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The Impact of Wireless Sensor Network in the Field of Precision Agriculture: A Review

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Abstract Precision agriculture (PA) is an interdisciplinary concept of integrating information technology in agriculture to increase the production and quality of the crops. One of the most important and interesting information of technology is Wireless Sensor Network (WSN). This technology is used to collect, monitor and analyse the data from the field of agriculture. This interdisciplinary technology will boost the crop productivity and maintain quality for example, monitoring the pest and disease control, animal tracking and strength of the crop. In this paper, we have surveyed the importance of sensor in PA and the importance of WSN technologies for remote monitoring in the various applications of the agriculture field.

Keywords Precision agriculture (PA) · Wireless sensor network · Sensors · Remote monitoring

1 Introduction

Global warming is the major area of concern and it has its effects across the globe. Decreasing ground water level and changes in monsoon patterns are all the impacts of global warming. In order to effectively use the ground water level for agricultural produce, by proper methods are inevitable in this current scenario. Reducing ground water level will affect the farmers in each and every walk of their lives. In the state of Karnataka and Tamil Nadu, around 87% of the farmers are holding land of less than 4 ha. More than 50% of the farming lands in these areas have water scarcity and it is without crops. Effective management of water is necessary in these drought-hit lands [2].

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Application of WSN in these fields is proved to be an effective way in our 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 [4]. The sensors are the majorly support to the Precision Agriculture, Smart Agriculture, etc. The sensors are so important in agriculture to collect the basic requirements of physical pre-nominal and environmental attributes. For example, the sensors collect information about weather and soil condition, pest and disease control and other animal tracking. The paper is structured as follows:

Section 2—Basics of wireless sensor networks in precision agriculture and its types.
Section 3—Communication technologies used in wsn for precision agriculture.
Section 4—Types of sensors used in the application of agriculture, application of wireless sensor network in precision agriculture.
Section 5—Case Study.
Section 6—Conclusion.

2 Basics of Wireless Sensor Network in Precision Agriculture

2.1 Sensor in Precision Agriculture

Wireless Sensor Network (WSN) is defined as collection of wireless sensor which is deployed in application field and based on the requirement of the data the sensor may differ, i.e., if once the node is deployed, the network is organised. Subsequently, the nodes will collect the data and transmit it to the centralised node to process the data as per the user requirement [23].

2.2 Types of Sensor Networks

The sensor networks are classified into various types based the location of the deployment, that is, below the ground and above the agriculture ground.

2.3 Based on the Deployment Location

Again, the sensor network is classified based on the location of the deployment:

2.3.1 Terrestrial Wireless Sensor Networks (TWSN)

In the agriculture 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 moister temperature and humidity.

2.3.2 Underground Sensor Networks (WUSN)

Wireless sensors are deployed inside the soil in the agriculture field. Though the sensor are placed inside soil, the communication range is affected. It is used to check the quality of the soil [7]. So it requires more number of sensors compared to TWSN.

2.4 Based on the characteristics of Sensors, the Network architecture is classified

Stationary the deployed nodes is stable always.
Mobile the deployed node is in mobility to track or get the data from the PA field.
Hybrid The deployed nodes areφ sometimes mobile and sometimes stable. In the PA field, some nodes may be mobile and some set of nodes may be mobile.

2.5 Based on the Sensing and Transmission Power

Homogeneous network All the nodes in the network sense the same attributes of the data, same level of the transmission power and send it to the centralised node.
Heterogeneous network The sensor nodes collect the different attributes of the data with difference in transmission range. Some set of sensor nodes have low transmission power and some nodes have high transmission power.

3 Technologies Used in Precision Agriculture

Various communication technologies are involved in WSN for Precision Agriculture for data collection and monitoring. The Table 1 is the summary of the comparison of various technologies is referred in [4, 23]. There is some standard and technology used for efficient data communication in sensor network. Depending on the application, frequency of band, data rate, distance and amount of power consumption, the technology is classified into ZigBee, Bluetooth, Wibree, Wifi, GPRS and WiMAX. As per Table 1, comparison is made for low data rate and low transmission and consumption ZigBee is the most suitable technology. If the application requires data transmission of longer distance with medium power consumption, WiMAX is the best option. Based on our requirement and application, we can choose the suitable technology to reduce the cost.

4 The Impact of Sensors in 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. Some of the sensors are important and parameter measure is defined below and it is tabulated in Tables 2 and 3 referred from [4].

Table 2: 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 shows the comparative study of various sensors used to measure the parameters of soil. For example, EC sensor (EC250) measures the temperature and moister content in soil but it does not measure the water level in agriculture field. This table will use the suitable sensors for our application.

Table 3: In general, the sensors are used to monitor the continuous and event-driven environmental applications. Here, Table 3 figures the comparison of various types of

Table 1 Communication technologies

S. no	ZigBee	Bluetooth	Wibree	WiFi	GPRS/3G/4G	WiMAX
Standard	IEEE 802.15.4	IEEE 802.15.1	–	IEEE 802.11a,b,g,n	–	IEEE 802.16a,e
Frequency band	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	865 MHz, 2.4 GHz	2–66 GHz
Range	30 m–1.6 km	30–300 ft	Up to 10 ft	100–150 ft	Entire GSM coverage area	<50 km
Data rate	250 kbps	1 Mbps	1 Mbps	11–54 Mbps	50–100 kbps/200 kbps/ 0.1–1 Gbps	0.4–1 Gbps (stationary), 50–100 mbps (mobile)
Power consumption	Low	Medium	Low	High	Medium	Medium
Cost	Low	Low	Low	High	Medium	High
Modulation/protocol	DSSS, CSMA/CA	FHSS	FHSS	DSSS/CC K, OFDM	–	–
Security	128 bit	64 or 128 bit	128 bit	128 bit	–	–

Table 2 Deployment parameters of soil

S. no	Sensors	Soil							
		Temparature	Moisture	Dielectric permittivity	Rain/ water flow	Water level	Conductivity	Salinity	References
1	Hydra probe II soil sensor	Y	Y	Y	Y	Y	Y	Y	www.stevenswater.com
2	Pogo portable soil sensor	Y	Y	Y	Y	N	Y	N	www.stevenswater.com
3	MP406 Soil moisture sensor	Y	Y	Y	N	N	N	N	www.ictinternational.com.au
4	ECH2O soil moisture sensor	Y	Y	Y	N	Y	Y	N	www.ictinternational.com.au
5	EC sensor (EC250)	Y	Y	N	Y	N	Y	Y	www.stevenswater.com/catalog/products/water_quality_sensors/manual
6	ECRN-50 low-REC rain gauge	N	N	N	Y	N	N	N	http://www.decagon.com
7	ECRN-100 high-REC rain gauge	N	N	N	Y	N	N	N	http://www.decagon.com
8	Tipping buket rain gage	N	N	N	Y	N	N	N	www.stevenswater.com
9	107-L temperature107-l Sensor (BetaTherm 100K6A1B Thermistor)	Y	N	N	N	N	N	N	http://www.campbellsci.com/107-l

Table 3 Deployment parameters of leave/plant

Leave/plant								
	Sensors	Photos ynthesis	Moisture	Hydrogen	Wetness	CO_2	Temperature	References
1	237 leaf wetness sensor	N	Y	N	Y	N	Y	http://www.campbellsci.com
2	LW100, leaf wetness sensor	N	Y	N	Y	N	Y	http://www.globalw.com
3	SenseH2^{TM} hydrogen sensor	N	N	Y	Y	Y	Y	LW100B.pdf
4	Leaf wetness sensor	N	Y	N	N	N	N	http://www.NTMSENSORS.com
5	YSI 6025 chlorophyll sensor	Y	N	N	N	N	N	http://www.decagon.com http://www.ysi.comysi_6025.pdf
6	Field scout CM1000TM	Y	N	N	N	N	N	http://www.specmeters.com/pdf/2950FS.pdf
7	TT4 multi-se nsor thermocouple	N	Y	N	N	N	Y	www.ictinternational.com.au/thermocouple.htm
8	LT-2 M (leaf temperature sensor)	N	N	N	N		Y	http://www.solfranc.com LT-2 M Leaflet SOLFRANC.pdf
9	TPS-2 portable photosynthesis	Y	Y	N	Y	Y	Y	www.ppsystems.com/Literature/EDSTPS2_System.pdf
10	PTM-48A pho tosynthesis monitor	Y	Y	N	Y	Y	Y	http://phyto-sensor.com/PTM-48A
11	Cl-340 hand-held photosynthesis	Y	Y	Y	Y	Y	Y	http://www.solfranc.com CI-340_hand-held_photosynthesis_solfranc_ENG.pdf
12	107-L temperature Sensor (BetaTherm 100K6A1B thermistor)	Y	N	N	N	N	N	http://www.campbellsci.com/107-lS

sensors 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, hydrogen and CO_2. These parameters will help us to know the strength and quality of plant.

4.1 Sensors in Precision Agriculture

The review of past and current research of various sensors for measuring the grain yield and moister content and some of the sensors are defined to calculate, measure the grain protein and growth of straw [6]. Vehicle-based sensors are used to measure the plant mass of crops. These sensors are used to measure the mass of different crops [12]. By using these mechanical sensors, the rate of specific fertilisation is measured and distributed [13]. For the best production and the increasing the productivity of the crops, the quality and strength of the soil are the most important factors in precision agriculture. To measure the quality of soil, a sample is taken and tested to measure the pF, water infiltration rate and other organic matter. All the measurements and testings are done by using soil strength sensors [16, 27]. Two different sensors are used that is plant sensors and soil sensors [32]. The plant sensors predict the harvesting time compared to soil sensor and CROP-meter is a sensor used to measure the density of the fungicide and also the plant's disease [8, 9].

The positioning sensor is used to spray thee agrochemicals in olive groves to minimise the chemical losses [24]. With the help of image processing technique, the research is carried out to predict the soil moisture and organic contents in the soil [30, 18].

4.2 Wireless Sensor Network in Precision Agriculture

Detecting the water leakage in irrigation pipes is a challenging task. As per the statistical report, 10,500 L of water is lost every second in UK. So the solution to identify the leakage by using the sensors network makes it easy; by placing acoustic sensor intimates the leakage by giving some sound or vibration [19].

WSN plays a vital role in irrigation management to monitor the crop growth and its harvesting time, and to calculate fertilizer requirement accurately [28]. As per the part of sensing, they used four types of sensors- soil mote, environmental mote, water mote and gateway mode. In the experimental scenario, soil sensor, that is, Stevens Hydra Probe II buried to 20–40 centimetres depth is used to measure the soil characteristics like temperature and moisture. The second network contains 10 environmental mote (SHT71 type) which are used to measure the temperature and humidity. Water mote (Stevens EC 250) is used to measure the salinity and water temperature to determine the quality of water for it suitability for irrigation. All these sensors are used to measure their parameters and send them to the gateway and base station which is away from the network.

Monitoring the various parameters of crop is quite interesting and most useful for the farmers along with the sensor network which is used to monitor the intruders like animals. Here they used video surveillance to monitor the animal or humans by using cost effective technology for local communication for 802.15.4. This technology collects the data and transmits it to the end user. The collected data first will go to farmers' cooperative and then it is transmitted to the farmer's home. The individual farmer receives the data and interacts with the system by modifying and monitor surveillance [15].

Precision Irrigation is the accurate method of distributing water to the crops and completely maintaining its water content to ensure proper growth of the crops. It identifies soil moisture and constantly intimates it to deliver the required quantity of water at regular

intervals. This system is based on Evapo-Transpiration (ET) scheduling. The evaporation of water is calculated through this ET method and the actual required quantity of water can be distributed to the crops at right times. The quantity of water will be determined by the data received from the sensor frequently. It will also alarm if the water level fluctuates at the specified threshold value. This project throws more light on the water level requirement for the grape field by ET and ETc Mechanisms.

The main server and vineyard monitoring test bed is located in Green House, IIT Bombay. It also possesses limited sensors and monitors and vital parameters like air temperature, humidity, soil moisture. Real Setup was deployed at Vineyard Nashik, which is 200 km away from the server. Through Multi-hop the data will be transmitted and reach the base station. At this base station, the data will be passed to gateway, which acts as a data logger and will execute the data aggregation and filtering process. Later, it will reach the server through GPRS and the accumulated data is stored in data structure format for forecasting and analysis. Subsequently, the data processed here will be intimated to the farmers. Sensor deployed in this application is ECH2O probe by Decagon Soil Moisture Sensor [5].

In this article, the author elaborates about the functionality of WSN for agriculture in smart field developed by the US Department of Agriculture (USDA). The nano sensors are used to supervise the agriculture field to find out the plant virus and soil nutrients. Based on the sensor data the plant will be administered with necessary pesticide, water and fertilizer. This system works on Zigbee-based soil-moisture-sensor-network. They had used four sensors meant to monitor humidity, soil moisture, soil conductivity and soil pH level. The gathered data will be passed to the data logger called Agrosense wireless data logger-where the data will be communicated to wireless router. Through the wireless router, the data will be relayed to the remote system coordinator from the field. The remote sensor coordinator is pre-programmed with Java-based GUI and the received data is analysed by using JFreechart and it will be represented in diagrammatic format [17].

To three different places with varied irrigation levels this WSN technology is deployed to ensure proper level of irrigation. In Zone 1, the water should be sprayed during summer to keep the plant in good moisture. Zone 2 requires water occasionally, whereas zone 3 requires irrigation at irregular intervals. All these zones should be monitored remotely and the plants should get adequate supply of water as and when it requires. The scheduling should be planned in such a way that each zone should be ensured with good standard of irrigation. Delta TSM300 moisture sensor from cross-bow technology is used. Based on the data received from the field, the scheduling will be prefixed [29].

Analysis by Water Poverty Index (WPI) unfolds that the turkey is facing water scarcity and managing water in all fields of its application which is mandatory. The one field which requires high water consumption is agriculture. Here, the water management is necessary in order to effectively use water. WSN technology comes in handy to manage the water. In sugarcane field, the WSN is deployed to monitor the soil moisture and other parameters. The data generated by the sensors is transferred to gateway directly or through multi hope. Later Geographic Information Systems (GIS) will receive the data and it will be stored, analyzed, and display the large amount of spatial data. The network path is formed by connecting WSN with GIS for convenient analysis of spatial data and GPS technology will monitor the sensor reading. At last, they found that the soil moisture fluctuates between 28% and 86%, whereas 28% of less water content and 86% of high water content. The result arrived will be analyzed and effectively the water body will be managed so that the crop will receive required water [31].

The application is used to monitor the crop, by using two different network protocols, one is collection tree protocol where data is collected and sent to the base station. The other one is dissemination protocol which is used to deliver the piece of control and sync with every node [20].

The WSN technology is used to monitor the water quality by solar powered panel. Monitoring the water quality in various fields is quite challenging. This prototype model is powered by solar cell and data is collected from various centres [33]. This research paper is developed a framework to collect the quality of data from water resource department in the Kingdom of Saudi Arabia. Acluster is formed by using huge number of sensors. The data travel through the backbone of the network [1] [14]. This project-based research work is going to map the historical data with independent sensor data and collect the soil samples data from the deployment place [22].

This real time project is to monitor the nutrient loss in New Zealand dairy due to cattle urine. With the help of urine sensors, the majority of urine is deposited is calculated and identified [2]. Yield monitoring is the important aspect to identify the reduced yields in the field. With the help of multi sensor like yield monitoring sensor and protein monitoring sensor, straw yield monitoring sensor is used to measure the parameters of the crops [10]. Soil roughness is another important parameter in agriculture. By using Microsoft Kinect sensors, one can easily monitor the character of the soil [21, 25]. The impact of the sensor are vary according to the weather condition. The parameters are listed in the Table 4 [4]. Table 4: 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 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.

This paper come with the survey features of WSN in PA. The list of parameters is tabulated in the Table 5: features of WSN in various parameters [3]. Table 5 discusses the comparison of various applications of agriculture like irrigation, scheduling, and monitoring the environment and features used in Precision for reliable efficient data transmission in various topologies. The precision agriculture application for data transfer is also executed with heterogeneous and homogeneous network with solar battery resource for energy consumption. In that, some applications execute the data aggregation to minimise the energy consumption and some are not used in aggregation techniques.

5 Case Study

5.1 Nanotechnology: The New Perspective in Precision Agriculture

Nanotechnology is used in various applications in the field of science like physics, pharmacy and medicine. Like any another field of science, it has a huge scope in agriculture also. Particularly, in Precision Agriculture, nanotechnology is required to meet the demands of soil and crop. Sometimes nanotechnology prevents the nutrient loss and prevents the infections.

Table 4 Impact of sensor deployment in various weather

Weather							
S. no	Sensors	Temperature	Humidity	Atmospheric pressure	Wind speed	Wind direction	References
1	CM-100 compact weather sensor	Y	Y	Y	Y	Y	www.stevenswater.com
2	Met station one (MSO)	Y	Y	Y	Y	Y	www.stevenswater.com
3	XFAM-115 K PASR	Y	Y	Y	N	N	http://www.pewatron.com 100-31-1 02-006-EH-0110.pdf
4	HMP45C m (Vaisala's HUMIC AP® H-chip)	Y	Y	Y	N	N	http://www.campbellsci.com HMP45C Temperature and Relative Humidity Probe
5	SHT71 (Humid ity and temperature sensor)	Y	Y	Y	N	N	http://www.sensirion.com/humidity
6	SHT75(Humid ity and temperature sensor)	Y	Y	Y	N	N	http://www.sensirion.com/humidity
7	Cl-340 hand-held photosynthesis	Y	Y	N	N	N	http://www.solfranc.com CI-340_hand-held_photosynthesis_solfranc_ENG.pdf
8	107-L temperatureSensor (BetaTherm 100K6A1B thermistor)	Y	N	N	N	N	http://www.campbellsci.com/107-l

Table 5 Featues of WSN in precision agriculture

	Application	Technical contribution	Topology	Heterogeous/ homogeneous	Energy source	Data aggregation
1	Irrigation scheduling	Reliability	Star single-hop star	Homogeneous	Battery	N
2	Middleware infrastructure iPAGAT	Middleware	Cluster tree-based multi hop	Heterogeous	Solar/battery	Y
3	TDMA scheduling irrigation	Energy	Star single-hop star	Homogeneous	Battery	Y
4	Irrigation scheduling	Reliability	Star single-hop star	Homogeneous	Battery/solar	N
5	Irrigation scheduling	Reliability	Cluster tree-based multi hop	Heterogeous	Battery	N
6	Monitor climatological controls	Energy/reliability	Tree-based multi hop	Homogeneous	Battery	N
7	Irrigation scheduling	Energy	Star single-hop star	Heterogeous	Battery	Y
8	WSN + DTMF irrigation control	Scheduling/energy	Star single-hop star	Homogeneous	Battery	N
9	WSN +and fuzzy irrigation control	Reliability	Mesh	Heterogeous	Solar	N
10	Irrigation scheduling	Reliability	Star single-hop star	Heterogeous	Battery	N
11	Monitoring fire and air pollution	Reliability	Cluster tree-based multi hop	Heterogeous	Battery	Y
12	Irrigation scheduling	Reliability	Mesh multi hop	Homogeneous	Solar	N
13	Monitoring and video transmission	Energy and transmission delay	Cluster tree-based multi hop	Heterogeous	Solar/battery	N
14	Data irrigation platform	Transducer-to-network interoperability	Mesh	Heterogeous	Solar/wind moving. Water irrigation pipes	Y
15	Irrigation scheduling	Scheduling	Cluster tree-based multi hop	Heterogeous	Battery	N
16	Irrigation scheduling	Scheduling	Star single-hop star	Homogeneous	Solar	Y

5.2 Problem Definition

As per the statistical report in research paper worldwide on pesticide use, there are nearly twenty lakh tons of pesticides used per year all over the world. Out of which 45% is consumed in Europe. So the increase in the use of a pesticide increases the pest resistance, kills the good soil microbes and reduces the soil biodiversity which leads the bio magnification of pesticides and desolation of the natural habits of birds. Some of the existing methods like silver nano particles, zinc oxide nano particles and titanium dioxide nano particles create a high anti-microbial effect which concentrates on crop protection. If fertilizers in the form of ammonium, urea, and nitrate are used to increase the productivity, it creates catastrophic effects to the soil and causes pollution. Nitrogen fertilizers like Urea increase the productivity as well as the greenhouse gas. The commercial herbicides wipe out the weeds in the field but damage the crops.

5.3 Nanotechnology in Precision Agriculture

Nanotechnology is extremely used in the field of agriculture to meet the demands of soil, crop and increase the quality of production. For example, Nano material coated over fertilizers can solve fungal diseases. Nano materials improve the slow discharge of fertilizers and grip the nano particles strongly so that it can be used for surface protection. Nano coated urea and phosphate meet the requirement of soil and crop by providing micro nutrients like nitrogen. Nano fertilizers increase the absorption of nutrition by a crop from soil. Nano fungicide is used as an antifungal agent for tackling pathogenic fungi. For instance, silver ions from a silver acts as a higher fungal agent which deactivates the cell wall. The nano herbicides remove the weed without affecting the crop in an eco-friendly way. The nano bio sensors are used to identify the plant viruses and the amount of soil nutrients. Nanotechnology is a remarkable potential in precision agriculture to monitor the biological sources. In future, the nanotechnology will be used for early identification and diagnosis of disease.

6 Conclusion

Wireless Sensor Network is an important and key technology in Precision Agriculture to increase the productivity, water resource monitoring, soil quality and its strength characteristics monitoring. In this paper, we have discussed the basic and the importance of wireless sensor network and precision agriculture. We also have summarised the various types of sensors used in agriculture. Morever, it includes the characteristics of sensors when they are deployed in soil and various weather conditions. The deployed sensors in field should collect the data and transmit it to the base station for data processing and monitoring. The basic and various communication technologies involved in data transfer to base station have been tabulated. Additionally, the features of sensor network are also defined in precision agriculture.

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