# Real Time Soil Monitoring Sensors

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## ABSTRACT

Real time soil monitoring provides efficient and timely information of crop and soil for precise decision making in the crop production and yield improvement. The high cost, time-consuming soil chemical analysis, and laborious collection of soil samples are significant problems in soil monitoring. In an attempt to solve these problems, different types of soil sensing systems have been developed with applications in site-specific nutrient management in precision agriculture. Most of these 'on-the-go' soil sensors are based on electrical or electromagnetic sensing. These 'on-the-go' soil sensors might be less accurate than conventional laboratory methods, but are still advantageous due to their high-resolution spatial information. Optical and radiometric sensors also require a higher initial equipment cost compared to the other sensors.

## INTRODUCTION

In precision agriculture, rapid, non-destructive, cost-effective and convenient soil analysis techniques are needed for applying fertilizers, manures and compost as per spatial variability of specific field which is usually done with the help of carriable rate applicators. Conventional soil management involves following steps: 1) a soil sample is prepared using samples collected from a field or an individual crop compartment; 2) a representative value of several soil properties (e.g., N, P, K, pH) is obtained by soil chemical analysis for field crop management; and 3) the amount of fertilizer, manure and compost input is adjusted for each field or crop compartment as per recommendations for crops. Soil monitoring sensors are sensors that are used to monitor various parameters of the soil including soil temperature, moisture, pH, conductivity, nitrogen, phosphorus and potassium content. These sensors can be used to monitor the condition of the soil for parameters such as fertility, moisture, aeration, etc., thus helping the farmer or gardener to better manage the crop and improve the quality of growth and yield as per current status. However, to reduce fertilizer costs, increase crop production and achieve environmental impact reduction, changing the fertilizer application is not sufficient. Also, to create several high-resolution soil maps by conventional soil survey techniques, a huge number of soil samples has to be collected according to the many separate grids of a field or crop compartment. Different on-line soil sensors in six main categories are available based on their design concepts such as, electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic and electrochemical soil sensors. The output of majority of the soil sensors is affected by more than one agronomic soil characteristic. Due to different soil types, parent materials, soil and environmental factors, for example, water content, temperature, humidity, organic matter, topography, and soil colour, the performance of different sensors varies considerably with mixed results reported.

Compared to the other sensors, optical and radiometric sensors demand a greater initial equipment cost. Additionally, chemometrics forms the basis of the analysis results (Guerrero *et al.*, 2021). This kind of sensing has not acquired trust since it is unclear exactly how optical and radiometric sensors connect to composition and absorption wavelength. This uncertainty is being progressively cleared up by recent research that examined the link between the absorption band of soil chemical analysis and chemometrics techniques including multiple linear regression (MLR), principal component regression (PCR), and partial least squares regression. Within this class of sensors various principles are being used to measure soil properties directly or indirectly through an assessment of electrical conductivity, resistivity, and permittivity. This class includes measurement of electrical resistivity (ER) or conductivity (EC), time domain reflectance (TDR), frequency domain reflectance (FDR), ground penetrating radar (GPR), and electromagnetic induction (EMI).

**Real Time Soil Sensor**

The RTSS is mounted on a tractor using a three-point hitch. The RTSS equipment captures several datasets simultaneously as a real-time soil measurement system for precision agriculture (Shibusawa *et al.*, 2022). It is made up of the soil penetrator, a touch panel, the housing for the probes, and the sensor unit. An inverter generator powered by gasoline provided electricity for the RTSS. The chisel unit is driven into the ground by the tractor's PTO (power take-off), which is coupled to the RTSS's hydraulic power. A personal computer, a 150-W Al- coated tungsten halogen light, a tiny CCD camera, a differential GPS receiver, and two spectrophotometers are among the essential components of the RTSS system that are housed in the housing of the sensor unit. The roof is where the DGPS antenna is installed. The linear photodiode array of the Vis spectrophotometer comprises 256 pixels. The spectra had intervals of around 3 nm, ranging from 305 to 1100 nm. A 128-pixel linear diode array of multiplexed InGaAs for NIR was used. The spectra ranged from 950 to 1700 nm with intervals of approximately 6.0 nm pixel pitch. Also, the spectral data collected from the two spectrometers was converted to 5-nm-interval data by interpolation. The spectra ranged from 350 to 1700 nm with intervals of approximately 5 nm.

**EMI based Sensors:**

The EMI sensors are based on Faraday's law used in physics. EMI is a contactless non-invasive method. In short, the transmitter coil at or above the ground surface is energized with an alternating current, creating a primary, time-varying magnetic field in the soil (Adamchuk *et al.*, 2010). This magnetic field induces small eddy currents in the soil, while the soil matrix produces a weak secondary magnetic field. The receiver coil responds to both the primary and weak secondary magnetic fields. The secondary magnetic field is, in general, a complicated function of the inter-coil spacing, operating frequency, and ground conductivity. As soil conductivity is not homogeneous, the EMI device measures electrical conductivity of the total volume of soil contributing to the signal. Soil conductivity is, therefore, called apparent or bulk soil electrical conductivity. Operating at low induction numbers, the ratio between the primary magnetic field and secondary magnetic field is a linear function of bulk or apparent soil electrical conductivity (ECa).

**Time Domain Reflectometry (TDR) Sensors**:

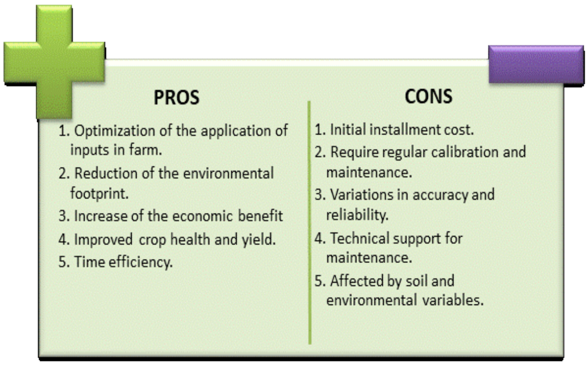
TDR sensors determine soil moisture by measuring the time it takes for an electromagnetic pulse to travel along a probe inserted into the soil. Moisture affects the dielectric properties of the soil, altering the travel time of the pulse. This information is then used to estimate soil moisture content.

**Gamma-ray spectrometry**

Gamma-ray spectrometry or radiometric technology is a non-invasive, non-destructive, and a passive technique. It is a relatively new soil sensing technique that measures gamma radiation emitted from the natural decay of radioactive isotopes that are present in all soils (Mahmood *et al.*, 2013). The ground-based gamma spectrometers are used as an on-line system to measure gamma counts. There are some small handheld gamma spectrometers to be used in situ as well as in the laboratory.

**Electrochemical based sensors**

Electrochemical sensors consist of an ion selective membrane, which selectively responds to a target ion, and a transducer, which transforms the reactions into detectable electrical signals. It converts the effect of the redox reaction on the surface of electrodes to electronically readable signals that show changes in potential, current, and conductivity.




## CONCLUSION

Real-time soil monitoring (RTCSM) possesses a great potential to revolutionize field measurements by providing first-hand information by continuously tracking variations of heterogeneous soil parameters in a timely manner and thus enable constant updates essential for system control and decision-making. Advancements in remote sensing, artificial intelligence and robotics has opened new chapters for soil resource management strategies.

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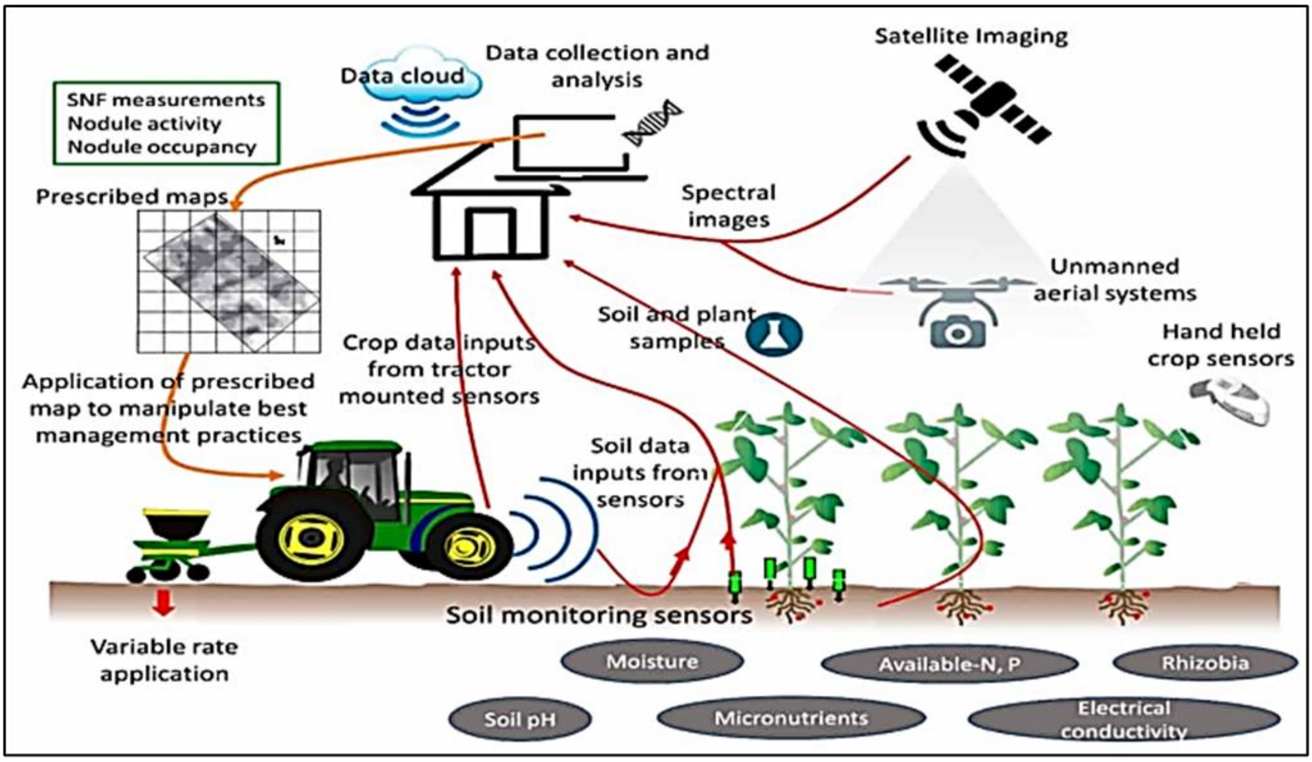


**Real Time Soil Monitoring (Thilakarathna and Raizada's, 2018)**