.	✓ Only works based on the commands from user	✓ Low cost ✓ Efficient growth of crops ✓ Faster growth of plants.	✓ Predict and tackle drought situations to prevent to loss of crops. ✓ Keep monitoring climate conditions.	✓ Agriculture
3	Zhao et al (2017) [3]	✓ Water Management	✓ Water level	✓ LoRa technology	✓ Can utilize the water usage.	✓ To identify the appropriate time and in the right amount of water. ✓ High power consumption. ✓ High cost. ✓ Low coverage of ZigBee and Wi-Fi.	✓ Minimize the cost of deployment and maintenance. ✓ More efficient. ✓ Cover wider area than ZigBee and Wi-Fi. ✓ Energy consumption is low.	✓ Users can remotely access irrigation system and check the status.	✓ Agriculture
4	Sagar S et al (2017) [4]	✓ Flood Avoidance	✓ Water level ✓ Soil moisture	✓ Mobile technology	✓ Lessen the human intercession. ✓ Lessen the probability of the flood occurrences. ✓ Faster the growth of the crops.	✓ Save water for the future. ✓ Save electricity for the future.	✓ Flood avoidance. ✓ Power cutoff is being reduced.	✓ Higher the revenue by faster the growth of crops. ✓ Ensure the durability of the soil.	✓ Agriculture

5	Saraf et al (2017) [5]	✓ Water Management	✓ Water level. ✓ Soil ✓ Moisture. ✓ Environment temperature. ✓ Humidity	✓ Wireless sensor network. ✓ ZigBee. ✓ Mobile technology .	✓ Lessen the human interaction. ✓ Efficiently managed the irrigation water system.	✓ High water consumption. ✓ Human interaction.	✓ The water consumption is reduced. ✓ Lessen the human interaction.	✓ Reduced water consumption.	✓ Agriculture
6	Upadhyaya et al (2017) [6]	✓ Water Management	✓ Soil Moisture ✓ Water requirements	✓ Wi-Fi ✓ Mobile technology	✓ Broader coverage. ✓ Notify user when any change happens.	✓ No attention to water management. ✓ No economic feasibility. ✓ Complicated data for understanding. ✓ Data display is not user friendly.	✓ Water requirements monitored. ✓ Immediate notification sends to farmer. ✓ User friendly data collection.	✓ Captured moisture values stored in the cloud. ✓ Compare captured values with predefined moisture values. ✓ Used solar powered battery.	✓ Agriculture
7	Udhayakumar S et al (2017) [7]	✓ Water Management	✓ Soil moisture ✓ Environment temperature. ✓ Humidity	✓ Raspberry pi ✓ Mobile technology	✓ Monitor plants through smart mobile. ✓ Efficient water supply management.	✓ Overhead sprinklers. ✓ Wastage of water.	✓ Watering crop without human interaction.	✓ Analyze moisture level of ground.	✓ Agriculture
8	Kumar et al (2017) [8]	✓ Water Management	✓ Soil moisture ✓ Environment temperature. ✓ Humidity	✓ Mobile technology ✓	✓ Higher the crop. ✓ Efficient water supply. ✓ Reduced cost. ✓ Resource optimization.	✓ Hard to water to crop equally due to unequal rain water distribution. ✓ Amount of water not defined.	✓ Farmers can know field status even they are at home. ✓ Efficient water management. ✓ Provide real time information.	✓ Automatic plan watering system.	✓ Agriculture
9	Mathew et al (2017) [9]	✓ Nutrient Management	✓ Environment temperature. ✓ Humidity ✓ Nitrogen level ✓ Prosperous level	✓ Raspberry pi ✓ Mobile technology ✓ Wi-Fi	✓ Can monitor whether conditions. ✓ Cost effective ✓ Automatically monitored disease associated with rice species.	✓ Low or high watering. ✓ Lack of nutrition management.	✓ Whether conditions detected. ✓ Enhanced the fertilizer amount.	✓ Can enhance the fertilizer amount.	✓ Agriculture
10	Suhas et al (2017) [10]	✓ Water Management	✓ Temperature ✓ Moisture level ✓ Humidity ✓ Light Intensity ✓ Nitrogen, ✓ Phosphorus ✓ Potassium	✓ Bluetooth ✓ Wi-Fi	✓ Cost effective. ✓ High efficient water management.	✓ Higher water consumption. ✓ High power utilization. ✓ Lack of useful inference.	✓ Reduced water consumption. ✓ Better power utilization.	✓ Automated water supply system.	✓ Agriculture

11	Wicha et al (2017) [11]	✓ Water Management	✓ Soil level ✓ Temperature	✓ Wi-Fi	✓ Efficient water management.	✓ High water consumption.	✓ Managed water system effective manner.	✓ Reveals the positive comparison results from the adaptive Wetting Front Detector (WFD).	✓ Agriculture
12	Rajakumar et al (2017) [12]	✓ Crop production	✓ Soil level ✓ Soil nutrient	✓ Mobile technology	✓ Increase the crop production. ✓ Can get current fertilizer requirements.	✓ Due to improper maintenance, the crop becomes damaged which causes a huge loss for a farmer.	✓ Enhance the crop. ✓ Control the agricultural product costs.	✓ Interfacing different soil nutrient sensors.	✓ Agriculture
13	Sachapara et al (2017) [13]	✓ Crop Production ✓ Water Management	✓ Temperature ✓ Humidity ✓ Soil ✓ moisture ✓ Leaf wetness ✓ Wind speed/direction ✓ Rainfall detection ✓ Soil ph. ✓ Seed recognition.	✓ Raspberry pi ✓ Mobile technology	✓ Enhanced crop production. ✓ Enhanced quality. ✓ Reduced costs.	✓ Poor risk management. ✓ Poor water management. ✓ Poor infrastructure. ✓ Poor crops yield and big loss for farmers.	✓ Enhanced crops yield by proper water management.	✓ Seed recognition system helps to know sustainable environmental conditions.	✓ Agriculture
14	Pooja S et al (2017) [14]	✓ Weather Monitoring ✓ Precision Farming	✓ Temperature ✓ Humidity ✓ Soil ✓ Moisture ✓ Light intensity	✓ Raspberry-Pi ✓ Wi-Fi	✓ Improve the crop traceability. ✓ Increase overall yield.	✓ Wastage of crops. ✓ Poor water system management.	✓ Crop productivity increased. ✓ Reduced wastage of crops. ✓ Reduced water use. ✓ Minimal maintenance required. ✓ High accuracy	✓ Use of decision making algorithm.	✓ Agriculture
15	Kavitha et al (2017) [15]	✓ Crop management	✓ Soil moisture ✓ pH level ✓ Temperature ✓ Humidity ✓ Light intensity ✓ Water level	✓ Mobile technology	✓ Improved crop growth. ✓ Efficient watering system.	✓ Difficulties in monitoring. ✓ Harvesting related problems. ✓ Poor crop growth. ✓ Poor power management. ✓ Poor water management.	✓ Effective water management. ✓ Effective power management.	✓ Reduced costs between central server and software.	✓ Agriculture
16	Jawahar et al (2017) [16]	✓ Crop management ✓ Water Management	✓ Temperature ✓ Humidity ✓ Soil moisture ✓ Water level	✓ Mobile technology	✓ Prevent crops from spoilage during rain. ✓ Recycling rain water in an efficient manner.	✓ Wastage of water. ✓ Human interaction. ✓ Hard to monitor field every time to avoid intrusion attacks.	✓ Update farmer with live condition of the field. ✓ Lessen human interaction. ✓ Notify intrusion detections with an alarm.	✓ Excess water from the cultivation field and recycled back to the tank.	✓ Agriculture

17	Nibi K V et al (2017) [17]	✓ Whether management ✓ Crop management	✓ Soil moisture ✓ Temperature ✓ pH level	✓ Mobile technology ✓ Wi-Fi	✓ Provide advice for farmers to properly grow and treat the crops. ✓ Provide suggestions to monitoring crops. ✓ Ex: Irrigation timings ✓ Optimum usage of fertilizers. ✓ Provide whether information.	✓ High human interaction. ✓ Hard to deal with changing whether parameters.	✓ Provide efficient suggestions about when and how mush to irrigate. ✓ Provide adequate fertilizer information.	✓ Provide farmer friendly alerts and guidance with their local language.	✓ Agriculture
18	Tran et al (2017) [18]	✓ Crop management ✓ Nutrient Detection	✓ Temperature ✓ Humidity	✓ ZigBee ✓ Raspberry Pi	✓ Could prevent soil erosion.	✓ High energy consumption. ✓ Soil and nutrient depletion.	✓ Reduced energy consumption. ✓ Could react changes in environment and soil.	✓ Reduce the consumption of energy ✓ Increase the number of sensors	✓ Agriculture
19	Muhammad et al (2017) [19]	✓ Water Management	✓ Water level ✓ Soil Moisture	✓ Wireless Sensor Network ✓ Radio Communication	✓ Efficient water management.	✓ Climate changes. ✓ Scarcity of water.	✓ Monitoring water in watercourses.	✓ Smart water metering system.	✓ Agriculture
20	Viswanathan et al (2017) [20]	✓ Crop management. ✓ Warehouse Management.	✓ Temperature ✓ Humidity ✓ Soil Moisture ✓ Rain fall ✓ Light intensity	✓ Wi-Fi	✓ Remote controlled processes to perform such tasks as; ✓ Spraying ✓ Weeding ✓ Bird and animal scaring ✓ Keeping vigilance ✓ Provide smart warehouse management. ✓ Theft detection in warehouse.	✓ High cost ✓ Human interaction for all activities.	✓ Reduced cost. ✓ Lessen human interaction. ✓ High reliability. ✓ Improved crop production.	✓ Smart warehouse management.	✓ Agriculture
21	Dai et al (2017) [21]	✓ Water Management ✓ Agricultural Greenhouse Management	✓ Soli environment: ✓ Temperature ✓ Humidity of soil ✓ Soil CO2 ✓ Soil pH ✓ Environmental: ✓ Temperature ✓ Humidity ✓ Wind speed ✓ Air pressure ✓ Rainfall	✓ ZigBee	✓ High irrigation efficiency. ✓ High flexibility.	✓ Low irrigation efficiency ✓ High labour cost ✓ Low precision ✓ High water consumption.	✓ Lessen labour cost. ✓ Reduced water wastage.	✓ Powerful servers to handle storage data.	✓ Agriculture
22	Yuan et al (2017) [22]	✓ Agricultural Greenhouse Management	✓ Temperature ✓ Humidity	✓ ZigBee	✓ More flexible. ✓ Low power consuming.	✓ Short distance communication. ✓ High power consumption.	✓ Lessen power consumption.	✓ Automated greenhouse management.	✓ Agriculture

23	Garcia et al (2017) [23]	✓ Water Management ✓ Energy Management	✓ Irrigation evets as: ✓ Flow level ✓ Pressure level ✓ Wind speed	✓ LoRa ✓ Wi-Fi	✓ Low cost irrigation control. ✓ Autonomous decision making without human interactions.	✓ Device scalability is low. ✓ Device manageability is low.	✓ Lessen human interaction. ✓ Efficient water management. ✓ Efficient power management.	✓ Autonomous decision making without human interactions.	✓ Agriculture
24	Janani V et al (2017) [24]	✓ Soil Management ✓ Nutrient Detection	✓ Soil Measures: ✓ Soil pH ✓ Soil Temperature ✓ Soil Humidity	✓ Wi-Fi ✓ Raspberry Pi	✓ Reduced manual monitoring of the field. ✓ Obtained nature of soil. ✓ Can monitored from anywhere.	✓ Manual field monitoring. ✓ Cost is high. ✓ Difficult to predict the crop for the field.	✓ Reduces the difficulty for identify the right crop for the field. ✓ Increased agricultural production ✓ Reduced time and money for farmers.	✓ Soli management with the attention of nutrient, fertilization.	✓ Agriculture
25	Jyothi et al (2017) [25]	✓ Crop Management	✓ Temperature ✓ Humidity	✓ Wi-Fi ✓ GPRS	✓ Provide accurate changes in the crop yield. ✓ Advance the harvest of the crop.	✓ Reduced human power. ✓ High cost. ✓ High power consumption.	✓ Automated monitoring of the crop. ✓ Notify corrective actions to be taken. ✓ Low cost. ✓ Consume less Power.	✓ Notify agricultural fields with a MMS to the farer.	✓ Agriculture
26	Javale et al (2017) [26]	✓ Water Management	✓ Soil moisture ✓ Soli temperature ✓ Soil pH ✓ Soil water level	✓ Mobile technology	✓ Help to irrigate farms efficiently. ✓ Lessen human interaction.	✓ Water scarcity ✓ Human interaction is high.	✓ Estimates water as per requirements. ✓ Depending on soli and crop, fertilizer suggestions provided. ✓ Estimate the rainfall based on whether forecast. ✓ Manage water level according to the predicted rainfall.	✓ Water supply can control by mobile application with the less human interaction.	✓ Agriculture
27	Sathyadevan et al (2017) [27]	✓ Soil Quality Management ✓ Water Management	✓ Temperature ✓ Humidity ✓ Soil moisture ✓ Water level	✓ ZigBee ✓ Wi-Fi ✓ Mobile technology	✓ Accurate measurements of the velocity of the liquid flowing inside the pipe. ✓ Pump monitoring.	✓ Water conservation. ✓ High labour cost. ✓ High electricity consumption. ✓ Overdependence on the chemical fertilizers.	✓ Automated water management. ✓ Lessen labour cost. ✓ Lessen power usage.	✓ Multiple sensor data collected into IoT framework.	✓ Agriculture
28	Kulkarni et al (2017) [28]	✓ Soil management ✓ Water Management	✓ Soil moisture ✓ Soil pH	✓ Android ✓ Wi-Fi	✓ Decreased cost in manufacturing. ✓ Reduced cost in maintenance.	✓ High chemical fertilizer use. ✓ High energy consumption. ✓ High fertilizer costs.	✓ Save water more efficiently. ✓ Increase the crop yield. ✓ Save energy costs. ✓ Save fertilizer costs.	✓ Monitor and control plant growth parameters. ✓ Replaces the current system for soil moisture, pH and salinity value testing.	✓ Agriculture
29	Mahalakshmi et al (2016) [29]	✓ Water Management	✓ Temperature ✓ Humidity ✓ Soil Moisture	✓ ZigBee	✓ Monitor crop field. ✓ Automate	✓ Water consumption is high.	✓ Continuous field monitoring	✓ Reduced water consumptio	✓ Agriculture

		✓ Crop Management	✓ Light Intensity		the irrigation system.	✓ High human interaction.	with the help of low-cost sensors. ✓ Reduces water consumption. ✓ Reduced power consumption. ✓ Increased crop productivity. ✓ Reduced wastage of crops.	n up to great extent.	
30	Zaman et al (2016) [30]	✓ Water Management	✓ Moisture level ✓ Light intensity	✓ Raspberry Pi ✓ Wi-Fi ✓ (Mobile Technology	✓ Detect appropriate time for water supply. ✓ Keep track of water level.	✓ Cannot predict the time for watering.	✓ Improved productivity. ✓ Low cost. ✓ Utilize water resources. ✓ Lessen human interaction.	✓ With the enhanced sensor technology will become more efficient.	✓ Agriculture
31	Biradar et al (2017) [31]	✓ Water Management ✓ Crop management	✓ Temperature ✓ humidity ✓ Soil PH ✓ Evapotranspiration	✓ Wireless Sensor network ✓ Mobile technology ✓ ZigBee ✓ RFID	✓ Helps for decision making process ✓ Can monitor and control the temperature, humidity and soil PH. ✓ It can sense the amount of the change through the integration process of components. ✓ Reduce cost	✓ Unequal distribution of rain water ✓ Differentiation of weather condition. ✓ Different soil types	✓ Crop management by providing required amount of water. ✓ Multidisciplinary monitoring leads to improvement of agricultural management.	✓ Decreases in the cost of sensors ✓ Increasing difficulty of big data analysis	✓ Agriculture
32	Ismail et al (2017) [32]	✓ Soil moisture level monitor	✓ Soil moisture ✓ Water content ✓ Temperature	✓ Wi-Fi	✓ Farmers can face the any environmental challenges easily. ✓ Reduce the harmful risk percentage ✓ Save money and water. ✓ Reduce pest population.	✓ Climatic change. ✓ Take long time to harvesting. ✓ Burnings in land preparation. ✓ Limitation of space.	✓ Monitor and control the soil moisture from the web server.	✓ Decreases in the cost of sensors and actuators. ✓ Recycling the resources.	✓ Agriculture
33	Amandeepet al (2017) [33]	✓ Machines for routine operations ✓ Ware house management.	✓ Soil moisture ✓ Temperature ✓ Humidity ✓ Water level	✓ ZigBee ✓ Mobile technology ✓ Wi-fi	✓ Increasing the crop productivity . ✓ Prevent thefts. ✓ Prevent attacking from birds, animals and other facts.	✓ Manual distribution of seeds. ✓ Pattern of two crops year. ✓ Unscientific system of cultivation. ✓ Unequal watering system.	✓ Using remote control vehicle keeps monitoring the humidity, soil condition and water level in the field.	✓ Improve the green energy concept for better productivity	✓ Farming
34	Dolci (2017) [34]	✓ Precision farming ✓ Prescriptive farming	✓ Temperature ✓ humidity ✓ Soil PH ✓ CO2	✓ Mobile technology	✓ Cost reduction ✓ Reduce the frequency	✓ Unequal distribution of air flow.	✓ Improving malt quality and efficiency in production with using Artificial Intelligence	✓ low cost sensors ✓ open source ✓ applications ✓ ability to increase the level of farming	✓ Farming

								sophistication	
35	Gokul et al (2017) [35]	✓ Livestock management ✓ Smart lightening ✓ Smart ventilation ✓ Water management	✓ Temperature ✓ humidity ✓ Milk production	✓ Mobile technology ✓ Wi-Fi	✓ Identifying the emergency conditions. ✓ Improves location tracking. ✓ Improves cattle health ✓ Improves availability	✓ Unable to detect illnesses early. ✓ Different environmental conditions ✓ Irregular feeding	✓ Make ✓ Infrastructure of cattle farming smarter. ✓ implement a noninvasive ✓ wearable to track physiological and biological activities of cattle.	✓ Improve the smart lightning and ventilation system	✓ Farming, Agriculture
36	Rajkumar et al (2017) [36]	✓ Irrigation management	✓ Temperature ✓ humidity ✓ Soil Moisture	✓ Mobile technology ✓ Wi-Fi	✓ Provides real time information ✓ Cost reduction ✓ Resource optimization ✓ Reduce water logging and shortage	✓ Water shortage ✓ Different environmental conditions	✓ ✓ Developing smart irrigation system to monitor at anywhere.	✓ Installing a water meter to estimate the amount of water. ✓ Using Wireless sensors.	✓ Agriculture
37.	Sri et al (2017) [37]	✓ Crop management ✓ Irrigation management	✓ Soil ✓ Temperature ✓ Humidity ✓ Rain fall ✓ Fertilizer efficiency	✓ Wi-Fi ✓ GPRS ✓ Zig Bee ✓ Raspberry pi ✓ Mobile technology	✓ ✓ Improve the yield ✓ Low cost	✓ Unpredictable weather ✓ Water scarcity ✓ Improper water usage	✓ ✓ Providing reliable and efficient agricultural system to monitor the field	✓ Improve ✓ by adding several modern techniques like irrigation ✓ Method, solar power source usage.	✓ Agriculture
38.	Rajarsri et al (2017) [38]	✓ Water management	✓ Water level	✓ Mobile technology	✓ Improve the efficiency ✓ Optimize resource ✓ Maximize the profit	✓ Unequal water distribution	✓ Build a well-connected farming network and create a knowledge sharing platform.	✓ Agro loan ✓ Inexpensive Agricultural consultation ✓ better ROI ✓ Agro networking ✓ Low cost products	✓ Agriculture
39.	Ruengittinun et al (2017) [39]	✓ Smart farming	✓ Temperature ✓ Humidity ✓ PH ✓ Electrical conductivity	✓ Wi-Fi	✓ Can farm in less space ✓ Provides many products	✓ Differential of temperature ✓ Lack of time to manage and plant.	✓ Build a smart hydroponic eco system	✓ Symmetrical ✓ plantation to check the accuracy of the HFE across multiple ✓ farms in the same area.	✓ Farming

40 .	✓Yoon et al (2018) ✓[40]	✓Smart farming ✓Irrigation management	✓Temperature ✓Humidity ✓CO2 ✓	✓Bluetooth ✓Wi-Fi ✓LPWAN ✓	✓can overcome distance ✓and place constraints. ✓save maintenance cost of existing devices ✓provide ✓compatibility with new devices	✓Power problem ✓Space limitation ✓difficulties in installing additional devices	✓Build a system with using Bluetooth and LPWAN to solve the power problem and space limitation.	✓System for studying the development of environmental ✓Algorithms .	✓Farming, Agriculture
41	Ezhilazhahi et al (2017) [41]	✓Smart Farming	✓Plant health ✓Soil Moisture ✓Temperature ✓Humidity	✓WSN ✓Zig Bee ✓Wi-Fi ✓Raspberry pi ✓GPRS	✓Enrich the productivity of food grains. ✓Prevent the plant from blight and harmful ✓insects.	✓water scarcity ✓unpredictable weather conditions	✓Developing a system to monitor continuously soil moisture of the plants.	✓Increasing the number of sensors.	✓Farming
42	Tanmayee (2017) [42]	✓Crop management	✓Temperature ✓Soil Moisture	✓Raspberry pi ✓Mobile technology	✓Reduces the wastage of pesticides ✓Reduces the human effort ✓Increase agricultural productivity	✓Bacterial diseases ✓unpredictable weather conditions	✓Implementing a rice crop monitoring System	✓Using multicolor detection for detect the disease in any stage.	✓Agriculture
43	Takecar et al (2017) [43]	✓Machines for routine operations	✓Soil Moisture ✓Temperature ✓Humidity	✓Wi-fi.	✓Increase the income ✓Cost reduction	✓Lack of Resource Management	✓Implementing a system to look after the plantation without disturbing busy schedule.	✓Improve the components in the PATRIOT system	✓Farming
44	Krishna et al (2017) [44]	✓Smart Farming ✓livestock management	✓Soil Moisture ✓Light intensity ✓Humidity ✓Temperature ✓Soil pH	✓Raspberry pi ✓Zig Bee ✓Wi-Fi	✓Reducing labor costs ✓Helps to ✓track the changes accurately occurring instantly in real time at the field.	✓lack of moisture in the fields ✓salinity ✓lack of application of fertilizers ✓Different sowing time.	✓Using wireless mobile robot performing various operations of the field.	✓Develop the capabilities of the robot.	✓Farming
45	Li et al (2017) [45]	✓Irrigation management ✓Greenhouse management	✓Humidity ✓Temperature	✓Zig Bee ✓Wi-Fi ✓Bluetooth ✓LAN	✓Reduce the labour cost. ✓Improve the efficiency of agricultural production.	✓low production efficiency ✓Waste of ✓resources ✓Environmental pollution.	✓Green house management to improve the agricultural production.	✓Implement a comprehensive promotion system.	✓Agriculture
46	Suciu et al (2016) [46]	✓Smart Farming	✓Temperature	✓Mobile technology ✓GPRS	✓Improve the quality and safety of the products ✓Detecting plant diseases, flood. Etc.	✓Climatic change ✓High temperature ✓Low profit margin	✓Assist for crop management by using smart agriculture	Allowing system to measure basic parameters for irrigation management.	✓Farming
47	Putjaika et al (2017) [47]	✓Intelligent farming	✓Humidity ✓Temperature ✓Soil moisture ✓Light intensity	✓Wi-Fi	✓Improve the production process ✓Managing resources	✓Unpredictable weather	✓Implement a system to monitor the harmful diseases.	✓Developing the sensor and control system by adding more components.	✓Farming

48	Okayasu et al (2017) [48]	✓Growth measurement	✓Humidity ✓Temperature ✓Solar radiation ✓CO2	✓Wi-Fi	✓Reduce production cost ✓Improve the quality of the products	✓High production cost ✓Less quality in products	✓Monitoring the plant growth measurement using smart agriculture.	✓Improve the accuracy of measurements.	✓Farming
49	Sreekantha et al (2017) [49]	✓Irrigation management. ✓Greenhouse management	✓Temperature ✓Soil moisture ✓Weather ✓Fertility of soil	✓Zig Bee ✓Mobile technology ✓Wi-Fi	✓Detection of seed, water level, pest, animal intrusion to the field. ✓Reduce cost and time ✓Enhance productivity	✓Environmental changes ✓High water consumption	✓Enhance the productivity by using crop monitoring system.	✓generalize event-condition-action ✓framework for programming reactive sensor networks	✓Agriculture
50	Rajendrakumar et al (2017) [50]	✓Water management ✓Crop management	✓Soil moisture ✓Temperature ✓Humidity ✓Soil pH	✓Mobile technology ✓Wi-Fi	✓Increase harvest efficiency ✓Decrease water wastage	✓Uncertain monsoon ✓Water scarcity ✓Climatic variation	✓Providing information to understand how to monitor and control the data remotely and apply to the fields.	✓Develop multiple systems.	✓Agriculture
51	Ferreira et al (2017) [51]	✓Smart Farming ✓Machines for routine operations	✓Temperature ✓Soil pH ✓Oxygen flow	✓Mobile technology	✓Improve the production.	✓Climate changes. ✓Insufficient available lands. ✓Air toxins.	✓Researching modules ✓related to IoT, event processing, situational awareness and data ✓harmonization	✓Developing all the apps and experiment with real cases.	✓Farming
52	Vernandhes et al (2017) [52]	✓Livestock management	✓Temperature ✓Humidity ✓Light	✓Mobile technology ✓Wi-Fi	✓Improve the cultivation	✓Limited lands. ✓Water scarcity	✓Smart aquaponic system to monitor and control cultivation	✓Increase the manual response speed.	✓Farming
53	Vaughan et al (2017) [53]	✓Livestock management. ✓Farm management.	✓Animal Weight	✓Mobile technology	✓Can monitor the performance of their animals. ✓Improve the livestock production	✓Weather condition ✓Maintaining balance ✓Large number of measurements.	✓Gaining data under the hostile conditions of a livestock farm.	✓Upstream and downstream the supply chain.	✓Farming
54	Padalalu et al (2017) [54]	✓Water management	✓Temperature ✓Humidity ✓Light ✓CO2 ✓Soil pH	✓Mobile technology	✓Conserve water ✓Avoidance of constant vigilance. ✓Remote automation	✓Water scarcity ✓High power consumption	✓Implementing system to to make the ✓irrigation system smart, autonomous and efficient	✓Estimate the irrigation cost. ✓Introducing wireless sensor. ✓Automatic watering	✓Agriculture
55	Bellini et al (2017) [55]	✓Cattle detection management	✓Temperature ✓Milk consumption	✓LoRa	✓Increase milk production	✓Heat detection ✓Intensification management techniques	✓By collecting activity data for heat detection for the cattle.	✓Developing power reduction systems.	✓Farming
56	Cambra et al (2017) [56]	✓Energy management ✓Water management	✓Temperature ✓Humidity	✓WSN ✓Mobile technology ✓LoRa ✓Zig Bee	✓Energy efficiency ✓Reduction in fertilizers in products ✓Saving water	✓Scalability ✓Manageability	✓Implement a smart communication system to monitor the agriculture	✓Developing irrigation services system in the domain of agricultural decision systems	✓Agriculture
57	Moon et al (2017) [57]	✓Smart farming	✓Temperature ✓Humidity ✓Rain fall ✓Wind speed	✓Wi-Fi	✓Improve crop yield. ✓ Reduce unnecessary	✓Managing big data	✓Applying lossy compression on IoT ✓big data.	✓Use lossy compression techniques	✓Farming

					costs.			✓ to reduce the high cost of data storage and transit	
58	Raghudathesh et al (2017) [58]	✓ Poultry management	✓ Temperature ✓ Humidity ✓ Light intensity ✓ Air quality	✓ Raspberry pi ✓ Wi-Fi	✓ Increases poultry ✓ production. ✓ optimizes resource utilization. ✓ Saves time ✓ Reduces human intervention	✓ High cost ✓ Maintenance of labour ✓ Wrong knowledge in farming practices.	✓ Develop a poultry management system using low cost commodity hardware and open source ✓ software	✓ Making wireless communication between sensor module and coordinator .	✓ Farming
59	Maina (2017) [59]	✓ Livestock management ✓ Smart farming	✓ Temperature ✓ Size of the cattle ✓ Activity of the cow	✓ RFID ✓ Raspberry pi	✓ Improve productivity ✓ Can effectively detect heat	✓ Heat detection ✓ Death of livestock	✓ Use prototype sensor to detect the activity of cow.	✓ Improving the system capability to detecting cow activity in real time	✓ Farming
60	Memon et al (2016) [60]	✓ Water management ✓ Waste management	✓ Temperature ✓ Humidity	✓ Wi-Fi ✓ LAN	✓ Provide required feed and water. ✓ Exhaust the excess of biogas of animals ✓ Surveillance of the entire farm	✓ Stock theft	✓ Develop a system to control and monitor the farm remotely	✓ Improve the features of the smart system	✓ Agriculture

IV. Discussion

In this review we have identified important attributes to analyse the research findings in agriculture and farming processes. We have gathered and analyzed data by using 60 recent scientific articles. Our survey shows the most researched sub-verticals are water management, crop management and smart farming. Water management is the most researched sub-vertical for the last few years as most countries mainly focus on the utilization of water resources due to its lack of abundance [61]. Irrigation patterns in agriculture influence crop production making irrigation management a central focus to increase productivity [8], [10]. The second most considered sub-vertical is crop management due to the importance of producing food for a growing global population. It is important to manage the quality, quantity and effectiveness of the agricultural production for sustainability [13]. Although a study [18] discussed that the widely used sensor data collections for measurements are soil conditions as pH and humidity, as per our analysis it shows environmental temperature followed by humidity and soil moisture are the most commonly measured data.

IoT can further be defined as a fusion of heterogeneous networks including chip technology that scopes gradually more and more, expanding due to the rapid growth of Internet applications such as logistics, agriculture, smart community, intelligent transposition, control and tracking systems. According to researchers' analysis, in 2020 IoT objects will be semi-intelligent and an important part of human social life [46]. As analyzed in our review Wi-Fi,mobile technology are the technologies which have a wide range of demand in agriculture and farming domain to monitor land and water resources in contrast to other technologies [33], [35]. Although our results demonstrate the results in such a way, a study [62] analyzed that use of RFID, a Wireless Sensor Network (WSN) technology that can be effectively used to increase the crop production to meet the growing needs of the increasing population. In developing countries with limited Internet speed, the other IoT technologies utilised rather than Wi-Fi include Low-Power, Short-Range IoT Networks, low-rate wireless PAN (LoRaWAN) or Low-Power and Wide-Area Networks.

Further research [61] shows that WSN is used in many applications such as health monitoring, agriculture, environmental monitoring, and military applications whereas our study demonstrates the agriculture sector using IoT in and farming sector using IoT. Our observations show that Agriculture is the primary source of income in developing countries, such as India with the sizeable geographical area when comparing with other countries [9].

Most of the research studies have performed on water management by monitoring such environmental parameters as temperature, humidity and soil moisture [1], [3], [5], [19], [25]. Many of the findings have focused on better water utilization, reduction inhuman intervention and the cost of production [18], [27]. Future research could draw more attention to further automate current processes in waste management, smart lightening and pest controlling sub-verticals by reducing existing drawbacks since it has received the least research attention in the considered period. Fog computing, as an innovation with cross over any barrier between remote data centres and IoT devices, should be considered in future IoT analysis [63], [64], [65], [66], [67]. While IoT has solved many issues related to agriculture and farming there are limitations that we need to consider. Lack of interoperability and compatibility in devices, network flexibility issues when more devices are connecting, and sensor lifetime is some of the limitations to be addressed in future research.

This study has found that industry 4.0 in agriculture focuses on IoT aspects transforming the production capabilities including the agricultural domain. This study has [68] considered soil quality, irrigation levels, weather, the presence of insects and pests as sensor data. Some of the significant aspects they have been researched are the driver's assistance to optimise routes and shorten harvesting and crop treatment while reducing fuel consumption CISCO [69]. Producing enough food for the entire world is a big challenge since the global population is rapidly changing as well as climate change and labour shortage. Currently researchers have focused more on robotics to address these problems. A growing number of researchers and companies have focused on Robotics and Artificial Intelligence (AI) to weeding by reducing the amount of herbicide used by farmers.

In contrast to edge computing, cloud computing requires a high-speed internet connection with sending and retrieving data from the cloud. As the process involves transferring and receiving data from the cloud, the process is time-consuming. Since the data capacity is higher than bandwidth, it is always essential to process data locally instead of sending data to the cloud. Edge computing is more efficient than cloud processing when processing data since the capacity doubles faster than the bandwidth doubles [70]. Since IoT uses sensor data collection for decision making, to process collected data, the cloud, or the edge based can be used on the system requirements.

Still, there are some challenges associated with IoT system deployment. Connecting so many devices to the IoT network is the biggest challenge in the future following lack of technical knowledge among farmers, current centralised architecture to support IoT systems is not much advanced as the growth of the network, centralised systems will turn into a bottleneck. Moreover, sensor battery capacity and lifetime and sensor data storage also more concentrated when IoT system deployment. Smart farming is the association with new advancements in technologies and the different crop and livestock, agriculture and farming in the digital age. Smart farming can deliver agriculture more beneficial for the farmer. This is because decreasing input resources will save farmers' money and labour, and hence, will increase reliability [71] and business outcome [72], [73].

Furthermore, studying diverse approaches for fog computing structure [63], decision making using prediction or pattern analysis [74], [75], [76], big data databases [77] could be an exciting way to make the Internet of Things (IoT) into the future dominating technology.

This survey will fill the gap by the identification of the different IoT sub-verticals and data collections for the measurements in the agriculture and farming process. Results are clearly showing that most considered sub-verticals and data collections for measurements in the field of agriculture and farming. Our study also indicates the technologies used for IoT application development in the reviewed period. To summarise this survey, this has broader knowledge about IoT applications developed for automating the agriculture and farming process. Moreover, this study identifies most considered sub-verticals, collected sensor data and technologies for the development of IoT based applications in agriculture and farming sector towards the significant improvement of the business.

Table II shows the other necessary data collection criteria which were not included in all studies.

TABLE II. IMPORTANT DATA INCLUSION CRITERIA FOR FUTURE IOT STUDIES

Criteria	Information to be Collected in IoT Domain	Addressed in this Review	To be Addressed in Future Research
IoT Sub Verticals	What are the sub-areas addressed?	✓	✓
Measures (Data Collection)	What sort of sensor data collected for measurements?	✓	✓
Technologies Used	Used technologies to develop or to solve problems.	✓	✓
Benefits of Proposed System	Advantages of having the system to address existing issues.	✓	✓
Challenges in Current Approach	Existing issues and problems in the current systems and methods.	✓	✓
Solution for Current Issues	Proposed solution to solve the issues in the current problems.	✓	✓
Drivers of IoT Countries	What are the novelty and future aspects of the proposed systems and methods?	✓	✓
IoT systems' Scalability	Number of sensors are deployed, a variety of sensors, amount of data collection (volume), speed (velocity) of data collection (days-hours, hours-minutes, seconds-microseconds)	x	✓
Heterogeneity Aspects	Are sensors and underlying technologies uniform or heterogeneous in the system?	x	✓

System Architecture	Complex is the adopted IoT architecture, sensors topology, information about intermediate gateways	x	✓
Data Analysis Methods	Business intelligence, Artificial Intelligence, learning algorithms (machine Learning algorithms, Deep learning), big data technologies (Hadoop, Spark) and other protocols	x	✓
Observed System	Size or scale of the observed land or agricultural domain	x	✓
Access to Natural resources	Water resources and weather condition	x	✓
IoT Security and Threat Solutions / Protocols	Encryption techniques for IoT data access, Vulnerable identity (change default passwords), self-error detection and possible cyber attacks	x	✓
Operational Technology	Control and automation hardware, controllers, sensors and actuators	x	✓
Data Storage and Cloud Platform	Public Cloud, Private Cloud, Hybrid Cloud, Cloud (data at rest and centralized data center), Fog (data in motion and distributed data center) or Edge computing	x	✓
Power Supplies	Battery, AC power, and other protocol to optimize energy savings	x	✓

V. Conclusion

From our observations from the 60 peer-reviewed publications (2016–2018) in discussing the potential applications of the Internet of Things, it was found that water management is the highest considered IoT sub-vertical followed by crop management, smart farming, livestock management, and irrigation management with the same percentage. As per the observation, the most critical sensor data collection for the measurement is environmental temperature, environmental humidity and also there are some other such sensor data also gathered for IoT applications as soil moisture and soil pH. Wi-Fi has the highest demand of usage in agriculture and farming industry, followed by mobile technology. Other technologies as ZigBee, RFID, Raspberry pi, WSN, Bluetooth, LoRa and GPRS have less demand in the agriculture and farming sectors. When compared to the agricultural sector, farming industry has a lesser percentage amount using IoT for the automation. This survey could be useful for researchers for finding new ways and solution to challenge in the current agricultural era and for agricultural and farming industries to make the automation process more effective and efficient, consequently, to obtain the good businesses outcome.

Authors' profile

R.M., S.W., and M.N.H. conceived the study idea and developed the analysis plan. R.M. and S.W. analyzed the data and wrote the initial paper.

M.N.H. helped to prepare the figures and tables and finalizing the manuscript. R.M. completed the final editing and figures of the manuscript. All authors read the manuscript.

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