Adoption of Novel Technologies to Boost Precision Agriculture (BPA) using Internet of Things (IOT)

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Abstract. Precision Farming (PF) or Precision Agriculture (PA) is a management of farming that uses modern technology to ensure that the soil gets what it needs to remain crop healthy for producing good productivity. Precision agriculture uses various ICT technologies such as Sensors, Actuators, GIS software, GPS, Variable Rate Technology, Robotics, Drone and other aerial imagery. Agriculture is important to our country's economic structure since it provides food, raw resources, and job opportunities to a big portion of the people. Previously farmers use the traditional approaches to cultivate the crops like without use of technological advancement for cultivating the crops, that reduces the farmers yield and profit. Now a day the farmers are coming forward to convert their farms from conventional approach to smart approach by using modern technologies. By using modern technological equipments, the farmers can monitor the crop cultivation and reduce the wastage of excess amount of input to the farms. With the help of drones we can know the status of the growth and condition of the crop which is cultivated in the farm filed, it reduces the human interventions. This paper discusses about the modern technologies based on Precision methodology, components involves in IOT with sensors, field in which the Precision farming is applied, where the Internet of Things used by precision agriculture and difficulties faced by farmers.

1 INTRODUCTION

Precision agriculture began in the early 1990s with the advent of GPS navigation for tractors, and the technology's adoption is now so prevalent around the world that it's perhaps the most widely utilized example of precision agriculture today. [1] The International Telecommunication Union (ITU) defined the IoT as “the network of physical objects or ‘things’ embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data”. A GPS-connected controller in a farmer's tractor directs the tractor automatically depending on field coordinates. This decreases driver steering errors and, as a result, any field overlap passes. It gives the result as less wasted seed, fertilizer, fuel, and time. Precision Agriculture is the use of modern technologies to operate a farmer's farmland with modern tools and help improve soil fertility and the farmer's economy. Agriculture should not be affected by the shortage of manpower and it will save time and labour by using the necessary tools. By using the novel technology with internet of things, devices and sensors will determine the nature, potential and nutrient deficiencies of

agricultural land. Global positioning systems, geographical information systems, grid sampling, variable rate technology, yield monitors, yield maps, remote sensors, auto-guidance systems, proximate sensors, computer hardware and software are some of the equipment used in precision farming.

[2] With the review of this paper shows that using the camera, sensors, drones and precision farming on the IoT device paves the way to save time and get higher yields. If the farmer is always at a loss, then the farmer is losing out due to untimely cultivation, untimely crop protection, unavailability of work personnel on time and depletion of crop pests and pesticide spraying. It is therefore necessary to provide awareness to the farmers about the need for modern tools and its benefits. Most of the farmers in India are cultivating manually without realizing the use and importance of technological tools. Modern unmanned aerial vehicles (UAVs) equipped with multispectral cameras, hyper-spectral sensors, and other unique instruments can enable rapid emergency responses and improve observation precision by providing high-throughput 3-D monitoring over a vast area. [3] This paper discussed about the new trends in precision agriculture and the overview of it. The farmer should come forward to increase the yield a lot in agriculture by using precision farming, improve the character of the land and protect the environment. [4] Here the sensors are equipped with agriculture land; data are collected for temperature, humidity and soil moisture. In this paper we analyze the technological overview of agriculture with effective use of modern tools in the field and yield good productivity with less labor cost. Precision agriculture is now possible for both small and large-scale agricultural operations thanks to technological improvements. Precision agriculture decreases agricultural waste while also lowering environmental effects. As a result, researchers believe precision agriculture is an effective strategy to address global food shortages.

2 ICT TECHNOLOGIES USED FOR PRECISION AGRICULTURE

Precision Farming is a technology-based approach to whole farm management. The above Fig.1 [5] shows the precision agriculture technologies and discussed in detail below with their benefits. Many groundbreaking precision agriculture technologies have been created over the previous few decades. Only a few examples are the Drones, Global Positioning System, Automated steering, Remote sensing, Geo-mapping, and Variable Rate Technology. When combined, this modern equipment provide a variety of high-resolution data on farm management operations like tillage, sowing, fertilization, pesticide application, and harvesting.

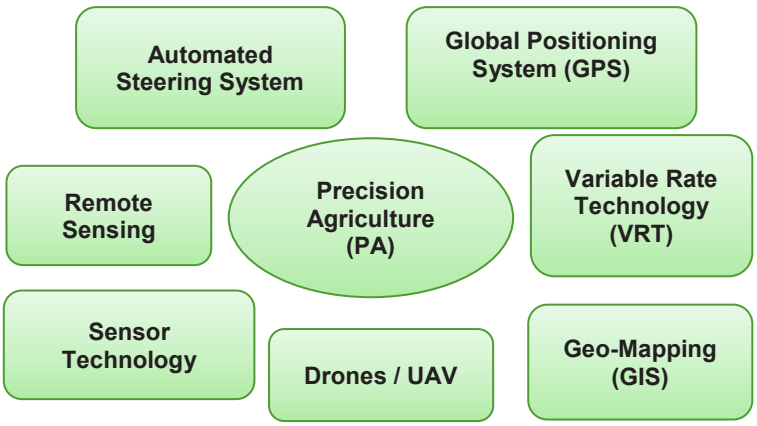

Fig. 1. Precision agriculture technologies

2.1 Automated steering system

The automated, hands-free steering technology integrates directly into the hydraulic system and provides the highest level of precision steering in any field. [6] In this study, researchers identified a 3–7% overlap reduction for auto-guidance systems, as well as the fact that agricultural input savings rise proportionally to un-overlapped area. [7] Automated steering system was discussed in detail with its schematic diagram. The automated steering technology keeps your vehicle on track with pinpoint accuracy. When your truck is disconnected from the internet, Autopilot instructs it to modify its position to follow the correct course, regardless of the field pattern or terrain type, so you can concentrate on the task at hand.

2.1.1 Benefits of automated steering system

- With one-inch repeatability, it provides automatic steering for the truck.
- For clear access to cab control, it integrates directly with the vehicle's hydraulics.
- For excellent accuracy on challenging terrain, terrain correction technology is used.
- Designed for the toughest row crop agricultural applications.
- Many guidance-ready vehicles can be connected, reducing the need for extra equipment.
- Fill out field applications in a timely and accurate manner.
- Operator fatigue is reduced, and safety is improved.
- Operate at any time of day or night, in dusty or low-visibility environments.

2.2 Global Positioning System (GPS)

GPS provides the facility to monitor and provide accurate location for the farmer to identify the field positions and can collect the conditions of the farm. Because of the combination of geographic information systems and global positioning systems, precision agriculture also known as site-specific farming and it has been developed and implemented. [8] One of the paper's key features is a sophisticated GPS-based remote controlled robot that can conduct activities like as weeding, spraying, moisture monitoring, bird and animal care, and vigilance. These technologies enable real-time data collecting to be integrated with accurate position data, allowing vast amounts of geographical data to be processed and analyzed quickly.

GPS, GIS, and remote sensing can provide the data needed to improve land and water utilization. Farmers can get even more advantages by combining improved fertilizer and other soil amendment use, estimating the cost-effective threshold for controlling insect and weed infestations, and protecting natural resources for future use.

2.2.1 Benefits of GPS in Precision Agriculture

- Depending on precise soil sampling, data collecting, and analysis, chemical treatments and planting density can be adjusted locally.
- Field navigation is precise.
- Working in low-visibility field situations is a must.
- Yield data has been monitored accurately.
- Human "flaggers" are no longer required.

2.3 Variable Rate Technology (VRT)

Variable Rate Technology (VRT) is a term used in precision agriculture to describe the application of a material where the rate of application is determined by the specific location or attributes of the area to which the material is being applied. This differs from uniform application in that it can save money (by using fewer products) and reduce environmental impact. [9] VRA or VRT is a Precision Farming application that optimizes crop management by using data on geographical and temporal change of specified soil or crop factors. Inputs are adjusted to meet site-specific requirements.

2.3.1 Benefits of Variable Rate Technology:

- The adoption of VRT has not only economic but also environmental benefits. These includes,
- Crop yield is improved by making the best use of available resources.
- Increased productivity and efficiency on the farm.
- Reduction in wasteful material consumption, resulting in increased efficiency and lower costs.
- Reduced over-application means less risk of run-off or unnecessary leaching.
- Excessive spraying is less likely, which could be hazardous to the environment.
- Water resource conservation and optimum utilization.

2.4 Remote Sensing:

The method of recognizing and monitoring an area with physical attributes by measuring reflected and emitted radiation from a distance is known as remote sensing. From satellite or aircraft user can take the input for the field to analyze the situations. [10] We evaluate the advancement of UAV-based remote sensing in scarcity pressure, unwanted plant and disease identification, nutritional status and growth vigour assessment, and yield prediction in this study. [11] Remote sensing is frequently utilized in Precision Agriculture in conjunction with geographic information systems and global positioning systems. By using modern technologies instead of traditional techniques the agriculturists can yield more benefits and can save inputs. Researcher can use the camera which is useful for capturing the image or video remotely with real pictures as like they appear in real in Earth.

2.4.1 Benefits of remote sensing in farming:

- Yield Sown Area Estimation.
- Normalized Difference Vegetation Index (NDVI).
- Crop Diseases Identification.
- Soil Properties.
- Flood Impact.
- Natural Catastrophe (NATCAT) Modelling.
- Drone Image Analysis for Crop Damage Assessment.

2.5 Geo-mapping/geographic Information Systems (GIS)

GIS applications in agriculture have become increasingly essential in agricultural production around the world, assisting farmers in improving output, lowering costs, and better managing their land resources. Agriculture GIS applications, such as agricultural mapping, are critical in the monitoring and control of soil and irrigation on each specific farm. By gathering and incorporating accurate information into a mapping environment, GIS provides the agriculture and agricultural mapping serve as critical tools for agricultural sector management. [12] GIS software for general-purpose use, such as ARCVIEW, IDRISI, and SURFER, has a lot of features, some of which aren't useful for PA applications. The majority of these packages is costly and requires computer platforms that most farmers do not have. The use of geographic information systems (GIS) in agriculture aids in the management and control of agricultural resources. GIS agriculture technology aids in the enhancement of current GIS agriculture and resource data acquisition and generation systems.

2.5.1 Benefits of geo-mapping:

- Cost reductions derive from increased efficiency.
- Ability to make better decisions.
- Communication has improved.
- Managing geographically.
- Improved archiving of geographic data.

2.6 Sensors

For precision agriculture, the sensor technology employed in this domain is highly effective, accurate, and productive. [13] Accelerometer sensor, Air Humidity sensor, Air Temperature sensor, Camera (PixyCam, Raspberry Pi), Capacitive Touch sensor, Depth (Microsoft Kinect 1 & 2), Force sensor, Indoor Localization (iBeacon), Light sensor, Proximity sensor, RGB Color sensor, Soil Moisture sensor. [14] Discusses the three types of sensors for variable rate sprayer for LIDAR, Ultrasonic and Infrared sensors.

2.6.1 Benefits of Sensors

- Agricultural sensors help farmers be more productive.
- It protects cultivable land from soil degradation.
- The usage of chemicals in excess has decreased.
- Water resources are being used more efficiently.
- Reduce the risk of water resources being depleted.
- Minimize risk of groundwater degradation.
- This field will provide jobs and provide opportunity for talented workers.

3 Components of Internet of Things

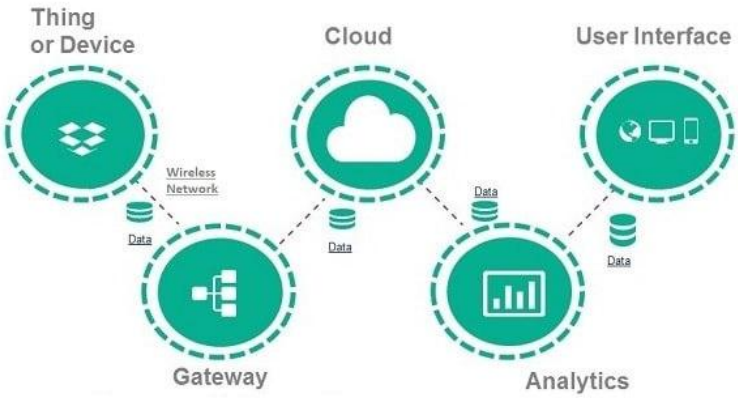

Fig. 2. Components of Internet of Things

[15] Fig.2 Shows about the components used in Internet of Things systems and the details were discussed in detail below;

3.1 Thing or Device

Devices and sensors make up the device connectivity layer. These smart sensors continuously collect data from the environment and send it to the next layer. Temperature and humidity sensors, pressure sensors, humidity / moisture level sensors, light intensity detectors, moisture sensors, proximity detection, and Radio Frequency Identification tags are some of the most commonly used sensors.
Wi-Fi, ZigBee, Bluetooth, Z-wave, LoRaWAN, and other low-power wireless networks can be used to connect most modern smart devices and sensors. [16] This comprehensive study is intended to provide a wealth of information to researchers, professionals, agriculturists, and policymakers working in the IoT and agricultural technology fields. [17] The goal of this research is to identify wireless communication technologies that are appropriate for PA applications. Low power consumption, long range, huge connection volume, and low cost are all characteristics of wireless communication systems that are appropriate for precision agriculture.

3.2 Wi-Fi (Wireless Fidelity)

Wi-Fi (Wireless Fidelity) is a networking technology that connects computers and other devices via a wireless signal. Any data will be transformed into digital data packets and sent over the network to connected devices. For a range of 0 to 100 meters, the IEEE 802.11 standard employs a bandwidth frequency of 2.4 GHz. The applications for the above standard include electronic devices such as mobile and smart devices.

3.3 Bluetooth

In terms of power consumption and execution, Bluetooth is a highly efficient technology. It's designed for short-range for a range of 0 to 10 meters; the IEEE 802.15.1 standard utilizes a

bandwidth frequency of 2.4 GHz. The applications for the above standard include wearable and smart devices.

3.4 Zigbee

IEEE designed the Zigbee wireless personal area network (WPAN) protocol, which is widely used in industrial applications. Wireless technologies such as Wi-Fi and Bluetooth are examples. For a range of 0 to 100 meters, the IEEE 802.15.4 standard employs a bandwidth frequency of 2.4 GHz. Internet of Things with sensor monitoring and industrial devices are examples of applications for the aforesaid standard.

3.5 LoRaWAN

In the field of IoT the wireless communication technologies called Low-Power Wide-Area Network (LPWAN) is used commonly. Using a centralized server unit, this technology will be utilized to link devices. Digital information will be delivered at various data rates over several frequency channels. The IEEE 802.15.4g standard uses bandwidth frequency of 2.4 GHz for the range of 0 to 20 kilometers. The applications for the above standard includes irrigation system with long range, Internet of Things, Industrial and Residential automation.

3.6 Z-Wave

Z-Wave is a wireless communication technology that was created with home automation in mind. It can be used to automate lighting controls and wirelessly collect data from sensors. For the range of 0 to 30 meters, the Z-Wave Alliance ZAD12837 / ITU-T G.9959 standard employs a bandwidth frequency of less than 1 GHz. The application for the above standard includes sensor technology and automation of home.

Technological advancements such as 5G and Internet of Things provide limitless opportunity for different technologies to meet a wide range of needs. Billions of devices are accommodated with wireless technology with reduced latency and increased security.

3.7 Gateway

Before transferring data from thousands of sensors to the next level, gateways can be set to do local pre-processing. [18] The gateways block is an intermediary block between the items and the network or cloud infrastructure for the purpose of connectivity. This connectivity may require in some cases due to TCP/IP protocol compatibility. By employing improved encryption technologies, Internet of things (IOT) gateways provides a side by side security for data which is transmitted over the network. It functions as a buffer between the devices and the cloud, protecting the system after mischievous occurrences and unapproved access.

3.8 Cloud

The significant volumes of data are generated from IOT devices, applications, and users which were handled successfully. In real time the Internet of Things cloud allows large volumes of data to be collected, processed, managed, and stored. To make an important or critical decisions and to have remote access for the cloud data we can use IoT cloud.

Networks of servers with complex high performance are designed to analyze billions of IoT devices at breakneck rates, manage traffic, and provide precise analytics. The distributed database management system (DDBMS) is one of the significant components of IoT cloud.

Some of the parts of systems for cloud are as follows as billions of devices can connect to cloud, sensors which sense the data, gateways, protocols, database to store data, and analytical graphs for data. Companies use problem solving data to improve their products and services, it takes some preventative actions in certain stages to build an accurate new business model.

3.9 Data Analytics for cloud data

Raw data are collected from billions of smart devices to convert into meaningful information for further research or to evaluate the data into research aspects. So, to manage and optimize the smart IOT system smart analytics are needed to build a smart devices. Real-time smart analytics, which allows engineers to recognize anomalies in collected data and respond promptly to avoid the catastrophic result, is one of most essential components of a well-designed IoT system. If information is acquired reliably and at the right moment, service providers can plan for the next steps.
To plan for future business opportunities, the corporate companies are analyzing the huge amount of information or data which are collected by IoT devices and utilizes it. Businesses can use cautious analysis to identify market developments and plan ahead for a successful implementation. Any business model requires information, and predictive modeling promotes efficiency with in necessary business line.

3.10 Interface for APIs

With the help of user interfaces, the humans can interact with the system efficiently and can make use of it effectively for further improvement. Software designers create a user interface that involves the small amount of effort from consumers for more interactions to engage them to encourage. Easy touch panel controls are designed with more interactive and dynamic designs for the user to play around the API interface more conveniently.
Now-a-days in domestic appliances hard switches are replaced with multicolor touch panels with new trending options in smart home gadgets. In today's market people are seeing the user interface rather than the functionality given in than gadgets. So user interface plays the main role in smart gadgets than the options or functionality. If new devices or smart gadgets are simple to use and compatible with common wireless protocols, users are more inclined to buy them.

3.11 Drones

The goal of implementing drone technology is to eliminate any uncertainty or assumption and instead focus on accurate and dependable data. Weather, soil conditions, and temperature are all important aspects in agriculture. Agriculture drones enable farmers to adapt to individual circumstances and make thoughtful decisions as a result. With the help of gathered data drones are able to analyze the following factors crop health, crop treatment, crop scouting, irrigation, field soil analysis and crop damage assessments. The drone survey increases crop yields while reducing time and costs. First step of drones is to analyze the field area where the crop is going to cultivate using GPS technology. Then the drones are allowed to fly above the field to capture the conditions and growth of the crop. After collecting required information using multispectral or RGB sensor, then the collected information will be sent to analyzing software for further processing.
With the advancement of technological enhancement the gathered data are fed into intelligent system to extract feature automatically using Machine Learning (ML) and Deep Learning

(DL) algorithms. [26] Describes about the adoption of technological growth in agriculture with advancement in traditional equipments.

4 DIFFICULTIES IN ADOPTING IOT IN AGRICULTURE BY FARMERS

We acquire tremendous benefits by implementing IoT in the agricultural sector, whereas IoT in agricultural industries still faces constraints. The constraints are absence of information, high implementation costs, and safety concerns are among the primary IoT challenges facing the agricultural sector. The majority of farmers are unaware of the use of IoT in agriculture. [19] Described about the challenges faced in Precision Agriculture with Internet of Things. The biggest concern is that some of them are resistant to new ideas and refuse to adopt them, even though they give several benefits. Showing farmers how to use IoT equipment like drones, sensors, and other technologies to make their tasks easier, followed by real-world examples, is the easiest approach to raise awareness of the Internet of Things' impact. The challenges are as follows as;

4.1 Lack of infrastructure

Agriculturalists will be incompetent to assistance from IOT machinery, even if they implement it, due to a lack of network set-up. For maintaining the equipment in the farm, sheds are built in rural areas with low network coverage. An agriculturalist needs continuous data from the infrastructure where the IOT device was deployed to monitor the system continuously for further action to be taken. So with the poor quality of infrastructure the data gathering is difficult for the user to identify the crop growth etc.

4.2 High Cost

Integrating IOT in agriculture necessitates the purchase of costly technologies. Sensors with minimum expensive module, but equipping every grower's field with them would cost more than $1,000. Farming management software, cloud data are included in the purchase to access their record; automatic machinery is further expensive than human-driven tools. Agriculturalists should use these machineries to increase their profits, but the cost of installing IOT devices on their farms is prohibitive.

4.3 Lack of security

Because IOT devices which is interacting with already installed equipment that has internet connectivity, accessing drone mapping data or sensor readouts over the public network is not guaranteed. Agriculture IOT equipment collects a lot of data, which is challenging to safeguard. Unsanctioned access to Internet of Things organizations' databases could lead to data stealing and management.

5 INTERNET OF THINGS APPLICATION IN AGRICULTURE

- Monitoring of Climate Conditions
- Precision Agriculture
- Greenhouse Automation
- Agricultural Drones
- Crop Management

- Predictive Analytics for Smart Farming
- Cattle Monitoring and Management
- End-to-End Farm Management Systems

[19] The few technologies in certain industrialized and developing countries were discussed in this research, as well as the disparities between them.

6 APPLICATION OF PRECISION AGRICULTURE USING INTERNET OF THINGS

Precision agriculture is a farming practice in which the farmer is only actively involved when there is a pressing need or an emergency, such as when the system malfunctions. IoT assists in preserving the established parameters required for day-to-day agricultural activities. [21] Precision Agriculture acts as a crop management system by using new technology for the whole farm basis instead of particular area of the field. Appropriate sensors attributes are tracked and it sends for remote monitoring. [22] This paper explains about the Internet of Things application in precision agriculture. Control functions, such as identifying and avoiding animal incursion in agriculture, can also be accomplished via the Internet of Things cloud. Sensors are a critical component of the Internet of Things (IOT) in precision agriculture since they make monitoring and control virtually impossible. IOT is employed in agriculture like data-storage technology for monitoring and controlling the IOT devices. The parameters like Soil quality, crop yield, regular performance data, and high temperature fluctuations are stored on the IOT cloud to help with analysis, forecast, and agricultural production decision-making.

7 CONCLUSION AND FUTURE ENHANCEMENT

This paper concludes with an overview of the Internet of Things and adoption benefits of novel technology utilized for Precision Agriculture, as well as the many sensors used in agriculture. Precision Agriculture plays the vital role by adopting novel technology in smart farming system with drones, sensors, GPS and GIS software. Collecting data from agricultural sensors from the field by drones are transferred to gateway through wireless networks (such as LoRaWAN, etc.), the local system will act as a coordinator for preprocessing the data by clearing the noise in data and passed to the cloud for further processing to predict or intimate the farmer to conclude the need for agriculture development using Internet of Things. Since its inception a few years ago, the Internet of Things has been expanding. New technologies and protocols are being combined to make the IOT ecosystem more reachable, profitable, energy-efficient, and safe. Because of the high demand in various industries, the Internet of Things will continue to develop.
[23] This study takes a fresh look at how farmers think about precision agriculture technologies, particularly the benefits they give. [24] This study shows the percentage of farmers adopted the drone's technology for their farms to prove the productivity and reduction of labours and water savings. [25] In this research an IoT-based control system was introduced for advancement in farming for rural areas was given in this research. This paper concludes the detailed view about advancement in traditional equipment with less human intervention, good profit and low costs cum less time consumption. In future the collected data can be visualized using intelligent system with the concept of Artificial Intelligent system. This adoption of drones systems are used in the field and the farmer can educate well with easy manner to use the intelligent system in future.

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