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USE OF SMART SENSORS IN SOIL MEASUREMENT

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Sensors are a modern agricultural technology, developed to help farmers obtain faster and better results, assisting in the determination of various soil characteristics. They can be used to measure in real-time thus controlling the variable rate application. A sensor detects events or changes in soil characteristics and provides a corresponding output, indicated through an electrical or optical signal. Sensors can improve the quality and reduce the cost of laboratory soil analysis, as well as improve crop management and overall crop production.

Introduction

Sensors are a modern agricultural technology, developed to help farmers obtain faster and better results, assisting in the determination of various soil characteristics. They can be used to measure in real-time thus controlling the variable rate application. It can also be used on-the-go, generating soil maps in conjunction with a GPS. These vehicle-based sensors are located in the front of the tractor or attached on its implement**,** in direct contact with the soil or near its surface. As the tractor passes over the field, the sensor collects data, processes it, and interprets on a soil map, thus providing multiple layer information regarding the soil**.** In the case of real-time sensors, collected and interpreted data leads to an instantaneous rate application change. There are a few sensors used for soil mapping, which vary in the area of measurement technique for the measuring of soil characteristics**.** These include:

1-Electromagnetic

2- Electrochemical

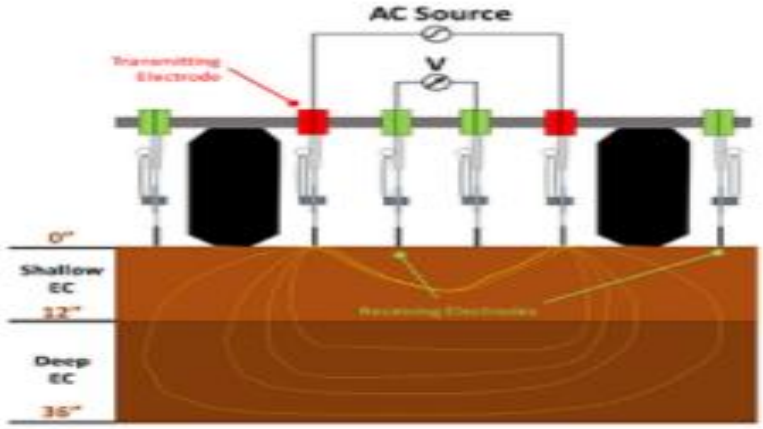
3-Mechanical

Electromagnetic sensors:

Electromagnetic sensors measure the various components of soil properties that may affect crop productivity, such as soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics**.** The sensors use electric circuits to

measure the capability of soil particles to conduct or accumulate electrical charge. Electromagnetic sensors measure soil EC by using two methods: contact and non-contact.

The contact method uses electrodes which penetrate into the soil. The sensor is installed on a device and pulled by a tractor or vehicle which is equipped with a GPS receiver. It's a widely used soil measuring method due to its ability to provide a precise mapping of the whole field. The only disadvantage is that it is not suitable for too large or too small fields. The non-contact method uses electromagnetic induction (EM) which does not make physical contact with the soil. The sensor is usually installed on the opposite side of a vehicle or a tractor and equipped with a GPS receiver.



Contact EC sensor which measures on two soil depths

Non-contact electromagnetic sensor for soil mapping

Application of soil electromagnetic sensors

Application of Soil EC Mapping	Soil Properties Estimated
Directed or smart soil sampling	Soil texture, organic matter, CEC, drainage conditions
Variable-rate seeding	Topsoil depth, CEC, soil productivity, organic matter
Variable-rate nutrient application based on soil productivity	Depth to claypan subsoil, soil texture, drainage conditions
Spot or targeted herbicide application	Soil texture, organic matter
Interpretation of yield and as-planted maps	Plant available water content
Soil salinity diagnosis	Electrolytes in soil solution
Drainage remediation planning	Water holding capacity, sub-soil properties, water content

Electrochemical sensors -Electrochemical sensors are used to measure the most important soil characteristics for precision management; soil nutrient levels and pH**.** It's a great replacement for standard chemical soil analysis, which is expensive and takes more time to get the results. These sensors use an ion-selective electrode (ISE) or an ion-selective field effect transistor (ISFET) to measure the voltage between the sensing and reference part of the system related to the concentration of specific ions (H^+, K^+, NO_3^-). The soil sampling mechanism scoops a soil sample and brings it in contact with the electrode. After a stable reading is measured, the electrode is rinsed before the next reading.

Mechanical sensors - Mechanical sensors are used to estimate soil mechanical resistance (compaction) as related to the variable level of compaction. These sensors use a mechanism that penetrates or cuts through the soil and records the force measured by strain gauges or load cells. When a sensor moves through the soil, it registers resistance forces arising from the cutting, breaking, and displacing of soil. Soil mechanical resistance is measured in a unit of pressure and represents the ratio of the force required to penetrate the soil medium to the frontal area of the tool engaged with the soil.

Electrochemical sensor for soil pH mapping

Mechanical soil sensor

Conclusion:

Soil productivity is limited by many different factors such as soil type, texture, organic matter content, and moisture. Therefore, there is a need to measure soil characteristics more accurately in order to make successful, data-driven decisions. Inadequate soil samplings and high cost are the main reasons to make a revolutionary change in farming, by using sensors. A sensor detects events or changes in soil characteristics and provides a corresponding output, indicated through an electrical or optical signal. Sensors can both improve the quality and reduce the cost of laboratory soil analysis, as well as improve crop management and overall crop production.

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