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Application of Wireless Nano Sensors Network and Nanotechnology in Precision Agriculture: Review

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Abstract:

Due to a series of global issues in recent years, such as the food crisis, the impact of fertilizer on climate change, and improper use of irrigation that's way precision agriculture is the best solution for alleviating this problem. One of the most important and interesting information technology is the wireless Nanosensor network with the help of Nanotechnology will boost crop productivity, maintain the fertility status of the soil, save the water with precise application of irrigation in the field and minimize the loss of excess fertilizer through the precise application. In this paper, we have surveyed the importance of sensor networks in precision agriculture and the importance of Nanosensors with the help of Nanotechnology for remote monitoring in the various application of the agriculture field.

Keywords: ***Wireless Nano sensors, Nanotechnology, Precision Agriculture, monitoring***

Introduction:

All around the world, the human population reaches a total of 10 billion people in 2050 **(United Nations 2017)**. It has been estimated that global food production must increase by at least 70% over the coming years to keep pace with this growth (Thornton et al. **2018**; Sonnino et al. **2019**; Dinar et al. **2019**). Farming practices have not changed much over the year, and the farmer still uses traditional approaches based on the assumption of the nutritional need of the crop. Application of the same input of nutrients across the entire farm is no longer the best option, as this leads to heavy use of fertilizers and pesticides, excessive water consumption, environmental degradation, and high operating cost **(Adila and Bahaman 2013; Blandford et al. 2014; Erbaugh et al. 2019).**

To help reverse this trend and generate enough food to meet the growing demands, the agriculture industry needs to embrace smarter farming methods. Innovative agricultural techniques such as precision agriculture methods can help alleviate some of these concerns. Precision agriculture aims to improve crop production by maximizing yield with a minimal chemical application **(Shi et al., 2016)**. Precision agriculture is a relatively new and mostly technology-driven approach. Precision Agriculture is an approach to farm management that uses information technology to distribute the resources efficiently and ensure that the crop and soil receive the exact nutrients required at the right time for optimum health and productivity **(Ullah et al., 2017)**. In precision farming, timely collection and analysis of the spatial and temporal variant information of crop, soil, and environment are important. This can be done by new emerging information technologies such as Global Information System (GIS), Global Positioning System (GPS), yield monitors, Remote sensing, etc. The data collected are to be analyzed using appropriate procedures to provide support for decision-making.

One of the most important and interesting information technology is Wireless Sensor Network (WSN). The rise of wireless sensor networks has stimulated a new direction in agriculture. Recently, WSNs have been widely applied in various agriculture applications.

The wireless sensor network (WSN) is a technology to collect information with sensing, communicating, and data processing abilities. It is composed of distributed small embedded devices called nodes **(Akyildiz I F et al., 2002)**. The Sensor nodes emerge as a miniature autonomous with advanced sensation abilities, which constitutes the core unit of a WSN. A sensor node is considered a micro-electromechanical system that measures or detects physical and environmental attributes (e.g., emission, pressure, humidity, and temperature) and convert them into a signal for surveillance and control purpose **(Hamami and Nassereddine, 2019)**. Wireless Sensor Network (WSN) is defined as a collection of wireless sensors which is deployed in the 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 organized. Subsequently, the nodes will collect the data and transmit it to the centralized node to process the data as per the user requirement. **(Ojha, T., et al., 2015)**. Among all these technologies, the agriculture domain is mostly explored concerning the application of WSNs in improving the traditional method of farming **(ur Rehman et al., 2014; Zhao et al., 2013; Wang et al., 2006; Akyildiz et al., 2002a,b; Akyildiz and Kasimoglu, 2004; Yick et al., 2008; Ruiz-Garcia et al., 2009)**. WSNs have emerged to offer low-cost, flexible, easy-deployment, and high-accuracy advantages **(Akyildiz I F et al., 2002; Akyildiz I F and Vuran M C ., 2010; Lopez J A et al., 2015)**. for crop monitoring in real-time. Furthermore, WSNs can cover densely the field, do not require a previous telecommunication facility, have reliable signal transmission, are easy to relocate, are non-intrusive, and offer dynamic and mobile monitoring **(Silva A R and Vuran M C 2010; Lichtenberg E et al., 2015)**. The recent study on wireless sensor network (WSN) technology has been able to mitigate certain issues related to the wired sensor system (**Patil and Kale 2016; Prathibha and Jyothi 2017; Ma and Chen 2018)**. WSN can operate in a wide range of environments and provide advantages in terms of cost, size, power consumption, flexibility, and distributed intelligence.

The idea of the Internet of Things (IoT) has the potential to enable the seamless integration of devices (things) into the Internet infrastructure. US National Intelligence Council has identified the "Internet of Things" as one of the six most disruptive technologies with the potential to impact US national interests leading to 2025 (Disruptive Civil Technologies, National Intelligence Council, April **2008**) A new and exciting long-range wireless communication protocol, LoRaWAN, has been steadily gaining traction in the wireless network community as of late. LoRa network was specifically designed for IoT applications to connect thousands of sensors, modules, and appliances over a large network. LoRa can achieve a data transmission range of 2–5 km in urban areas and up to 15 km in suburban areas. The network requires minimal maintenance with low power consumption which makes it ideal for a large number of sensors. LoRa can be used in applications where there is no external power supply, such as in agriculture fields, as LoRa applications can run on the battery power supply for years. One disadvantage of the LoRa network is its low data rates which prevent this protocol to be used in real-time and high-throughput applications such as VoIP and video transmission **(Adelantado et al. 2017)**.

An agricultural monitoring system based on the LoRa network for long-range and low-power consumption data transmission from the sensor nodes to the cloud services was developed. This system of cloud services is highly scalable and utilizes multiple data streams for analytics purposes. The system was tested in a vineyard field to collect air temperature and humidity, as well as leaf wetness and soil moisture readings. The prototype consists of three collector nodes and one executor node which are positioned within a 1 km radius from the base station. Based on the soil moisture and leaf wetness measurements, the data analytics service decides if the irrigation system needs to be turned on or off **(Davcev et al. 2018)**.

WSNs can be further categorized based on the type of power supply. Many wireless systems still rely on an external power supply via cable; defeating the purpose of having wireless data transmission capability **(Rehaman et al. 2011; Roselin and Jawahar 2017; Kavitha et al. 2018)**. Some fully wireless data acquisition units use rechargeable batteries capable of powering the devices for several months, though these systems require extensive maintenance to charge or replace the batteries **(Kumar and Kumar 2015; John 2016; Mat et al. 2015)**.

Thus, there exists a need for a low-cost, simple, wireless precision agriculture monitoring system that is highly portable for outdoor use, self-powered to reduce the need for extensive power supply cabling, while providing added functionality that not only reduces agriculture workload but also increases crop yield and profits.

Type of Sensor Network and it's used:

In this section, we discuss two widely used Various of WSNs –Terrestrial Wireless Sensor Networks (TWSN) and Wireless Underground Sensor Networks (WUSN), specifically used in agriculture applications.

1. Terrestrial Wireless Sensor Networks (TWSN):

In the agriculture field, the sensor nodes are placed above the ground to create a smart network using small and low-cost sensors. WSNs are a network of battery-powered sensors interconnected through wireless medium and typically deployed to serve a specific application purpose (**Akyildiz et al., 2002a,b; Akyildiz and Kasimoglu, 2004**). These powerful sensors empower a sensor node or mote to accurately collect the surrounding data. Based on the sensed information, these nodes then network among themselves to perform the application requirements. For example, consider a precision agriculture environment where WSNs are deployed throughout the field to automate the irrigation system. All these sensors determine the moisture content of the soil, and further, collaboratively decide the time and duration of irrigation scheduling on that field. Then, using the same network, the decision is conveyed to the sensor node attached to a water pump. **(Gutiérrez et al., 2014)** proposed one such automated irrigation system using a WSN and GPRS module.

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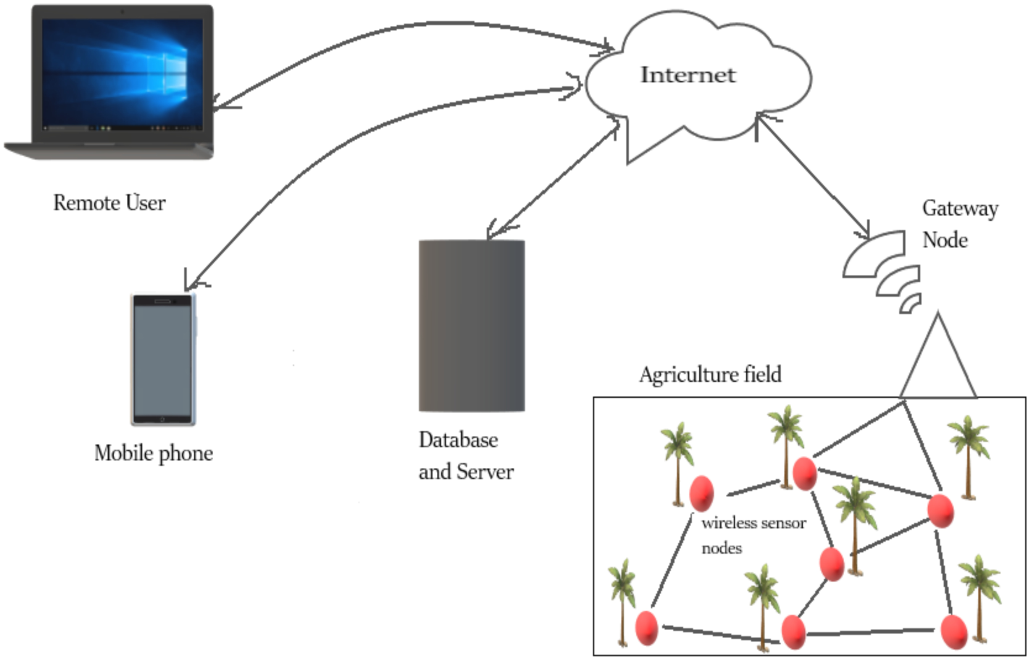

Fig.1. Overview of Precision Agriculture and wireless sensor network deployed for agriculture application.

Fig.1 depicts a typical wireless sensor network deployed on the field for agricultural applications. The field consists of sensor nodes powered with application-specific onboard sensors. The nodes in the on-field sensor network communicate among themselves using radio-frequency (RF) links of industrial, scientific, and medical (ISM) radio bands (such as 902–928 MHz and 2.4–2.5 GHz). Typically, a gateway node is also deployed along with the sensor nodes to enable a connection between the sensor network and the outer world. Thus, the gateway node is powered with both RF and Global System for Mobile Communications (GSM) or GPRS. A remote user can monitor the state of the field, and control the on-field sensors and actuator devices. For example, a user can switch on/off a pump/valve when the water level applied to the field reaches some predefined threshold value. Users carrying mobile phones can also remotely monitor and control the on-field sensors. The mobile user is connected via GPRS or even through Short Message Service (SMS). Periodic information updates from the sensors and on-demand system control for both types of users can also be designed.

2. Wireless Underground Sensor Networks (WUSN):

Another variant of the WSNs is its underground counterpart— Wireless Underground Sensor Networks (WUSNs) (**Akyildiz and Stuntebeck, 2006; Vuran and Akyildiz, 2008**). In this version, the wireless sensors are planted inside the soil. It is used for the analysis of soil properties and monitoring and also for toxic substances for environmental monitoring (**Akyildiz and Stuntebeck E P 2006**). In this setting, higher frequencies suffer severe attenuation, and comparatively lower frequencies can penetrate through the soil (**Silva and Vuran, 2010; Yu et al., 2013**). Thus, the communication radius gets limited and the network requires a higher number of nodes to cover a large area. The application of wired sensors increases the network coverage by requiring a relatively smaller number of sensors. However, in this design, the sensors and the wires may be vulnerable to farming activities. A typical agricultural application based on underground sensor networks is shown in Fig. 2. Unlike the TWSN-based applications shown in Fig. 1, in this figure, the sensor nodes are buried inside the soil. One gateway node is also deployed to transmit the information collected by the underground sensor nodes to the surface sink placed over the ground. Thereafter, the information can be transmitted over the Internet to store in remote databases and can be used for notifying a cell phone-carrying user. However, due to comparatively shorter communication distance, more nodes are required to be deployed for use in WUSNs.

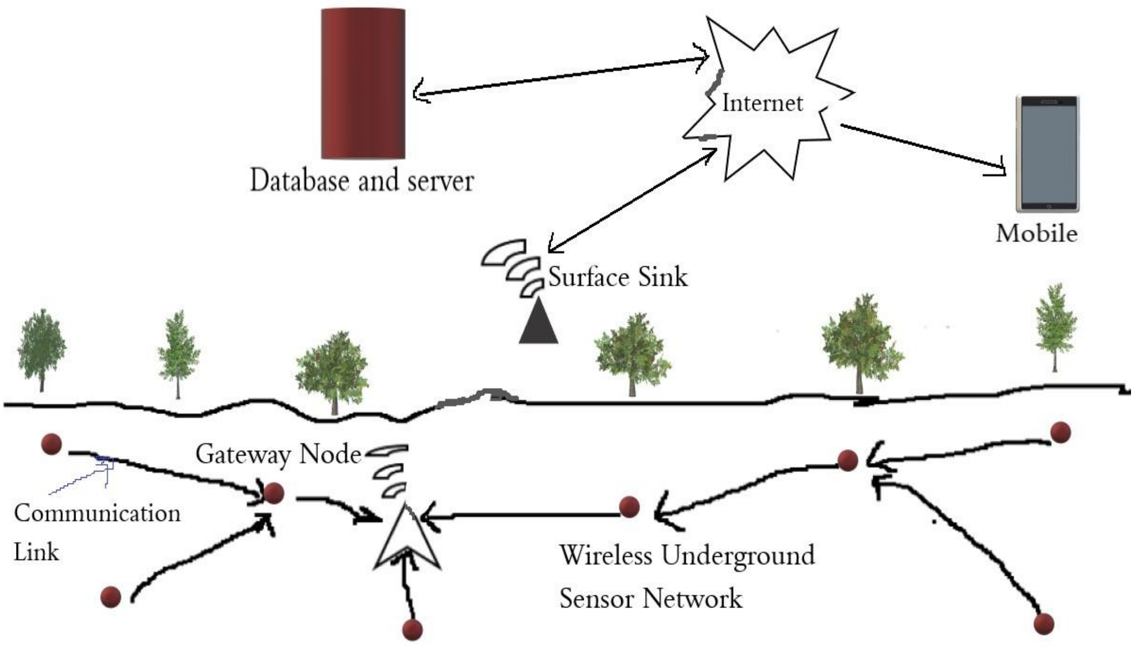

Fig.2. Overview of Underground Sensor Networks

3. Differences between TWSNs and WUSNs:

Table:1

Feature	**TWSNs**	**WUSNs**
Deployment	Placed overground	Buried under-ground
Communication range	~ 100m	~ 0.1 – 10 m
Depth	Anywhere over ground	Topsoil (0 – 30 cm) And subsoil (>30 cm)
Communication frequency	Higher (868/915 MHz, 2.4 GHz)	Lower 433 MHz, 8-300 kHz)
Energy consumption	Lower	Higher
Antenna size	Smaller	Higher
Cost	Lower	Higher

References Martinez et al. (2004) and Vuran and Silva (2009) reported a glacier monitoring network where underground communications over 30 m distance were possible. Further, using higher transmission power, 80 m distance under the ice was also covered.

Wireless sensor network technologies:

In this technologies section, we discuss the detail of the wireless communication technologies, and the standards used in various agriculture applications. Also, we study the different wireless sensor nodes available in the market for use in these applications.

1. Wireless communication technology:

ZigBee: ZigBee (**Baronti et al., 2007; Wang et al., 2016)**. technology introduced by the ZigBee Alliance (**ZigBee Specifications**, **2020**). It is based on the IEEE 802.15.4 standard **(IEEE Standard for Information technology, 2006)**, which specifies the number of communication protocols employed in the design and the establishment of a personal wireless local area network with low power radio signals and low data rate **(IEEE Std, 2011)**. It is a wireless communication protocol widely used in precision agriculture to monitor environmental conditions related to crops' health **(Sarode, K et al 2018)**. ZigBee is very common in smart agriculture applications such as smart greenhouses and smart irrigation systems **(Zhou, et al., 2007)**. It is energy-efficient, low cost and reliable, the ZigBee technology is preferred for WSN-based applications in the agriculture and farming domain. ZigBee also supports short-distance (10–20 m) data communication over multi-tier, decentralized, ad-hoc, and mesh networks. The ZigBee-enabled devices have a low-duty cycle, and thus, are suitable for agricultural applications such as irrigation management, pesticide and fertilizer control, and water quality management, where periodic information update is required. However, ZigBee applications yield low data rates of only 20–40 kbps and 250 kbps at 868/915 MHz and 2.4 GHz frequencies of the ISM band, respectively. Typically, this standard requires low specification hardware (such as a microprocessor with 50–60 kb memory) and includes security encryption techniques.

Bluetooth: Bluetooth (**IEEE Standard for Information technology**, **2012b**; **Bluetooth Technology Special Interest Group)**, which is based on the IEEE 802.15.1 standard, is a low power, a low-cost wireless technology used for communication between portable devices and desktops over a short-range (8–10 m). The Bluetooth standard defines a personal area network (PAN) communication using the 2.4 GHz frequency of the ISM band. The data rate achieved in various versions of the Bluetooth ranges from 1 to 24 Mbps. This Bluetooth technology is used for multiple areas in the agriculture domain. The ultra-low power, low-cost version of this standard is named Bluetooth Low Energy (BLE) **(Xhafa and Ho, 2013, 2015; Linde and Tucker, 2013)**, which was initially introduced by Nokia in 2006 as Wibree **(Nokia, 2006)**. However, in 2010, BLE was merged with the main Bluetooth standard version 4.0. BLE also uses the 2.4 GHz ISM frequency band with adaptive frequency hopping to reduce interference. Also, BLE includes 24-bit CRC and AES 128-bit encryption techniques on all packets to guarantee robustness and authentication. BLE topology supports one-to-one as well as one-to-many connections between devices.

WiFi: WiFi is a wireless local area network (WLAN) standard for information exchange or connecting to the Internet wirelessly based on the IEEE 802.11 standards family (IEEE 802.11, 802.11a/b/g/n) **(IEEE Standard for Information technology, 2005, 2012a).** Currently, it is the most widely used wireless technology found in devices ranging from smartphones and tablets to desktops and laptops. WiFi provides a decent communication range in the order of 20 m (indoor) to 100 m (outdoor) with a data transmission rate in the order of 2–54 Mbps at the 2.4 GHz frequency of the ISM band. In agricultural applications, WiFi broadens the use of heterogeneous architectures connecting multiple types of devices over an ad-hoc network.

LoRaWAN: LoRaWAN operates on the LoRa network. LoRaWAN defines the system architecture and communication protocol of the network, while the physical layer of LoRa enables the link for long-range communication. LoRaWAN maintains the frequencies in communication, data rate, and power consumption for all devices. LoRaWAN is common in agricultural applications because of its large coverage area and low power consumption **(Davcev, D et al., 2018).** In **(Zhou, Y., et al 2007)** a smart irrigation system based on LoRaWAN was presented. Among all wireless communication technologies, 6LoWPAN and ZigBee are considered to be more suitable for PA applications because both are based on mesh networking, which makes them suitable to cover a large area.

GPRS/3G/4G: GPRS (General Packet Radio Service) is a packet data service for GSM-based cellular phones. A data rate of 50– 100 kbps is achieved in the 2G systems. However, in GPRS, throughput and delay are variable, and they depend on the number of other users sharing the same resource. Although the biggest advantage that GPRS brings is in relieving the range limitation of wireless devices. Any two devices can communicate provided they both are in the GSM service area. However, it is better suited for periodic monitoring applications than for real-time tracking-type applications. The advanced version of GPRS is Enhanced Data rates for Global Evolution (EDGE), which offers an increased data rate with no hardware/software changes in the GSM core networks. 3G **(Goodman and Myers, 2005) and 4G (Parkvall et al., 2008)** is the third and fourth generations of mobile communication technology. The corresponding data transfer rate achieved in these technologies is 200 kbps and 100 Mbps to 1 Gbps in 3G and 4G, respectively.

RFID: RFID systems consist of a reader and a transponder, which have a very small radio frequency, called the RF tag. This tag is programmed electronically with distinctive information that has a reading characteristic. RFID has two technologies for the tag system the first is the active reader tag system, and the other is the passive reader tag. Active reader tag systems are more expensive, as they utilize more battery power and use high frequencies. However, passive reader tag systems are low-powered. Some IoT applications using RFID include smart shopping, healthcare, national security, and smart agriculture applications. An IoT-based smart irrigation system based on RFID was presented **(Wasson., et al 2017).** The system was comprised of soil moisture and soil temperature sensors along with a water

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control system, so it collected the reading of the sensors and sent these readings to the cloud using RFID communication protocols, where the user-controlled a water pump based on the water level of the soil.

WiMAX: WiMAX is the acronym for Worldwide Interoperability for Microwave Access, a wireless communication standard referring to the interoperable implementations of the IEEE 802.16 standards **(IEEE Standard for Local and metropolitan area networks, 2011)** family. WiMAX is targeted to achieve a 0.4–1 Gbps data rate on fixed stations, and the maximum transmission range using this technology is 50 km. The Mobile WiMAX (IEEE 802.16e standard) provides data rates in the order of 50–100 Mbps. Also, WiMAX is stated to be energy-efficient over the pre-4G Long-Term Evaluation (LTE) and Evolved High-Speed Packet Access (HSPA+) **(Deruyck et al., 2010; Louta et al., 2014).** The long-range support together with high-speed communication features place WiMAX as the best suitable technology for agricultural applications involving asset monitoring such as farming system monitoring, crop-area border monitoring, and real-time diagnostics such as remote controlling of water pumps, lights, gates, remote diagnosis of farming systems.

Cellular: Cellular technology is most suitable for applications that require an extraordinary data rate. It can utilize GSM, 3G, and 4G cellular communication capabilities by providing reliable high-speed connectivity to the Internet, requiring higher power consumption. It requires infrastructure to be deployed and operation cost and backup staff for it with a centralized managed authority. 4G cellular technology requires more battery power, but cellular technology is a good option in underground wireless sensor networks, such as security systems in smart home projects and agriculture applications **(Zhang., et al 2017)**. A smart irrigation system was presented by **(Khelifa., et al 2015),** in which several soil moisture sensors were deployed in the field in the ZigBee mesh network. The reading captured from the fields were transmitted over the cloud using the cellular 4G LTE network.

6LoWPAN: 6LoWPAN is an IP-based communication protocol, which was the first protocol used for IoT communication. 6LoWPAN is also low cost because of the low bandwidth and low power consumption. 6LoWPAN supports multiple topologies such as star and mesh topologies. To handle interoperability between IPv6 and IEEE 802.15.4, there is an adaptation layer between the network layer and the MAC layer **(Al-Sahrawi ., et al 2017)**. The applications for 6LoWPAN are monitoring the health equipment, environment monitoring, and security and home automation systems. In **(Paventhan, et al 2012)**, a 6LoWPAN-enabled wireless sensor network was presented to monitor the soil properties of crops. The 6LoWPAN system architecture for precision agriculture application was discussed in **(Suryady, et al 2011)** where the performance evaluation of this protocol was discussed with several baud rates and power constraints.

2. Wireless sensor nodes:

The sensor nodes developed as miniature autonomous systems with advanced sensation abilities, which constitute the core unit of the wireless sensor network. A sensor node is considered a micro-electrochemical system. They help to detect and measure physical and environmental attributes such as emission, temperature, pressure, and humidity) and convert them into a signal for control purposes, monitoring and surveillance.

Application of WSNs in Precision agriculture:

1, *WSNs in soil analysis:*

Soil is generally one of the most important factors for crop production. Therefore, knowledge of the physical and mechanical properties of soil is very important, as well as the spatial variability of these properties is essential as decision-support information for modifying culture operation. Up to now, data collection on soil is mostly made by grid sampling to determine, e.g., texture, pF, water content, water infiltration rate, bulk density, cone index, organic matter, and shear strength. Measurements of these properties are labor-intensive, time-consuming, and expensive. Thus, the development of sensors suited to quantify soil properties at the scale required for accurately mapping within-field variations is a necessity so that precision agriculture can be widely practiced **(Stafford, 2000).** For the best products and to increase 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 testing are done by using soil strength sensors (**Hanquet, et al 2004, Hedley, et al 2012**). Pendulum sensors are used to measure the mass and crop density sensors.

Steven Hydra probe II buried to 20-40 centimeters depth is used to measure the soil characteristics like temperature and moisture. Recent advanced technologies **(Wang., et al 2006)** provide opportunities for rapid assessment of Soil Organic Carbon (SOC) in the field based on soil color **(Stiglitz., et al 2017)**. An inexpensive color sensor (Nix Pro^{TM}) was used for rapid assessment of SOC in a dry and moist soil sample from Ultisols of the Piedmont region of South Carolina **(Stiglitz., et al 2017)**. Nguyen and Kodagoda proposed a Gaussian process-based method to estimate the soil organic matter content using WSNs. The soil organic matter predicted by a low-cost Gaussian process-based algorithm is highly comparable to those at corresponding points on a realistic image taken by a very expensive and complex remote sensing system.

2. WSNs in fertilizer management:

Soil fertility is an important factor for produce as it varies the rate of plant growth and the essence of food. Soil fertility can be affected to a desirable level by the application of fertilizers. Broadcasting, manual spreading, and spraying are some of the various ways of the use of fertilizers. The supply of fertilizer to the necessary place requires sensing ability to make it more effective. Many researchers have demonstrated a variety of solutions for optimal fertilization.

A mechanical sensor was developed for area-specific fertilization (Pendulum meter) by a German research team **(Ehlert et al. 2004).** This pendulum meter was used to analyze the density of plantations and was mounted in the forepart of the tractor. A fertilizer spreader and onboard computer were used along with the pendulum meter to determine the level of N applied in the region. Another agri-researcher **(He et al. 2011)** developed an integrated support system to make decisions related to the use of fertilizers using wireless sensors LAN with IEEE entente and GPS server analysis. Real-time soil moisture, temperature, conductivity, air moisture, pH value, radiance, etc., can be monitored using this sensor system.

Considerable progress has been made in the use of proximal remote measurements with handheld and tractor-mounted sensors for nutrient management in arable farming **(Samborski et al 2009, Goffart, et al 2008).** For these so-called near-sensing systems, different commercial devices are currently on the market (e.g., Yara N-sensor, green seeker, Crop circle, Isaria) which measure reflectance in a small number of relatively broad spectral bands using their active light-source. In an operational setting, the sensors are mounted on the tractor or the spraying boom, and measurements are acquired when agricultural activities on the field are carried out **(Tremblay, et al 2009).** This results in a regular point sampling of the field depending on the number of sensors and distance between them and the velocity of the mobile platform during acquisition. The output of near-sensing instruments consists either of more general vegetation indices like normalized difference vegetation index (NDVI) and red-edge position (REP) or system-specific indices that represent the relative difference in crop conditions. Based on this relation, variable-rate technology is developed for spraying and fertilization based on real-time sensor data acquisition**. (Zerger, et al 2010).**

Most studies focus on the use of near-sensing systems for optimization of nitrogen fertilization in arable crops like wheat **(Li, et al 2009, Berntsen, et al 2006)**, corn **(Tremblay, et al 2009 Barker, et al 2010)**, potato (**Goffart, et al 2008)** and cotton **(Gwathmey, et al 2010)** but also for automated fertilizer application in tree crops **(Cugati, 2003).** For example, in 2006 Berntsen et al. **(Berntsen, et al 2006)** adopted the Yara N-sensor to target nitrogen fertilizer in fields of winter wheat. Their results showed that better relationships between sensor measurements and grain yield could be achieved when improved sensors would be able to describe additional crop features (e.g., LAI and canopy characteristics) or soil properties (e.g., soil organic matter, water content). An inter-comparison study by Tremblay et al. 2009 **(Tremblay, et al 2009)** showed that although both commercial sensors **(Greenseeker and Yara N-sensor)** were capable of characterizing differences in crop growth resulting from variation in nitrogen status, marked differences between sensors were observed in NDVI development over the growing season. The studies indicated that the integration of near-sensing instruments or the combined use of near-sensing systems with remote sensing data sources still requires further improvement in farming **(Samborski, et al 2009).** In addition, recently published vegetation indices like the Normalized Area Over reflectance Curve (NAOC) **(Delegido, et al 2010)** and the Double-peak Canopy Nitrogen Index (DCNI) **(Chen, et al 2010)** combined with biomass indices (e.g., weighted difference vegetation index (WDVI) **(Clevers, et al 1997)** showed promising results to assess crop nitrogen status. To improve site-specific nitrogen management, plant growth models require accurate information on the whole cropping system, including the crop nitrogen status, and supply and losses from the soil with a high temporal and spatial resolution **(Hatfield, et al 2010).**

3. WSNs for scheduling of irrigation:

Irrigation is a key factor for the agricultural sector, which is one of the most vital services in this sector. It is an important practice for most crops in areas with insufficient rainfall to meet the water needs of crops, as insufficient irrigation generally leads to a reduction in crop quality and yield **(Baggio, 2005).**

Gutierrez et al. (**2014**) proposed and developed an automated irrigation system based on the use of the wireless sensor network and other technologies to manage and optimize the use of water for crops. The proposed system consists of a distributed wireless network with many soil moisture and temperature sensors to monitor and control soil parameters. It also consists of a control unit that allows identifying, evaluating, and storing the collected data, as well as automatic irrigation activation management with the help of a developed program containing threshold values of measured information. The authors tested this automated system in a greenhouse for organic sage cultivation for 136 days, in which test results demonstrated significant water savings, i.e., up to 90%, compared to traditional irrigation techniques.

Avatade and Dhanure (**2015**) developed an automated irrigation system using a wireless sensor network and GPRS technology. The developed system is based on an embedded platform using an ARM micro-controller for the water irrigation system. This system allows the measuring and monitoring of the temperature and moisture level of the soil using numerous wireless sensor nodes based on an ARM micro-controller. It controls the water flow in the field using the measured values to reduce the water consumption of irrigation. This embedded project also allows monitoring and controlling of the status of the sensors used on a remote PC via a web page by entering an IP address specified for the system.

Kim and Evan (**2009**) developed a software system for irrigation control using WSNs. They presented the design of decision support software and the integration of this software with an in-field WSN for the control and monitoring of sprinkler irrigation techniques. The authors developed wireless in-field sensing and control (WISC) software for remote access to information, decision-making, and real-time monitoring and control of site-specific sprinkler irrigation via WSN and Bluetooth.

Viani et al. (**2017**) developed a low-cost decision support system to manage the irrigation system efficiency and thus save water in agriculture. The suggested system is based on the integration of an innovative decision support methodology and a low-cost wireless sensor and actuation network (WSAN). The innovative methodology helps decision support using fuzzy logic (FL); this methodology was calibrated and designed based on the indications given by farmers to understand the state of the crop and reproduce the human experience. The WSAN consists of a set of sensor nodes and is used to measure and monitor environmental conditions and manage the irrigation system. The suggested smart irrigation system aims to achieve many benefits, including a fully autonomous wireless system, a low level of water stress, increased water conservation, and increased crop productivity.

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Table: 3

Sr. No.	**Name of the sensor**	**Parameter Captured**	**References**
1.	ECH2O soil moisture sensor	Soil Temperature, Soil Moisture, Conductivity	http://envcoglobal.com
2.	MP406 Soil moisture sensor	Soil Temperature, Soil Moisture	https://www.bwallen.com
3.	Pogo portable soil sensor	Soil Temperature, Soil Moisture	https://www.bwallen.com
4.	237 leaf wetness sensor	Plant Moisture, Plant Wetness, Plant Temperature	https://www.campbellsci.com
5.	Field scout CM1000TM	Photosynthesis	http://www.specmeters.com

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6.	LW100, leaf wetness sensor	Plant Moisture, Plant Wetness, Plant Temperature	https://www.campbellsci.com
7.	TPS-2 portable photosynthesis	Photosynthesis, Plant Moisture, CO2	http://ppsystems.com
8.	PTM-48A photosynthesis monitor	Photosynthesis, Plant Moisture, Plant Wetness, CO2, Plant Temperature	http://ppsystems.com
10.	Met Station One (MSO)	Air Humidity, Air Temperature, Wind Speed, Air Pressure	https://metone.com
11.	SHT71, SHT75 (Humidity and temperature sensor)	Humidity and Temperature Sensor	https://www.sensirion.com
12.	Cl-340 hand-held photosynthesis	Air Temperature, Air Humidity	https://cid-inc.com

13.	CS625	Soil moisture	Kim and Evan (2009)
14.	SEN10972 pH Sensor kit	pH value of soil	Nagarajan and Minu (2018)
15.	LM35 IC	Temperature	Nagarajan and Minu (2018)
16.	TDR-3A	Soil humidity and temperature	Katyra et al. (2017)
17.	DS200	Soil moisture	Isilk et al. (2017)
18.	DHT22	Humidity and temperature	Shaker and Imran (2013)
19.	SHT75	Temperature and air humidity	Rahim Khan et al (2013)
20.	DS18B20 probe	Soil temperature acquisition	Nagarajan and Minu (2018)
21.	Watermark 200SS probe	Soil moisture	Viani et al (2017)
22.	Hydra probe II soil sensor	Soil Temperature, Salinity level, Soil Moisture, Conductivity	https://www.licor.com
23.	EC sensor (EC250)	Soil Temperature, Salinity level, Soil Moisture, Conductivity	http://envcoglobal.com

24.	107-L temperature Sensor (BetaTherm 100K6A1B Thermistor)	Plant temperature	Kim et al (2008)
25.	YSI 6025 chlorophyll sensor	Photosynthesis	https://www.xylem-analytics.in
26.	SenseH2TM hydrogen sensor	Hydrogen, Plant Wetness, CO2, Plant Temperature	http://www.ntmsensors.com
27.	TT4 multi-sensor thermocouple	Plant Moisture, Plant Temperature	https://tempsens.com
28.	LT-2 M (leaf temperature sensor)	Plant Temperature	http://phyto-sensor.com
29.	Cl-340 hand-held photosynthesis	Photosynthesis, Plant Moisture, Plant Wetness, CO2, Plant Temperature, Hydrogen level in Plant	https://cid-inc.com

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30.	107-L Temperature Sensor (BetaTherm 100K6A1B thermistor)	Air Temperature and soil temperature measurement	Kim et al (2008)
31.	XFAM-115KPASR	Air Temperature, Air Pressure, Air Humidity	https://www.distrelec.biz
32.	DELTA –T SM300	Soil moisture	Hedley et al (2013)
34.	HMP45C (Vaisala's HUMICAP R H-chip)	Air Temperature, Air Humidity, Air Pressure	https://www.campbellsci.com
35.	GS3	Moisture, conductivity, and temperature	Navarro-Hellin et al (2015)
36.	LMK	Pressure	Navarro-Hellin et al (2015)
37.	ES-2	Water electrical conductivity and temperature	Navarro-Hellin et al (2015)

Case Study:

Nanotechnology with Wireless Nanosensors: The New Perspective in Precision Agriculture

Sensors are used in various agriculture operations to detect and monitor various processes. Wireless nanosensors worked in the same as conventional sensors, but the defining difference is that nanosensors use nanomaterials as their active sensing element.

`Nanotechnology is used in various fields of science like physics, chemistry, pharmaceutical science, medicinal and material science right now in the field of agriculture nanotechnology has a wide range of scope. According to the Directorate-General for internal policies of the European Union; precision agriculture is a farming management concept of measuring and responding to inter and intra-field varying in crops to form a decision support system for whole-farm management and to reap the maximum output from the available resources. Now a day, nanotechnology is extensively used in modern agriculture to make true the concept of precision agriculture. Nanotechnology includes nanoparticles having one or more dimensions in the order of 100 nm or less.

Problem definition:

Fertilizers have to change the way the words produce food. They have not only brought large benefits for food security, but they also bring environmental benefits through higher yield. When we apply excess fertilizers – no matter whether they are natural ones like manure or synthetic fertilizers – excess nutrients is washed off and pollute the natural environment. In addition to excess salts from fertilizer diminishing the crops' ability to take up water, over-fertilized crops may take up more nitrogen than they need, which disrupts the balance of nutrients in plant tissue. The result is that crops will be deficient in those other necessary nutrients, such as sulfur and zinc, reducing crop quality. Above a certain threshold, any nutrients, including nitrogen, cease to promote plant growth and can be toxic. Below the toxicity threshold, deficiency in other nutrients will prevent the crop from responding effectively to the application of anyone nutrient. For example, sulfur is necessary for the plant to metabolize nitrogen, but isn't included in typical superphosphate fertilizer.

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Use of Nanotechnology with wireless sensor network:

Excess amounts of fertilizer in the form of ammonium salts, urea, and nitrate or phosphate compounds have increased crop production considerably, they harm the beneficial soil microflora. Most of the fertilizers are not available to plants due to run-off and cause pollution. We have already seen the above problems; how over fertilizer affect crop yields? and nutrient status. Fertilizers coated in nanomaterials can solve this problem. Nanomaterials have potential contributions to the slow release of fertilizers as nanoparticles hold the material more strongly from the plant due to the higher surface tension of nanoparticles than conventional surfaces. Moreover, nanocoating provides surface protection for larger particles.

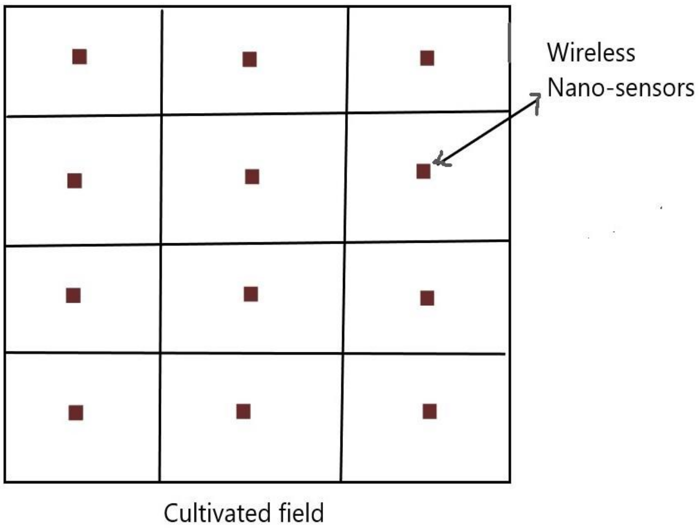

Fig.3 Overview of deployed Nanosensor in the field

Precise application of fertilizers, irrigation and moisture level, soil fertility, soil temperature, nutrient status in soil, etc. can be monitored through advanced nanotechnology. Such real-time monitoring is done by deploying a network of wireless Nano-sensors across the cultivated field. **(fig.3).**

Wireless nanosensors deployed in the field at a particular location and can monitor that location only, and they will give all information on that field at a particular location in a very precise manner, like how much fertilizer is required in that location? , is it required irrigation? Or not, which fertilizer deficiency in that location? They can also monitor soil moisture status, soil fertility, and all problems and solution regarding soil and irrigation related.

Conclusion:

Deployment of wireless Nanosensors in the field helps to provide an efficient and cost-effective solution for supporting, improving, and strengthening precise fertilizer applications with Nanotechnology. They indirectly help alleviate the global food crisis through Wireless Nanosensors and Nanotechnology. The present paper has provided a comprehensive review of the application and deployment of Wireless Nanosensor and Nanotechnology for precise fertilizer application within the stipulated field and also helps in the management of irrigation, monitoring fertility status of the field, and soil-related problems and solutions to the field of the crop. Firstly, we presented and explained various aspects of wireless sensor networks in precision agriculture. Next, we presented different WSNs, then we explained various wireless sensor network technologies such as communication technology and sensor nodes. After that, we presented the application of Wireless sensor networks for soil analysis, fertilizer management, and irrigation management. Lastly, we conclude that wireless Nano-sensors with the help of Nano-technology are the best solution in precision agriculture.

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