**A SURVEY ON WIRELESS TECHNOLOGIES,SENSORS AND DATA ANALYSIS IN PRECISION AGRICULTURE**

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*Abstract*— Precision Agriculture (PA) enables us to ensure food availability and helps farmers enhance crop yeild. Wireless Sensor Network (WSN) can improve the effectiveness of farming by suggesting optimum time for harvest, and detect diseases using sensors and monitor water and organic fertilizer supply for crop. In this paper we survey the Wireless technologies such as Zigbee, wi-fi, Bluetooth and 5G . A survey on different soil, weather and leaf sensors is also done to enhance productivity in crops. The data gathered from these sensors can be analysed using IoT Apps and various data mining techniques.

Keywords: Precision Agriculture; Wireless Sensor Network; Big Data Analysis.

I INTRODUCTION

**1.1 Precision Agriculture**

Precision Agriculture is an approach to use Information Technology (IT) to improve the quality of crops and increase yields [1]. Modern agriculture, especially Precision Agriculture (PA), has a key role in helping to enhance crop yields[2]. Precision Agriculture promises to make agriculture extremely effective to make sure high productivity levels and reduce the environmental impact of farming.

 Precision Agriculture (PA) is a modern management approach benefit from Information Technology, Geographic Information System (GIS), GPS, WSN, data collecting etc. These technologies try to increase crop yields and reduce the environmental impact. In that way, the internet of things with help of its enabling technologies is a candidate for using in the Precision Agriculture.

 The technological advance in low-power and low-cost sensors enable the WSN to collect a body of environmental data and send through wireless media to a database. The gathered data may undergo an abstract analysis for essential feedback or directly send to the database for an in-depth analysis[3]. A scalable WSN can improve the performance of a current sensor based applications by adding new sensors to the network to measure extra parameters. Some challenges associated with the sensors signal strength and selected area for implementation of the network[4].

 According to the[5], there are two major challenged associated with security algorithms in WSNs that included: 1) the security algorithms impose an overload of data on messages that must be decline as much as possible to increase the lifetime of the sensor node, 2) the sensor nodes have small memory size; indeed small memory size can lead to the small security key.

 Precision Agriculture [6], [1] is one of the solutions to ensure food security for the entire world [7]. Precision agriculture also abbreviated as Digital Agriculture is a technology enabled, data-driven sustainable farm management system. It is basically the adoption of modern information technologies, software tools, and smart embedded devices for decision support in agriculture [2] as shown in figure 1. Mechanized agriculture and the green revolution are the two key components of the first and second agriculture revolution. Precision farming is an important part of the third agriculture revolution [8].



**Figure-1 Precision Agriculture**

 **1.2 Wireless Sensor Network**

 In such optimization of agriculture, installing a Wireless Sensor Network(WSN) in the ﬁeld has improved eﬀectiveness and eﬃciency of the farmers [9],[10],[11],[12]. WSN can be used to monitor and control factors that inﬂuence crop growth and yield. They can also be used to determine the optimum time to harvest, which farmer is more suitable for what conditions, detect diseases, control machinery, etc[13].

Wireless Sensors Network (WSN) is most commonly used in the process for observing the climate and utilizing the data of soil nutrient to estimate the crops health and the superiority of agricultural produces [14].

 Sensor node, communication device, power supply and processors are the devices of WSN. In clustering or direct way the sensor nodes broadcast the data to the base station. By monitoring the weather conditions (particularly temperature and humidity)and soil moisture for precision agriculture. In present times[15],[16] to build Decision Support Systems (DSS) to increase agricultural yield, irrigation can be planned.

 The Wireless Sensor Network is a key technology in the current century. Some characteristics such as scalability, homogeneity, and heterogeneity of nodes, fault tolerance, energy efficiency, and communication capabilities make them suitable for monitoring agriculture and greenhouse environment. WSN made up of a number of nodes with sensing, communication, and computational abilities. WSN’s sensor nodes can measure and process several environmental parameters e.g. soil moisture, temperature, humidity, water pH, wind speed, good nutrition etc.[17].

**1.2.1 Wireless Sensor Networks types in Agriculture**

Application of WSN in these fields is proved to be an effective way in this study. This sensor will monitor the vital parameters for crop yielding like soil moisture content, humidity, temperature and pH level and also the soil nutrition [2].

 The WSNs have several characteristics e.g., continuous monitoring, on-demand, event-based [18]. These characteristics help to monitor multiple ecological parameters such as temperature, atmospheric carbon dioxide, soil carbon dioxide, wind speed and direction, relative humidity, and others.

#### **1.2.1.1 Terrestrial Wireless Sensor Networks (TWSN)**

 In the agricultural field, the sensor nodes are placed above the ground to create smart network using small and low cost sensors. In PA, the technology (TWSN) is used in the soil moisture temperature and humidity.

#### **1.2.1.2 Underground Sensor Networks (WUSN)**

 Wireless sensors are deployed inside the soil in the agriculture field. Though the sensors are placed inside the soil, the communication range is affected. Since it is used to check the quality of the soil [19], it requires more number of sensors compared to TWSN.

**2. Wireless technologies used in Precision Agriculture**

 There are different wired and wireless types of M2M connectivity technologies . The wireless technology especially WiFi, Zigbee, Bluetooth,5G, blockchain, and Wide Area Networks (WAN) are being used widely in agriculture IOT solutions[20]. In this case, the study takes interest in the WAN (cellular M2M). Cellular M2M communication is a fresh type of wireless communication[21].The characteristics of these technologies are compared in the table below **(Table-1).**

**2.1 ZigBee Technology**

 The ZigBee protocol is based on the principle of a hierarchical 7-tier model of data transmission protocols (Open System Interconnection) in open OSI systems and the IEEE 802.15.4. includes ZigBee software network and software support level.

The IEEE 802.15.4 standard distribution medium (PHY) means the average access rate (MAC) and the physical signal layer, i.e. the lower layers of the wireless data protocol. The Alliance defines ZigBee stack software from the data transfer layer (DLC) to the device profile level (ZigBee Profiles).

Data is received and transmitted at the PHY physical level, which determines the operating frequency range, modulation type, maximum speed, number of channels: O-QPSK - offset square phase toggle switch with 2.4 GHz band (16 channels, 250 kbit BPSK - Binary phase switch for frequencies 915 MHz (10 channels, 40 Kbit / s) and 868 MHz (1channel, 20 Kbit / s) [22].

ZigBee network security level: Free access to the network access control list time to determine data transmission delays and expediency of data packets. Encryption using a 128-bit AES symmetric key network access mechanism, time distribution functions and guaranteed time interval, access to the media channel.

**2.2.Wi-Fi technology**

Itis one of the most promising computer networks in the computer world today. Wi-Fi (Wireless Fidelity) is an English word meaning "wireless connection". Wi-Fi technology is one of the types of digital data transmission via radio channels [23].

 In the creation of this technology, it was designed primarily for corporate users, it was predicted to replace the cable network. It is known that to create a computer network with a wired network, you need to manually set up several thousand cable networks and set up a special network topology.

 Standardized wireless data exchange technology is, operating at reduced control frequencies of Wi-Fi radio frequencies. This system is used in the expansion of a cable network or as an alternative to a single office, an entire building or an area. While Wi-Fi technology saves you money on a costly process such as unloading thousands of cable networks, the simplicity of installation saves time on complex technical installation processes, making this network superior to other networks.

The reason wireless networks use radio frequencies is that radio waves can also pass through a wall or similar barrier in a building or office in general, and nothing can interfere with it at all (except remotely).

**2.3 Bluetooth technology**

It is a technology designed to make it easier to connect a computer and other peripherals over a radio channel instead of connecting them to each other using wires.

 In early 1998, Ericsson, IBM, Intel, Toshiba and Nokia - the largest companies in the computer and telecommunications market teamed up to develop wireless technology for mobile devices. On May 20, 1998, the official presentation of the Special Interest Group (SIG) was held to ensure the smooth implementation of a technology called Bluetooth.

 Bluetooth IEEE 802.11 is the most common technology for wirelessly connecting computers and peripherals, based on the standard. On analyzing the historical facts, it is seen that Bluetooth technology has come to the forefront among similar technologies in a very short time [22]. In wireless data transmission networks, ZigBee, Wi-Fi and Bluetooth, V2X,VLC,5G are widely used in most areas of society because they have advantages over others:

 Low price Mobility Independence from cable infrastructure Fast internet connection Ease of connection and use.

**2.4 5G Technology**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Standard** | **ZigBee****(IEEE 802.15.4)** | **Wi-Fi****(IEEE 802.11b)** | **Bluetooth****(IEEE 802.15.1)** | **5G(IEEE 1914.3)** |
| **Frequency****Range** | 2.4 GHz | 5 GHz | 5 GHz | 28 GHz |
| **The transfer rate****is kbit / s** | 250 | 11000 | 723.1 | 900 |
| **Battry consumption** | 100-1000 | 0.5-5 | 1-10 | 80-90 |
| **maximum number of nodes in the****network** | 65536 | 10 | 7 | 100 |
| **Performanc****e range M** | 10-100m | 20-300m | 10-100m | GSM Coverage area |
| **Area of application** | Remote monitoringAndmanageent | Transmitting multimedia data | Instead of a wired connection | to connect to a large number of [devices](https://en.wikipedia.org/wiki/LPWAN) |
| **Price** | Average | Expensive | Cheap | Expensive |
| **Latest version** | Xiaomi light sensor,xiaomi smart light sensor | Arduino Yun, Arduino Uno | Raspberry Pi3 (B model), Beaglebone Black | 5G NR |
| **Uses** | Lighting | Monitoring | Control of devices | Weather forecasting |

5G is the fifth generation mobile communication technology, which is extended on the 4G system to obtain a new generation of cellular mobile communication technology. Compared with 3G and 4G, it has shown great advantages in data rate, energy saving, cost investment, equipment connection and so on. The development of 5G is due to the

growing demand for sports data. With the increasing number of mobile network access users, many new services and applications are emerging, making network capacity show a rapid growth trend in recent years. This situation has caused certain problems in the energy consumption, spectrum utilization efficiency and resource intelligent utilization of mobile communication networks.

 Therefore, the development of a new generation of 5G mobile communication networks is an inevitable trend in the development of the communication field. At this stage, although 5G technology has not yet been fully popularized, it has been effectively applied in many fields.

 For example, the Internet of Vehicles built on 5G technology laid the foundation for the realization of autonomous driving [24].

* Expensive
* mobility
* Independence from cable infrastructure
* Fast internet connection
* E3Ease of connection and use.
* More secure

The wireless sensor network is a key technology in the current century. The some characteristics such as scalability, homogeneity, and heterogeneity of nodes, fault tolerance, energy efficiency, and communication capabilities that make them suitable for monitoring agriculture and greenhouse environment. WSN made up of a number of nodes with sensing, communication, and computational abilities. WSN’s sensor nodes can measure and process several .environmental parameters e.g. soil moisture, temperature, humidity, Leaf, water pH, wind speed, good nutrition etc[17].

**TABLE-1 WIRELESS SENSOR TECHNOLOGIES**

**3. Sensors used in Precision Agriculture**

The sensors play a major role in various applications. Especially in agriculture, sensors are used to measure the various parameters depending on the requirements.

For instance, pendulum sensors are used to measure the mass, crop density sensors. Soil sensors, Leaf Sensors, Weather sensors are some of the sensors that are important and parameter measure is defined below and it is tabulated in Tables [2,3](#_bookmark4) and 4 referred from [25].

**3.1 Soil Sensors**

The value of parameters of soil like temperature, moisture, water level and conductivity is important in Precision Agriculture to increase the quality and quantity of the crop. Single sensor will not measure all the parameters of soil. Table [2](#_bookmark4) shows the comparative study of various sensors used to measure the parameters of soil.

For example, EC sensor (EC250) measures the temperature and moisture content in soil but it does not measure the water level in agriculture field. This table will use the suitable sensors for our application.[26].

**3.2. Leaf Sensors**

 The sensors are used to measure the parameter of plant or leave for crop monitoring. For example, LW100 Leaf Wetness Sensor is used to measure the moisture, wetness**,** and temperature in leaf. Some sensors are used to measure and monitor the level of photosynthesis,

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. no** | **Sensors** | **Temparature** | **Moisture** | **Dielectric primitivity** | **Rain/water flow** | **Water level** | **Conductivity** | **Salinity** | **GPS Location** | **References** |
| **1** | **Hydro Go** | YES | YES | YES | YES |  YES | YES | YES | YES | <https://stevenswater.com> |
| **2** | **Hydra GO Field Version** | YES | YES | YES | YES |  YES | YES | YES | YES | <https://stevenswater.com> |
| **3** | **CS650-30 CM** | YES | YES | YES | NO |  YES | YES | YES | YES | <https://www.campbellsci.com> |
| **3** | **POGOPRO+** | YES | YES | YES | NO | NO | YES | YES | YES | <https://stevenswater.com> |
| **4** | **Gro Point™ Profile** | YES | YES | NO | NO | YES | YES | YES | YES | <https://stevenswater.com> |
| **5** | **Tempe Cell System** | YES | YES | NO | YES | YES | NO | NO | NO | <https://stevenswater.com> |
| **6** | **Water Scout SMEC 300 Sensor** | YES | YES | NO | YES | YES | YES | YES | NO | <https://www.specmeters.com> |

hydrogen and CO2. These parameters will help us to know the strength and quality of plant. The above Table -3 is represented by leaf sensor types and Characteristics.

**3.3 Weather sensors**

 The impact of the sensor are vary according to the weather condition. The parameters are listed in the Table [4](#_bookmark7) .

Identification and Deployment of sensors plays a major role in sensor network applications because every sensor will not suit for all the application with environment changes. Some sensor will suit for some application with suitable weather condition. So the Table [4](#_bookmark7) list and compare the sensors that will be suitable for various weather conditions like temperature, humidity, atmospheric pressure, wind direction.

Certain types of sensors that are suitable for temperature and humidity are not suitable for wind direction and wind speed [26]. The tables are given below :-

**TABLE-2 SOIL SENSORS**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.NO** | **Sensors** | **Photos ynthesis** | **Moisture** | **Hydrogen** | **Wetness** | **CO2** | **Temperature** | **References** |
| **1** | **THERM-MICRO** | YES | NO | NO | NO | YES | YES | <https://au.ictinternational.com> |
| **2** | **LS-C MINI QUANTUM SENSOR** | YES | NO | YES | YES | YES | YES | <https://au.ictinternational.com> |
| **3** | **Photosynthetic Active Radiation (PAR)** | YES | YES | YES | NO | YES | YES | h[ttps://www.ysi.com](https://www.ysi.com/products/global-water) |
| **4** | **LW100 Leaf Wetness/Rainfall Sensor** | NO | YES | YES | YES | YES | YES | h[ttps://www.ysi.com](https://www.ysi.com/products/global-water) |
| **5** | **CI-340 Hand Held Photosynthesis** | YES | YES | NO | YES | YES | YES | <https://ppsystems.com> |

**TABLE-3 LEAF SENSOR**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No** | **Sensors** | **Temperature** | **Humidity** | **Atmospheic Pressure** | **Wind Speed** | **Wind Direction** | **References** |
| **1** | **We600 Humidity Sensor** | YES | YES | YES | YES | YES | <https://www.ysi.com/products/global-water> |
| **2** | **Vaisala Humicap Hmp155** | YES | YES | NO | YES | YES | [Https://Stevenswater.Com](https://stevenswater.com) |
| **3** | **Lufft Ws-500** | YES | YES | YES | YES | YES | [Https://Stevenswater.Com](https://stevenswater.com) |
| **4** | **Lufft Ws-800** | YES | YES | YES | YES | YES | [Https://Stevenswater.Com](https://stevenswater.com) |
| **5** | **Sht41i** | YES | YES | YES | NO | NO | [Https://Sensirion.Com](https://sensirion.com) |
| **6** | **Atmos22** | YES | NO | NO | YES | YES | [Https://Www.Metergroup.Com](https://www.metergroup.com) |

**TABLE-4 WEATHER SENSOR**

**4. Applications in Precision Agriculture**

 Information and communication technologies have spread around the world and in almost everywhere there are signs of technology. ICT has played an important role in Precision Agriculture (PA) and has facilitated agricultural tasks especially with the help of telecommunication and smart phones [26].

 Today due to the advances in smart phones processor and operating systems, these devices are increasingly being used in the many sectors (e.g. healthcare, industries, smart grid, and agriculture). Almost all new smart phones can perform most of the tasks of a computer. Moreover, according to the increasing rate of use of smart phones, a large number of Apps has been developed for a large number of operations. Almost there is an App for each profession and sector in order

**TABLE-5 APPS IN PRECISION AGRICULTURE**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Apps Name** | **E-Luminate Mobile** | **Case IH AFS connect farm(updated)** | **Agvance grower360** | **market + by indigo** | **Valley Insights** | **Drift** |
| **Operating System** | iphone,ipad | Android,iphone,ipad | Android,iphone,ipad | Android,iphone | Android,iphone | Iphone |
| **Released date** | 2021 | 2020 | 2020 | 2022 | 2022 | 2020 |
| **Description** | Golden Harvest farmers now have access to the E-Luminate Mobile app, a digital agronomy platform designed to deliver timely insights directly to farmers from their trusted seed advisors. The E-Luminate Mobile app helps farmers get a real-time look at their farm and see their data in a new way | The latest update for the AFS Connect Farm mobile app includes support for prescriptions and large square balers; new layer visualizations; machine utilization maps | Grower360 provides the portal to let customers view their accounts in real-time, see past activity, and view the details needed to make informed decisions. Designed with a “mobile-first” user experience, ag retailers' customers will have access to their data on any device…anywhere, anytime | Market+ by Indigo is the digital merchandising application for the ag supply chain that increases efficiency, optimizes assets, and unlocks sustainably sourced contracts, to expand revenue opportunities. | Valley Insights virtually scouts your field and alerts you to crop health concerns and irrigation issues before they become problems its allows you to get real-time notifications of issues in your fields, so you can take immediate action. Reduce input costs by focusing on the relevant areas of your fields. | Drift App organizes seed trait information in your fields and neighboring fields in order to mitigate potential spray drift damage each season. The app takes the guesswork out of when and where to spray by auto-generating the Spray Planner “to-do list”. |
| **Features** | E-Luminate Mobile's suite of features includes creating and editing fields and reviewing field data, including yield as planted, imagery, scouting, weather, crop monitoring, and more. | AFS Connect Farm provides users with a continually expanding feature set designed to optimize performance, productivity, and flexibility at no cost to them. Users have access to a wealth of field information when they select a map from the main map scre en. | Growers can view field boundaries, soil tests, maps, weather data, and a detailed timeline of activity for each field. On the grain side, customers will have a real-time view of all grain activity in addition to e-signature on contracts, cash bids, and futures price information. | Market+ (formerly Marketplace) directly connects a wide set of stakeholders across the agricultural supply chain (farmers, cooperatives, processors, merchants, carriers, shippers, and consumer brands) with a suite of integrated and data-driven tools that move businesses forward faster. | Features of the valley insightsUse the information to adjust your pivots and maintain crop uniformity. Get access to field imagery, for continuous monitoring and analysis, and easily share insights with your collaborators. The app, which was designed to be intuitive and easy-to-use for every day use, is currently only available in select regions. | The goal of Drift App is to give growers and applicators an easy-to-use tool to manage spray operations, so that we can spray more herbicide on-target, keeping our fields clean and protecting our traits from regulation in the future. |

to help and facilitate the tasks. Likewise, for agriculture, many Apps are developed that can help to the farmers in different methods. We have done research on Apps in the context of agriculture that they provide a different range of services in agriculture[5]. Table 5 presents a summary description of these Apps. The Smart phones listed Apps are Given below:-

* **E-Luminate Mobile**
* **Case IH AFS connect farm(updated)**
* **Agvance grower360**
* **market + by indigo**
* **Valley Insights**
* **Drift**

**5. Data Analysis in Precision Agriculture**

Before the advent of information technology, various traditional methods like manual detection of crop diseases and pests, calculations based on statistics to estimate the quantity and predict the production and loss of crops were generally cumbersome, this results in human error due to the lack of experience of inspectors [27].

Data is a potential tool for taking decision according to analyzing the situation. Agricultural big data means a lot of data is created naturally from different stages from seed sawing to harvesting. Big data in agriculture can help to renovate the practices of agriculture which can easily contribute in all dimensions of agriculture viz crop, livestock, fish, and agribusiness. Big data technology in agriculture is able to collect and analyze the lots of data which usually generated from various sectors and stages in agriculture [28].

Agricultural big data can be used for analyzing seed characteristics, weather pattern, soil properties like pH or nutrient content, marketing and trade management, consumers behavior and inventory management [29].

Data mining was applied to extract important and useful knowledge from large data on crops, obtained with IoTs. The knowledge discovery processes are discussed in [24]. Data mining refers to extracting knowledge from large amounts of data. This paper divides data mining into 3 steps as follows.



**Figure-2 Data Analysis Using In Precision Agriculture**

* 1. **Data preprocessing**

This is an important step in the knowledge discovery process, because the quality of knowledge depends on the quality of data. In the real world, data tends to be dirty, incomplete, and inconsistent. Thus, this step can help improve the accuracy and eﬃciency of the subsequent mining. This step includes data cleaning, data integration, and data transformation. This work used the large amounts of data from IoTs devices on temperature, humidity, and soil moisture, to predict yields, and. We converted the IoTs information to discrete format in order to support data modeling [30].

**5.2. Data Reduction**

For the successful application of data mining a huge set of dataset is required. The data which is acquired from various resources are sometime in raw form. It may contain some incomplete, redundant, inconsistent data. Therefore in this step such redundant data should be filtered. Data should be normalized [31].

This step can encode the data to a smaller reduced representation. The integrity of the original data is preserved in order that mining the reduced data should be more eﬃcient yet produce the same (or almost the same) analysis results. This work used numerosity reduction, where nonparametric methods for storing reduced representations of the data [30].

* 1. **Data Modeling and Discovery**

This step extracts knowledge from the prepared data. Mostly, data modeling/discovery applies intelligent methods to identify patterns in the data. Further, an administrator can manipulate the obtained IoTs information and control the data from each installation. The admin can also mine the data to discover knowledge. The knowledge discovery from real data is illustrated in. We found that the knowledge discovery represented the real data well.

 **Conclusion**

Wireless Sensor Network is technology in Precision Agriculture to increase the crop productivity, water and fertilizer resource monitoring, soil and crop quality monitoring. In this paper, we have discussed the importance of Wireless Sensor Network and Precision Agriculture. We also have summarized the various types of sensors to be soil, leaf and weather used in agriculture. The deployed sensors in field should collect the data and transmit it to the Base Station for data processing and monitoring. The IoTs Apps used for data collections are also discussed daboratly in this paper.

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