Adamawa State University Journal of Scientific Research
Volume 10 Issue 2, 2022; Article no. ADSUJSR-1001013
ISSN: 2705-1900 (Online); ISSN: 2251-0702 (Print)
http://www.adsujsr.com

Development of A Smart Soil Nutrient and Water Level Analysis System for Different Land Use Options Using Internet of Things (Iot)

Adebisi S. L.[1]*, Babalola A. D.[2] and Adesina O. D.[3]
1. Department of Agricultural Technology, Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria
2. Department of Computer Engineering Technology, Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria
3. Department of Accountancy, Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria
Contact: adebisisunday@gmail.com/sunadebisi@fedpolel.edu.ng, +234(7)031664721

(Received in October 2022; Accepted in November 2022)

Abstract
An experiment was conducted to study soil analysis methods (conventional laboratory and a smart soil analyses) on nutrient mining and availability under different land use patterns; Arable Land (AL), Cocoa Plantation (CP), Oil palm Plantation (OP) and Forest (FR) at Ile-Oluji in the rain forest zone of Nigeria. The conventional soil test is faced with different challenges and may fail to be effective since it takes more time to get the results and it is difficult to take the regular tests during the single crop life time. Smart soil analyzer was designed, developed and compared with the conventional laboratory soil analysis. Coordinate data (Northings, Eastings and Elevation) of the fifteen (15) Sampling Points were taken with the Global Positioning System (GPS) receiver, forty five (45) soil samples were collected at three different depths 0 - 15, 15 – 30 and 30 – 75 cm using soil auger, bulked for different depths, air dried and prepared for laboratory analysis to determine soil N, P, K, pH and MC while developed smart soil analyzer was used to determine the selected soil properties at three different depths. Both the results from the conventional laboratory and smart soil analysis were compared. Values of soil N, P, K, pH and MC obtained showed no significant difference at different depths across the four land use patterns. The developed smart soil analyzer is recommended for the determination of soil MC, pH, N, P and K.

Keywords: Smart soil analysis; Laboratory soil analysis; Land use patterns; soil depth; soil properties.

Introduction

Soil, a vital natural resource that performs key environmental, economic, and social functions, is also the most important resource required for Agricultural production (Khanif, 2010). Soil a fragile earth's skin depended upon by the entire life on Earth and is among the most precious resources to human nature. Increase in population and demand for food to sustain human lives lead to conversion of forests and plantations to arable lands. Exposure of land due to change in its use results in degradation of soil beyond what its ability can manage. Change in land use leads to an alteration in the chemical, physical and biological properties of the soil (Houghton et al., 1999; Zhang et al. 2004; Viollete et al., 2009). Crop varieties with high yielding potentiasl cultivated without regular nutrients replenishment fail due to nutrient loss through plant uptake, volatility, acidity and erosion. Poor land management is found to escalate the loss of soil chemical properties and declines crop productivity (Byiringiro, 1996). Information on different land use is highly critical for decision making particularly on agricultural production and usage. There is the need to carry out soil test before planting of crops and nutrient addition. Collection of a representative soil sample and transportation to the Laboratory for analysis is more challenging due to high cost, loss in soil properties as a result of transit,and identification problem due to large quantity of samples which leads to erroneous decisions in most times. Better method of soil properties tracking using sensors technologies in order to improve the soil quality and productivity is essential towards ensuring food security.

Therefore, the objectives of this study were to determine the rate and magnitude of changes in selected soil properties at different soil depths using laboratory and smart soil analyses, design and construct a smart soil analysis device with a cloud server system to facilitate the storage of analysed soil data, test and validate the device using laboratory analysis results, provide farmers with an integrated platform to access the analysed data to know the crop to be planted based on required nutrition.

Materials and Methods

Study area

The study was conducted at the Teaching and Research Farm, Federal Polytechnic Ile Oluji, Ondo State. Ondo State located in the rainforest zone of Nigeria on latitude 6.04^0 E and longitude 7.50^0 N and Altitude of 427 metres with annual average rainfall of 130 cm and mean annual temperature between 28.8°C to 35°C. The annual relative humidity is 81.2 percent. The potential land use in the area includes oil palm plantation, cocoa plantation, forest and arable land

Experimental design

The Experiment consisted of 2 x 4 x 3 factorial combination of two soil analysis methods (Conventional laboratory and Smart Soil analyses) on four land use options (Oil palm plantation, Cocoa plantation, Forest, and Arable land) at three different levels (0 -15, 15 -30 and 30 – 75 cm).

Coordinate data collection and Soil sampling techniques

Coordinate data (Northings, Eastings and Elevation) of the fifteen (15) sampling points were taken with the Global Positioning System receiver (GARMIN, GPS 12H) with accuracy level within 5 – 10 meters. Forty five (45) Soil samples were collected at three different depths 0 - 15, 15 – 30 and 30 – 75 cm using soil auger, bulked for different depths air dried and prepared for laboratory analysis to determine soil N, P, K, pH and MC while designed smart soil analyzer was used to determine the selected soil properties at three different depths. Soil pH was determined in soil water (1:2) medium using the digital electronic pH meter, total N was determined by micro-Kjeldahl digestion method (Bremner, 1996), available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998), exchangeable K, was extracted using 1.0 N ammonium acetate and determined using a flame photometer while gravimetric moisture content was determined after oven dried soil sample.

Components and description of Soil Analyzer

(i) Arduino Uno
(ii) SIM 808 GSM Module
(iii) Soil NPK sensor
(iv) Soil pH sensor
(v) Soil Moisture sensor
(vi) UV sensor
(vii) Temperature and relative humidity sensor

The device is made up of a Microcontroller unit, communication module, sensors and power supply system. It has three classes of sensors namely soil sensor class, environmental sensor class and solar sensor class. The soil sensor class consists of Soil NPK sensor, Soil pH sensor and Soil moisture sensor. The environmental sensor class consists of Temperature sensor and Relative humidity sensor. The solar sensor class consists of UV sensor.

The microcontroller unit is the Arduino uno is the "brain" of the device which handles communication with sensors, processing of sensor data and communication with the communication module. The communication module is the SIM808 GSM/GPS module which handles the upload of data from the device to the cloud. The power supply system is made up of Li ion batteries, TP4056 charger modules, buck converter and two solar panels. This system powers the device with the ability to recharge from the sun.

Connection Procedure

The terminals VCC and GND of the soil NPK, pH sensors and SIM808 are connected to the terminals VCC_RS485 and GND respectively (VCC_RS485 is the positive terminal of the two-celled Li ion battery). The terminals VCC and GND of the RS485 to TTL modules, UV sensor, soil moisture sensor, temperature and humidity sensor are connected to the terminals VCC and GND respectively (VCC is a stabilized 5V output from the buck converter).

Note: The two Li ion batteries used in this device are connected in series to produce a nominal voltage of 7.4V with each of them being 3.7V and are independently connected to a TP4056 charging module. Each TP4056 charging module is connected to a solar panel making a total of two solar panels, two TP4056 charging modules and two Li i

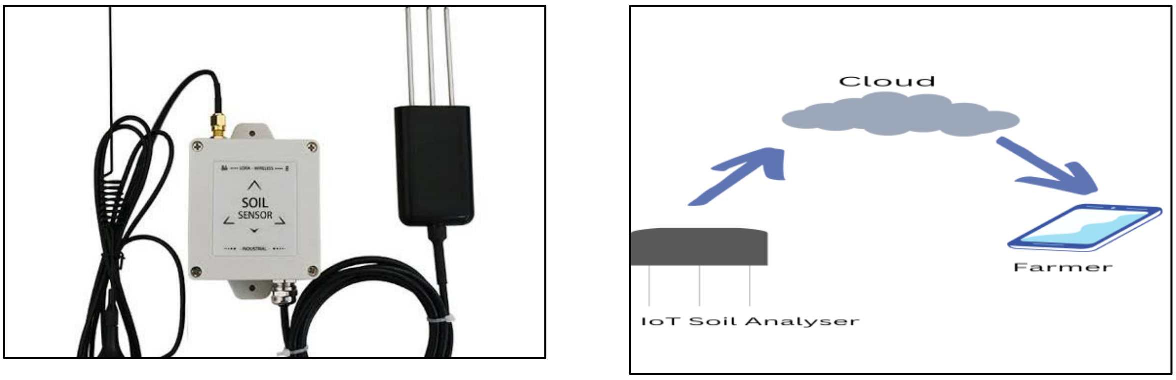

Figure 1: Soil Analyzer and Block diagram

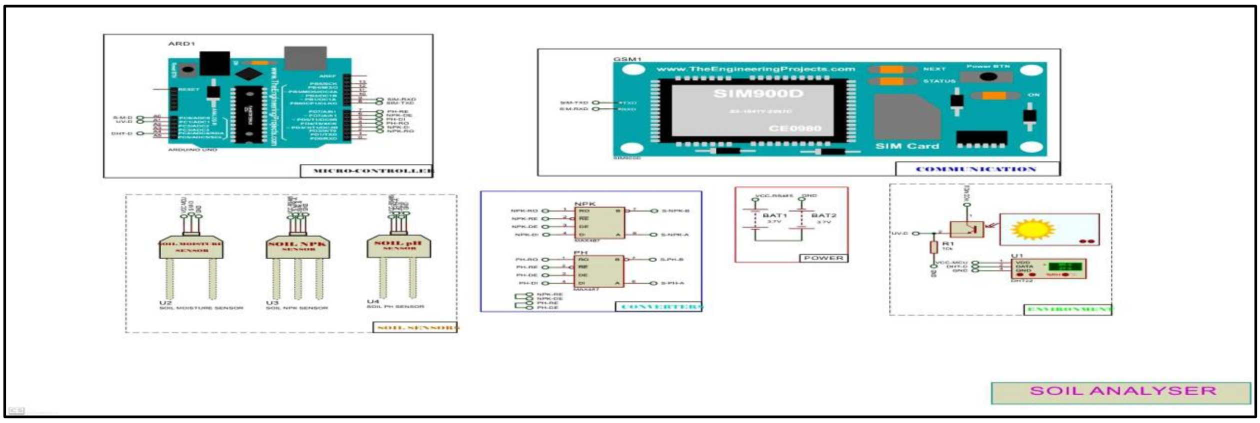

Figure 2: Circuit diagram

Figure 3: Device Picture

Working procedure

The microcontroller unit requests data from the NPK and pH sensors via RS485 communication protocol when powered on while data is also requested from the temperature and humidity sensor via one wire serial data line. UV and soil moisture sensor data are measured via analog input and are altogether processed by the MCU. The processed data is then sent to the SIM808 GSM Module for upload to the cloud via UART serial protocol.

Note: The Soil sensor probes must be inserted into the soil and be allowed to stabilize for at least 10 minutes before power on.

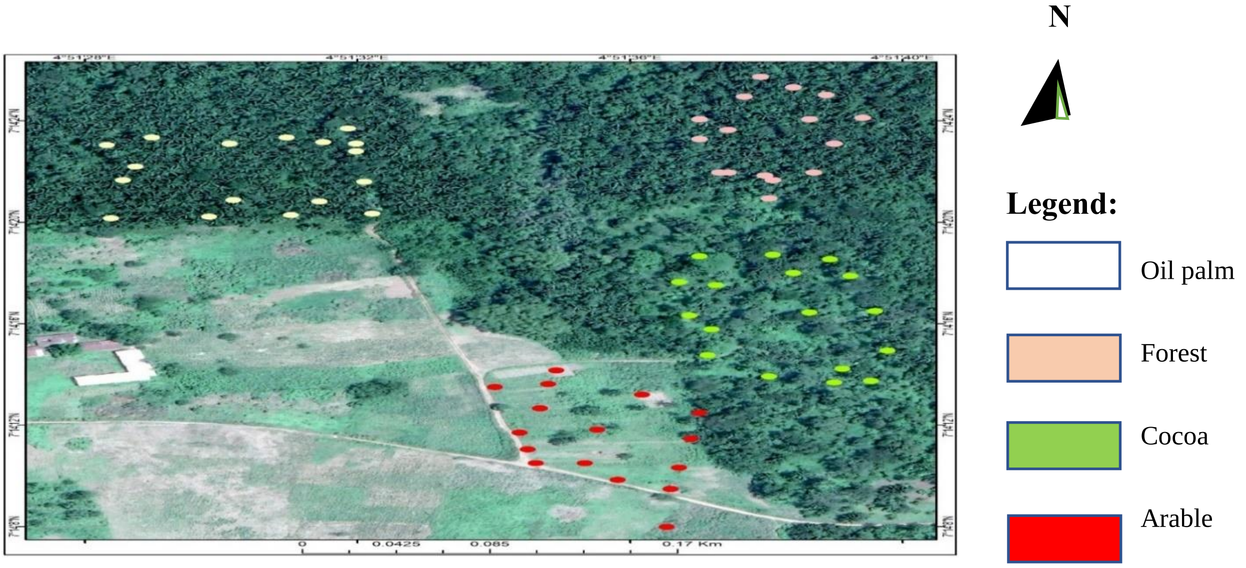

Figure 4: Location of the study area showing different land use patterns

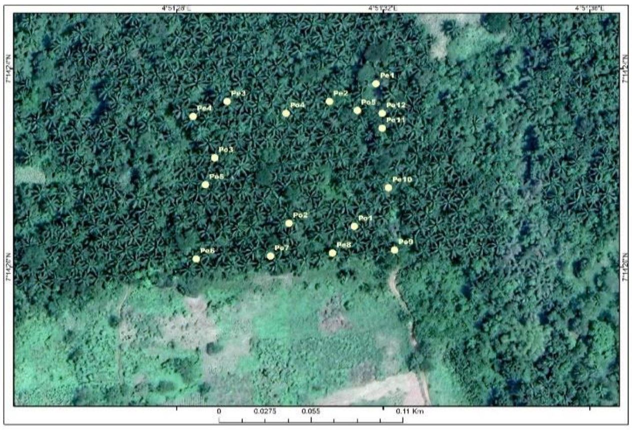

Figure 5: Oil palm Plantation

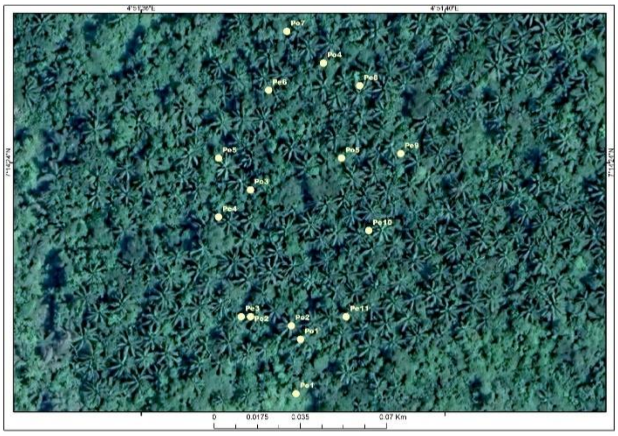

Figure 6: Forest

Figure 7: Cocoa Plantation

Figure 8: Arable land

The terminals A and B of the NPK and pH sensors are connected to the terminals A and B of their respective RS485 to TTL converter modules with the RO, DI and RE/DE terminals of the NPK and pH sensors connecting to the pins 2, 3, 6; 4, 5, 7 of the Arduino uno respectively. The serial line of the SIM808; RXD and TXD are connected to the pins 9 and 8 of the Arduino uno respectively.

The analog terminals of the Soil moisture sensor and the UV sensor are connected to the analog pins 0 and 1 of the Arduino uno respectively, while the data pin of the DHT22 is connected to the analog pin 4 of the Arduino uno.

Statistical Analysis

Data collected from the developed smart soil analyzer and laboratory were subjected to analysis of variance (ANOVA) using (SPSS version 21) and means were compared using LSD and Tukey's HSD (honestly significant difference) test at P< 0.05 level.

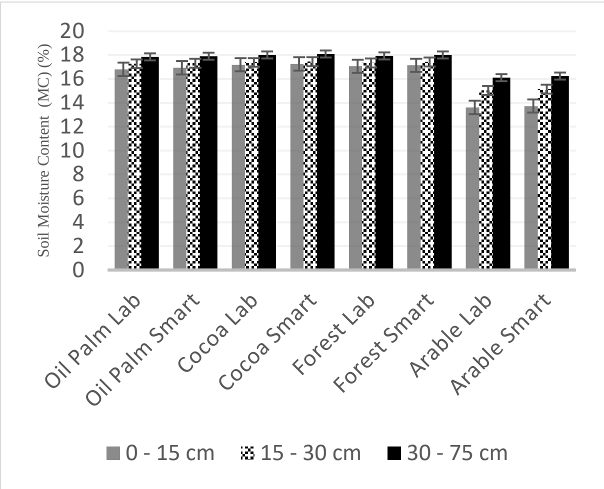

Figure 9: Soil moisture content (MC) (%) influenced by method, land analysis method, land use method and depth

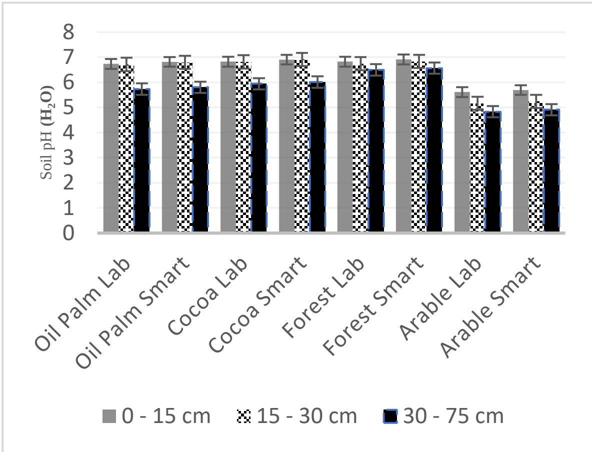

Figure 10: Soil pH (H_2O) influenced by analysis land use method and depth

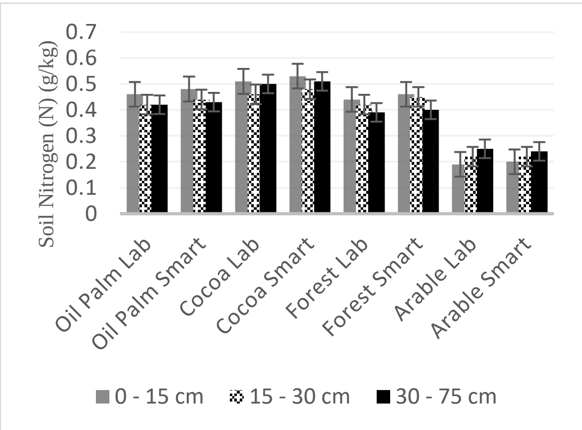

Figure 11: Soil Nitrogen (N) (g/kg) influenced by analysis method, land use method and depth

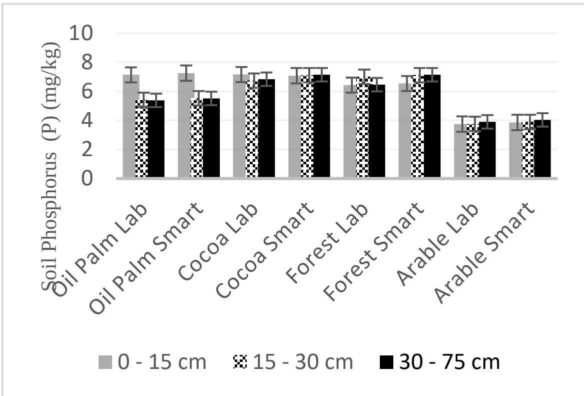

Figure 12: Soil Phosphorus (P) (mg/kg) influenced by analysis method, land use method and depth

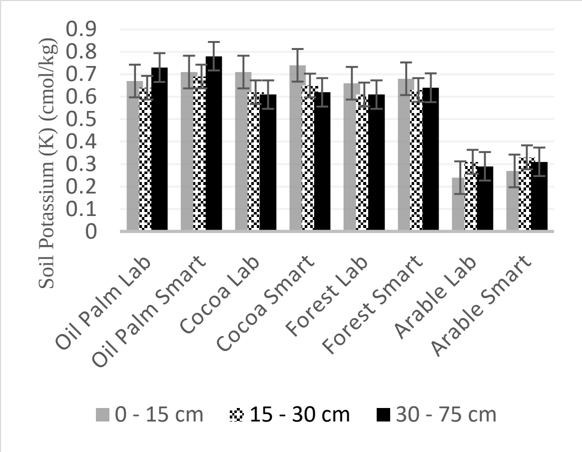

Figure 13: Soil Potassium (k) (cmol/kg) influenced by analysis method, land use method and depth

Results

The major focus of this research work was to develop a smart soil analyzer, test and compare its results with conventional laboratory analysis results using land use patterns at different soil depth. The values of soil moisture content (MC %) obtained from 0 -15, 15 – 30, 30 - 75 cm and examined by the developed soil analyzer were higher than the results from the laboratory analysis across the four land use patterns at different soil depths, However, the difference was not significant at $p < 0.05$ according to LSD. (Figure 9). The results of soil moisture content (MC %) from 0 -15, 15 – 30, 30 - 75 cm obtained for cocoa plantation were the highest among the land use patterns and were significantly higher than the MC values recorded for oil palm, forest and the arable land while the least value of MC was recorded for the arable land.

The results of soil pH are shown in (Figure 10). Soil pH varied across the land use patterns oil palm, cocoa, forest and arable land, The values of soil pH recorded for arable land from 0 -15, 15 – 30, 30 - 75 cm soil depths were least among the land use patterns examined while the highest values were obtained for cocoa plantation though showed no significant differences compared with the values obtained for forest across the soil depths but significantly higher than what was obtained for oil palm plantation. At 30 – 75 cm depth, soil pH recorded for forest was the highest and significantly higher than the values obtained for other land use. Soil pH values obtained from the developed smart soil analyzer were found to be higher than the pH values obtained through Convectional laboratory analysis although, there were no significant differences at $p < 0.005$.

Soil Nitrogen (N) concentration at 0 – 15 cm ranged from (0.19 - 0.51 g/kg)) and (0.20 – 0.53 g/kg) for convectional laboratory analysis and the developed smart soil analyzer respectively. Values of soil N recorded for laboratory analysis were lower than that of smart soil analyzer but showed no significant differences at $p < 0.05$. (Figure 11). Soil N concentration at arable land was the least among the land use methods. Highest value of soil N was recorded for cocoa plantation and it was significantly higher than the values obtained for other land use patterns.

Soil phosphorus (P) concentration varied across the land use patterns. The value of soil (P) ranged from (3.75 – 716 mg/kg**)** and (3.86 – 7.26 mg/kg**)** as respectively revealed by the results of convectional laboratory and developed smart soil analyses. Soil (P) concentration was found to be low under arable land compared with other land use patterns (Figure 12). Values of soil (P) under cocoa plantation and forest were not significantly different from each other at $p < 0.05$.

The result on soil potassium (K) is shown in (Figure 13). Soil K concentration varied across the land use patterns as revealed by the results obtained from the convectional soil laboratory and developed smart soil analyses. Highest value (0.73 and 0.78 cmol/kg) of soil K was obtained from convectional soil laboratory and developed smart soil analyses for Oil palm plantation at 30 cm dept while arable land recorded the least value of soil P.

Discussion

In this study, smart soil analyzer was developed, tested and the outputs (MC, pH, N, P and K) obtained from the sensor readings were transmitted and stored on the website https://ubdots.com. where the accessibility of soil data was achieved through a phone or personal computer connected to internet. The results were compared with the convectional laboratory soil analysis. The results of soil moisture content (MC), pH, N, P, and K obtained from three different soil depts as analyzed by the developed soil analyzer were found to be higher than the results obtained from the soil laboratory. This could be as a result of the fact that the soil properties were determine in situ compared with the results of soil laboratory which required substantial alteration in the soil properties as a result of samples collection, transportation and the time interval between collection and analysis.

Land use patterns influenced soil properties as found in this study. Soil MC, pH, N, P and K were very low in arable land compared with other land use patterns. The low concentration could be attributed to continuous alteration in soil properties as a result of cultivation. Studies have shown that continuous cultivation leads to decline in the quality of soil particularly where no substantial amount of residue returned to the soil (Gong et al., 2005; Havlin et al., 1999; Islam, 2000). Change in land use patterns was found to have a significant effect on soil structure as well as its nutrients (Yeshanew et al., 2004). Variation in nutrient concentration at different soil depths as a result of differences in land use could be attributed to the effect of continuous braking, turning and mixing of soil that aggravate loss in soil properties (Lal, 1996; Solomon et al., 2002; Yeshanew et al., 2004; David et al., 2006)

Conclusion

The main objective of this work was to develop a soil analyzer that will enable farmers to have seamless monitoring of soil data from farmland purposely to improve agricultural productivity. The device has been developed and tested, the results of soil pH, MC, N, P and K obtained from the developed soil analyzer as compared with the convectional laboratory analysis showed that the soil device is effective in measuring the selected soil properties. The developed smart soil analyzer is recommended for the determination of soil MC, pH, N, P and K.

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