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Testing/Monitoring of Soil Chemical Level Using Wireless Sensor Network Technology

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ABSTRACT

Demographically agriculture accounts for the broadest economic sector and plays a key role in the overall socio-economic development of India. Despite attaining self-sufficiency in food staples, the productivity of Indian farms is below that of other nations. The low productivity is a result of inadequate use and adoption of modern agricultural practices and technologies, affected by negligence of such practices, high costs and impracticality in the case of small land holdings. The application of commercial N, P, and K fertilizers has contributed to a tremendous increase in yields of agricultural crops. However, excessive use of these fertilizers has been cited as a source of contamination of surface and groundwater. There are different stages in crop cultivation and each stage requires different nutrient levels. Therefore, a farmer has to spend a lot of time in monitoring the fields. With recent advancement in Wireless Sensor Network (WSN) technology, various techniques are available to measure soil nutrients. On the basis of knowledge of soil nutrients level, farmers can enhance the crop productivity because insufficient nutrient levels can adversely affect crop productivity while excess nutrient levels will either have a similar effect or simply be wasted.

Keywords: Wireless Sensor Networks, Soil nutrient and its sensors, Agriculture, Crop productivity

1. Introduction

Healthy soil forms the foundation of the food system in India. A healthy soil produces healthy crops. Maintaining a healthy soil demands care and effort from farmers. In the recent years, a declining trend of total factor productivity and compound growth rates of major crops and low nutrient use efficiency have been observed primarily due to deterioration of soil health. The main reasons for soil health deterioration are: a) wide nutrient gap between nutrient demand and supply, b) high nutrient turnover in soil-plant system coupled with low and imbalanced fertilizer use, c) decline in organic matter status, d) emerging deficiencies of secondary and micronutrients, e) nutrient leaching and fixation problems, f) soil pollution and soil acidity, etc. Deficiencies in micro and secondary nutrient in soils leads to mineral deficiency disorders..Therefore to enhance sustainable production, timely testing of soil nutrients and prevention and soil degradation through improved soil health is important.[1] Various crucial issues need to be addressed in future research activities in nutrient management and fertility improvement domain.

This paper describes the use of Wireless Sensor Network technology to determine the level of soil nutrients. Since no proven economical methods has been yet devised to effectively and efficiently allocate chemicals to meet crop needs, significant energy waste occurs in application of agriculture chemicals. Consequently chemicals and fertilizers are applied in uniform amount irrespective of local changes in soil chemical conditions. Wireless sensor networks are widely used in agriculture to increase the productivity and monitor the various physical and chemical properties of the soil. Various types of sensors are used which perform various task like water monitoring, soil moisture monitoring, monitoring of soil chemical level and climate change effects. The sensor network in this paper senses the soil chemical condition in real time and as per the measured deficit or excess chemical condition, appropriate amount of fertilizer and compost are applied to the soil. [2].

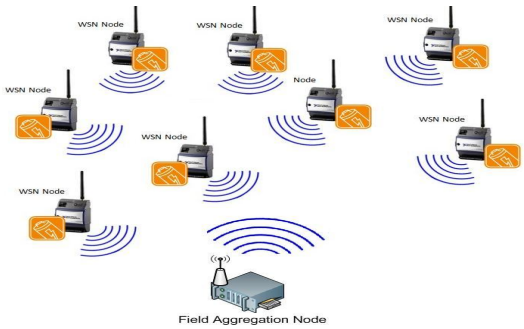

Fig: 1 Shows the sensors placed in the field at various points

Sensors are connected to base stations through a network. Base station is connected with local management by gateway networks to control and monitor the crops and field conditions. Such farming is known as precision farming. Precision farming is the ability to handle different types of problem in productivity, increase financial return and reduce waste by using automated data collection and implementation using sensing, controlling and communication technology[3].

2. Elements of Soil

Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, iron, boron, manganese, copper, zinc, molybdenum and chlorine are considered as 16 most essential nutrients of soil. These nutrients can be classified as:

- The primary macronutrients: nitrogen (N), phosphorus (P), potassium (K)
- The secondary macronutrients: calcium (Ca), sulfur (S), magnesium (Mg)
- The micronutrients: boron (B), chlorine (Cl), manganese (Mn), iron (Fe), zinc (Zn), copper (Cu),molybdenum (Mo), nickel (Ni)

These nutrients are supplied by the soil and by the addition of fertilizers such as manure, compost, and fertilizer salts.

3. Various Methods of Soil Nutrients Testing

The various types of sensing techniques available are as follows:

- Optical sensing that uses reflectance spectroscopy to detect the level of energy absorbed/reflected by soil particles and nutrient ions,
- Electrochemical sensing that uses ion-selective electrodes which generate a voltage or current output in response to the activity of selected ions.

3.1 Spectroscopy: The interaction between incident light and soil surface properties, such that the characteristics of the reflected light vary due to the soil physical and chemical properties, makes the basis for diffuse reflectance spectroscopy. Such optical methods are preferred by many researchers due to their attractive advantages such as non-destructive measurement and no need to take a soil sample over electrochemical technology [4].

Although reflectance spectroscopy can respond to total nutrient concentrations in soil, calibration of the reflectance signal to the plant available portion of the nutrient pool measured by standard soil tests is a considerable challenge. This challenge has contributed to the inability to obtain consistently good estimates across a range of soils, relatively high standard errors and significant effects of soil type.

3.2 Electrochemical Sensing: Most of the electrochemical methods used to determine soil nutrient levels are based on the use of an ion-selective electrode (ISE), with glass or a polymer membrane, or an ion-selective field effect transistor (ISFET). Ion-selective membranes are available for sensing most of the important soil nutrients, including NO3, K, Na, Ca, Mg, and Cl. In general, laboratory tests using ISEs or ISFETs (fig. 2) have shown to be feasible to determine macronutrients in moist soils or soil extracts due to a strong linear relationship to standard methods.[5].

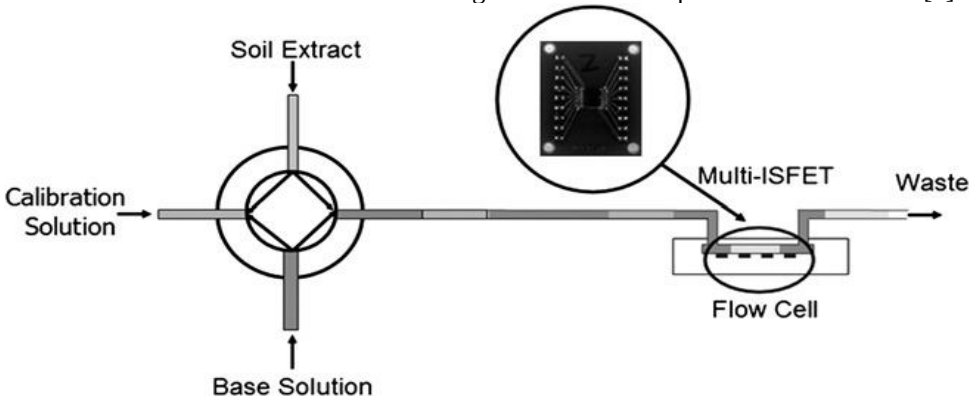

Fig.2 Shows a schematic of an ion-selective field effect transistor (ISFET)

It is a flow injection analysis (FIA) system. The soil extract sample, calibration and base solutions are sequentially introduced through a flow injection line system with multiple inlets, and are transported to a multi-ISFET chip with outputs that continuously change due to the passage of the sample through the flow cell.

3.3 On-the-go soil macronutrient sensing: Since on-site, rapid measurements of soil nutrients are an ideal approach to variable-rate application of agricultural fertilizer, several researchers, have reported real-time on-the-go soil nutrient sensing using custom-designed soil samplers and commercially available ion-selective electrodes for sensing nitrate and pH in soils. The system consists of a soil sampler, an extraction unit, a flow cell, and a controller. A designed prototype shows a tractor-mounted field monitoring system to measure soil nitrate levels in fields using ISEs because it was found that a nitrate ion-selective electrode gave more reliable sensor readings and acceptable response. However, the disadvantage of on-the-go sensors based on ion selective technology is that soil sampling and nutrient extraction are required, increasing the complexity of the system and the time required for a measurement.

4. Wireless Sensor Network

Wireless sensor networks (WSNs) are composed of sensor nodes with limited resources. A sensor node consists of three main components: a sensor, a processor and a wireless communication device. These sensor nodes are dispersed through the area of interest to monitor, collect, and transmit data.

4.1 Sensor Technology

For sensing soil nutrient level, the sensors are deployed spatially in whole field. Different sensors are deployed in different manner but the basic technology employed in the sensors remains the same[6]. But this different arrangement plays an important role as when used efficiently these sensors save time, required power and also may decrease the channel traffic, thus increasing the overall efficiency of the whole network [7].

4.2 Different Sensors Arrangement

Different sensors play different role. So the arrangement of sensors is done in a specific way. Arrangement is done in a hexagonal geometry because it is the best geometry among three (triangle, square & hexagon). Hexagon has the largest area of the three. Minimum numbers of hexagon can cover maximum area.

Each color indicate different sensor. Six types of sensors are used for measurement of six different nutrients & no one sensor of same type is interferes to other due to such arrangement. Each sensor is work at different frequency that's why there is no problem of interference in between different type of sensors. As shown in the figure below-

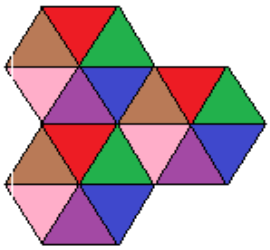

Fig.3 Sensors Arrangement in Field

4.3 Mechanism of a Sensor Network Technology

These nodes comprise of following:

a) Microcontroller: It controls the monitoring for which various sensors have been employed.

b) Built-in radio transceiver: It used to generate radio waves to transmit data obtained from sensors over wireless communications. The communication is carried out between a gateway and a sensor node and also between two sensor nodes.

Power generation and power storage devices such battery. Repeating data relays, these sensor nodes safely transmit data to the gateway. Further, the gateway sends the data to a server or the cloud. The server or cloud analyzes the data for convenient use. This system can support every aspect of wireless sensor networks, including uploading data to the cloud via a gateway or router and distributing data to your smart phone or other terminal.

c) The entire network is based on the phenomenon of multi routing algorithm which is also termed as wireless ad hoc networking. As shown in the fig. 4-

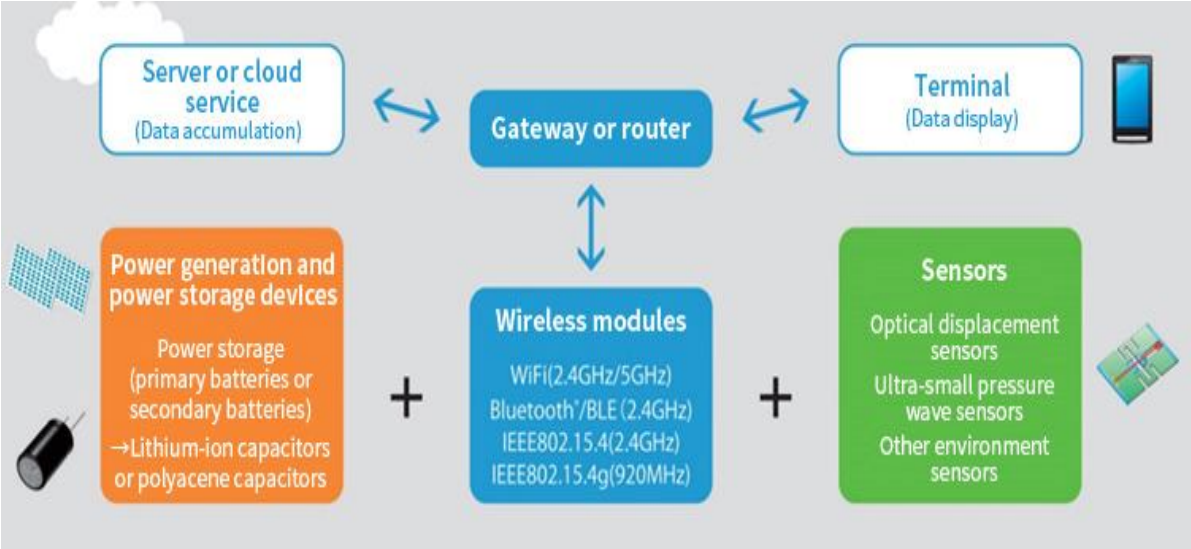

Fig.4 Block Diagram [9]

4.4 Proposed Method

The sensor nodes are scattered in the desired locations. Theses nodes collect data and transmit it through radio transceivers over wireless communications modules to the base station or server where the data is accumulated. The stored data is then processed and is transmitted to data display terminal which can a smart phone, tablet or laptop etc [8].

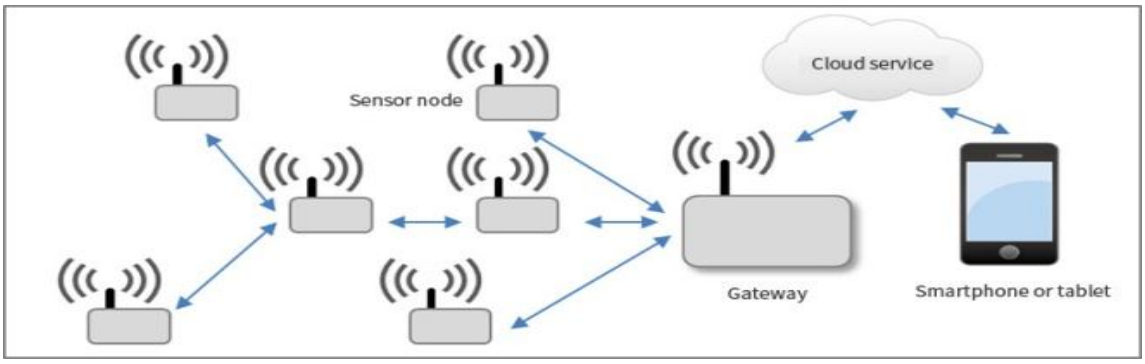

Fig.5 Sensor network technology for soil nutrient [10]

As shown above in this case, the chemical level of the soil is monitored by the sensors and data is transmitted over the wireless channel to the farmer's phone through which he can timely get the knowledge of chemical level of the soil in his field and accordingly he can apply fertilizers to his farm. In this way the sensor technology can help farmer know the exact time to apply fertilizers and compost to the field to increase productivity, save time, money and energy.

5. Conclusion

Growing concerns about environmental pollution by excessive use of fertilizers have led to increasing needs to monitor soil nutrients required for crop growth. The sensor network technology will help the farmers to know the soil requirements which will help them take better decisions and preventive measures at the right time. This will lead to tremendous improvement in the crop productivity. This, in turn, will save their time, labor, money and make effective use of resources.

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