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CORRELATION BETWEEN DIELECTRIC CONSTANT AND PH FOR SOIL TYPES IN THE SOUTHERN PART OF KATSINA STATE, NIGERIA

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ABSTRACT

The correlation between dielectric constant and pH of different soil types of southern part of Katsina state, Nigeria, was determined. The capacitance of the soil was measured using LCR Meter in order to calculate the dielectric constant of the soil. The calculated mean values of dielectric constant were found to be in the range of 3.90-25.60 with mean values of 7.95±1.64, 5.75±1.45, 5.01±0.37, 5.39±0.17, 5.43±0.49, 5.99±0.49, 6.29±0.49 and 5.38±0.21 for soil type Acrisols, Arenosols, Cambisols, Fluvisols, Leptosols, Lixisols, Luvisols and Regosols respectively. The mean pH values measured for each soil type ranges from 5.50-7.22 with a mean value of 6.38±0.05, 6.51±0.11, 6.26±0.13, 5.73±0.08, 6.15±0.16, 6.33±0.17, 6.44±0.12, and 6.56±0.07 for soil type Acrisols, Arenosols, Cambisols, Fluvisols, Leptosols, Lixisols, Luvisols and Regosols respectively. The correlation coefficient between dielectric constant and pH for soil types from the study area was found to indicate a weak correlation between the two soil parameters with a value of R = +0.30.

Keywords: Dielectric, LCR meter, Katsina State, pH

INTRODUCTION

The soil is made up of natural bodies on the surface of the earth, which comprise of living matter and it provide support for the growth of plants (Akhtar et al., 2013). It is formed as a result of the impact of living matter and climate on the parent rock materials over a period of time (Johar et al., 2016). Soil dielectric is a significant parameter in soil science (Jafery et al., 2018). The dielectric properties of soil are the function of its chemical and physical properties upon the available micronutrients. The dielectric properties cover several parameters such as resistivity, permittivity and dielectric constant (Sternberg and Levitskaya, 2001). Soil is a medium with non-homogenous constituent; as such its dielectric is a consolidation of the individual dielectric constant of organic and inorganic matter content, macronutrients, mineral, chemical and physical properties (Chaudhari, 2015). Dielectric properties of soil are useful in microwave remote sensing and increasing agricultural productivity (Navarkhele et al., 2009).

In additions, most studies on the dielectric properties of soil are associated with the measurement of dielectric properties of different materials using different techniques. Therefore, the study of soil dielectric in relation to the soil pH is very significant as it will ex-pose the correlation between the two soil physical parameters. Therefore, this research work studied the correlation of the soil dielectric constants with the soil pH for soil types from Katsina south, Nigeria.

METHODOLOGY

Study area

The study area is the southern parts of Katsina State, Nigeria. It lies between Latitude 11° 10´ N and 12° 23´ N and Longitude 06° 52´ E and 07° 54´ E. It consists of 11 local government areas and is bounded in the north by Dan-Musa local government area, in the east by Kano State, in the west by Zamfara State and in the south by Kaduna State. Based on the World Reference Base for Soil Resources (FAO, 1998), the study area has a total of 8 soil types which were grouped into 5 sets on the basis of dominant identifiers, i.e. those soil forming factors which most clearly conditioned soil formation. Table 1 present the soil types of the study area and their formation factors.

Table 1: Soil types of the study area and their mode of formation

Label	FAO-UNESCO Name	Formation
Set 3	Arenosols	From parent material
Set 4	Fluvisols Leptosols Regosols	By topography/physiography of the terrain
Set 5	Cambisols	By their limited age
Set 6	Acrisols Lixisols	By climate: (sub-humid) tropics
Set 9	Luvisols	By climate: (sub-humid) temperate regions

Sample collection

Soil samples were collected from 27 selected locations which were determined based on soil types with the aid of Global Positioning System (GPS). Each soil type has a number of representative samples depending upon the geographical area covered by each soil type. Samples were collected at a depth of 10-20 cm at each spot using a hand auger. The collected samples were packed and sealed in a well-labeled polyethylene bag in order to avoid cross-contamination. Table 2 present the sample identification and coordinates of their location.

Table 2: Soil samples and GPS coordinates

Soil sample ID	Coordinates
Acrisols-1	N11°34′41.21″, E7°7′12.83″
Acrisols-2	N11°38′48.2″, E7°24′6.41″
Lixisols-1	N11°26′27.09″, E6°58′20.70″
Luvisols-4	N11°50′6.11″, E7°50′11.13″
Leptosols-3	N11°49′53.44″, E7°9′57.54″
Regosols-1	N11°23′17.05″, E7°26′6.78″
Fluvisols-1	N11°20′38.67″, E7°19′59.53″
Cambisols-2	N11°37′19.59″, E7°32′58.55″
Cambisols-3	N11°30′21.48″, E7°24′57.09″
Cambisols-4	N11°27′43.11″, E7°36′52.94″
Luvisols-1	N12°11′0.42″, E7°42′35.02″
Luvisols-2	N12°2′8.28″, E7°31′55.20″
Luvisols-3	N11°59′23.58″, E7°24′57″
Arenosols-1	N12°5′31″, E7°12′4.24″
Arenosols-2	N12°15′20.15″, E7°33′11.22″
Arenosols-3	N11°52′0.14″, E7°18′30.67″
Leptosols-1	N12°0′7.9″, E7°44′54.39″
Leptosols-2	N12°0′26.93″, E7°15′7.95″
Arenosols-4	N11°51′3.12″, E7°34′20.90″
Arenosols-5	N11°43′52.35″, E7°16′11.30″
Cambisols-1	N11°44′55.7″, E7°44′35.38″
Luvisols-5	N11°47′27.74″, E7°31′48.8″
Luvisols-6	N11°38′54.61″, E6°59′30.39″
Lixisols-4	N11°22.345′, E7°34.468′
Lixisols-2	N11°24′52.07″, E7°17′33.65″
Lixisols-3	N11°18′57.32″, E7°40′15.65″
Cambisols-5	N11°38′56″, E7°41′17″

Measurement of dielectric constant

The setup consists of a test cell, four connecting cables, and a programmable LCR Bridge as shown in fig. 1. The test cell is made up of a square box housing the electrode. The anode and the cathode of the electrode are connected to the LCR Bridge through the connecting cables, and the LCR Bridge is connected to a power source and it has a digital interface to display the result of the analysis. The contacting electrode method using an LCR meter is a quick and simple way of calculating the dielectric constant of any material (QuadTech, 2003), in this case, soil. The sample in form of a pellet was inserted in the test cell and the electrodes were closed using the micrometer screw until it touches the pellet lightly and the value of the capacitance, C_x was measured by the LCR meter, which is connected to the test cell. The sample was removed from the test cell and the micrometer readjusted to the same distance as used for the sample, the value of the capacitance was measured for air as C_0. The same procedure was repeated for all the samples.

Fig. 1: LCR meter and a test cell

The dielectric constant of the soil was measured by evaluating the ratio of capacitance of the soil to the capacitance of air using equation 1 (QuadTech, 2003).

$$\varepsilon' = \frac{(1.00053)C_x}{C_0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where ε' = dielectric constant, C_x = capacitance with a dielectric material (soil), C_0 = capacitance without material, for air.

The factor 1.00053 in the formula for ε' corrects for the dielectric constant of (dry) air.

Measurement of soil pH

The measurement of the pH for the soil samples collected was done at Centre for Energy Research and Training, A.B.U., Zaria. Using a 20 cm3 scoop, one scoop of soil was placed in a 90 mL plastic cup. 40 mL of water (distilled water) was added into the cup using a suitable volumetric container. The solution was stirred using a glass rod and was allowed to settle for 30 min. The glass electrode was immersed into the clear solution of the sample to establish a good electrical contact, after which the readings were taken.

RESULTS AND DISCUSSION

The discussion of the results is based on the dielectric constant measurements and soil pH of each soil sample. All data are presented in tables 3-6.

Soil dielectric constant

Tables 3-4 present the results for the dielectric constant measurement of the soil samples. From the mean of dielectric constant measurement of each soil type, Cambisols has the lowest value of dielectric constant of 5.01±0.37 while Acrisols was found to have the highest value of dielectric constant of 7.95±1.64, Arenosols was found to have the largest range of values from 3.90-25.60 with a mean of 5.75±1.45 while Fluvisols have the closest range of 5.13-5.70 with a mean of 5.39±0.17.

Table 3. Dielectric constant measurement of soil samples and GPS coordinates

Soil sample	GPS Coordinates	Dielectric constant
Acrisols-1	N11°34′41.21″, E7°7′12.83″	11.40 ± 1.21
Acrisols-2	N11°38′48.2″, E7°24′6.41″	4.49 ± 0.07
Lixisols-1	N11°26′27.09″, E6°58′20.70″	7.77 ± 0.17
Luvisols-4	N11°50′6.11″, E7°50′11.13″	8.54 ± 0.99
Leptosols-3	N11°49′53.44″, E7°9′57.54″	7.26 ± 0.24
Regosols-1	N11°23′17.05″, E7°26′6.78″	5.38 ± 0.21
Fluvisols-1	N11°20′38.67″, E7°19′59.53″	5.39 ± 0.17
Cambisols-2	N11°37′19.59″, E7°32′58.55″	5.27 ± 0.51
Cambisols-3	N11°30′21.48″, E7°24′57.09″	5.80 ± 0.39
Cambisols-4	N11°27′43.11″, E7°36′52.94″	4.24 ± 0.09
Luvisols-1	N12°11′0.42″, E7°42′35.02″	6.89 ± 0.32
Luvisols-2	N12°2′8.28″, E7°31′55.20″	8.10 ± 0.53
Luvisols-3	N11°59′23.58″, E7°24′57″	6.72 ± 0.38
Arenosols-1	N12°5′31″, E7°12′4.24″	6.76 ± 1.17

Arenosols-2	N12°15′20.15″, E7°33′11.22″	6.40 ± 0.36
Arenosols-3	N11°52′0.14″, E7°18′30.67″	4.08 ± 0.11
Leptosols-1	N12°0′7.9″, E7°44′54.39″	4.98 ± 0.13
Leptosols-2	N12°0′26.93″, E7°15′7.95″	4.04 ± 0.09
Arenosols-4	N11°51′3.12″, E7°34′20.90″	4.64 ± 0.39
Arenosols-5	N11°43′52.35″, E7°16′11.30″	16.24 ± 4.81
Cambisols-1	N11°44′55.7″, E7°44′35.38″	3.36 ± 0.02
Luvisols-5	N11°47′27.74″, E7°31′48.8″	3.37 ± 0.07
Luvisols-6	N11°38′54.61″, E6°59′30.39″	4.10 ± 0.15
Lixisols-4	N11°22.345′, E7°34.468′	4.42 ± 0.21
Lixisols-2	N11°24′52.07″, E7°17′33.65″	5.52 ± 1.09
Lixisols-3	N11°18′57.32″, E7°40′15.65″	6.25 ± 1.01
Cambisols-5	N11°38′56″, E7°41′17″	6.41 ± 1.19

Table 4: Mean and range of dielectric constant for soil types

Soil type	Mean	Range
Acrisols	7.95 ± 1.64	4.36-13.51
Arenosols	5.75 ± 1.45	3.90-25.60
Cambisols	5.01 ± 0.37	3.34-8.73
Fluvisols	5.39 ± 0.17	5.13-5.70
Leptosols	5.43 ± 0.49	3.91-7.71
Lixisols	5.99 ± 0.49	4.08-8.19
Luvisols	6.29 ± 0.49	3.26-10.38
Regosols	5.38 ± 0.21	5.01-5.74

Soil pH

Soil pH is a measure of the soil solution's acidity and alkalinity. pH levels range from 0 to 14, with 7 being neutral, below 7 acidic and above 7 alkaline (McCauley et al., 2009). Tables 4-6 present the results of the pH measurements of the soil samples and their GPS coordinates. The pH values for all the soil types fall within the range of 5.50-7.22, Fluvisols was found to have the least pH of 5.73±0.08 while Regosols were found to have the maximum pH of 6.56±0.07.

Table 5: pH measurement of soil samples and GPS coordinates

Soil sample	Coordinates	pH
Acrisols-1	N11°34′41.21″, E7°7′12.83″	6.47 ± 0.06
Acrisols-2	N11°38′48.2″, E7°24′6.41″	6.30 ± 0.01
Lixisols-1	N11°26′27.09″, E6°58′20.70″	5.79 ± 0.04
Luvisols-4	N11°50′6.11″, E7°50′11.13″	5.59 ± 0.01
Leptosols-3	N11°49′53.44″, E7°9′57.54″	5.51 ± 0.01
Regosols-1	N11°23′17.05″, E7°26′6.78″	6.56 ± 0.07
Fluvisols-1	N11°20′38.67″, E7°19′59.53″	5.73 ± 0.08
Cambisols-2	N11°37′19.59″, E7°32′58.55″	6.73 ± 0.01
Cambisols-3	N11°30′21.48″, E7°24′57.09″	6.89 ± 0.02
Cambisols-4	N11°27′43.11″, E7°36′52.94″	5.73 ± 0.08

Luvisols-1	N12°11′0.42″, E7°42′35.02″	6.80 ± 0.01
Luvisols-2	N12°2′8.28″, E7°31′55.20″	6.53 ± 0.03
Luvisols-3	N11°59′23.58″, E7°24′57″	5.97 ± 0.03
Arenosols-1	N12°5′31″, E7°12′4.24″	6.51 ± 0.01
Arenosols-2	N12°15′20.15″, E7°33′11.22″	6.29 ± 0.13
Arenosols-3	N11°52′0.14″, E7°18′30.67″	5.95 ± 0.06
Leptosols-1	N12°0′7.9″, E7°44′54.39″	6.44 ± 0.02
Leptosols-2	N12°0′26.93″, E7°15′7.95″	6.51 ± 0.01
Arenosols-4	N11°51′3.12″, E7°34′20.90″	7.21 ± 0.01
Arenosols-5	N11°43′52.35″, E7°16′11.30″	6.57 ± 0.01
Cambisols-1	N11°44′55.7″, E7°44′35.38″	6.01 ± 0.06
Luvisols-5	N11°47′27.74″, E7°31′48.8″	6.75 ± 0.01
Luvisols-6	N11°38′54.61″, E6°59′30.39″	7.02 ± 0.01
Lixisols-4	N11°22.345′, E7°34.468′	6.96 ± 0.01
Lixisols-2	N11°24′52.07″, E7°17′33.65″	6.73 ± 0.26
Lixisols-3	N11°18′57.32″, E7°40′15.65″	5.84 ± 0.02
Cambisols-5	N11°38′56″, E7°41′17″	5.93 ± 0.03

Table 6: Mean and range of pH measurements for soil types

Soil type	Mean	Range
Acrisols	6.38 ± 0.05	6.29-6.53
Arenosols	6.51 ± 0.11	5.83-7.22
Cambisols	6.26 ± 0.13	5.60-6.91
Fluvisols	5.73 ± 0.08	5.66-5.90
Leptosols	6.15 ± 0.16	5.50-6.52
Lixisols	6.33 ± 0.17	5.74-6.99
Luvisols	6.44 ± 0.12	5.58-7.03
Regosols	6.56 ± 0.07	6.49-6.70

Correlation between pH measurement and dielectric constant measurement

Linear correlation between two variables shows a statistical result of their association by yielding in the -1 to 1 (Pandis, 2016). The correlation coefficient between mean values of pH and dielectric constant measurement for different soil types from the study area was calculated using Microsoft excel and was found to be R =+0.30. The trend line for the linear series is illustrated in Fig. 2.

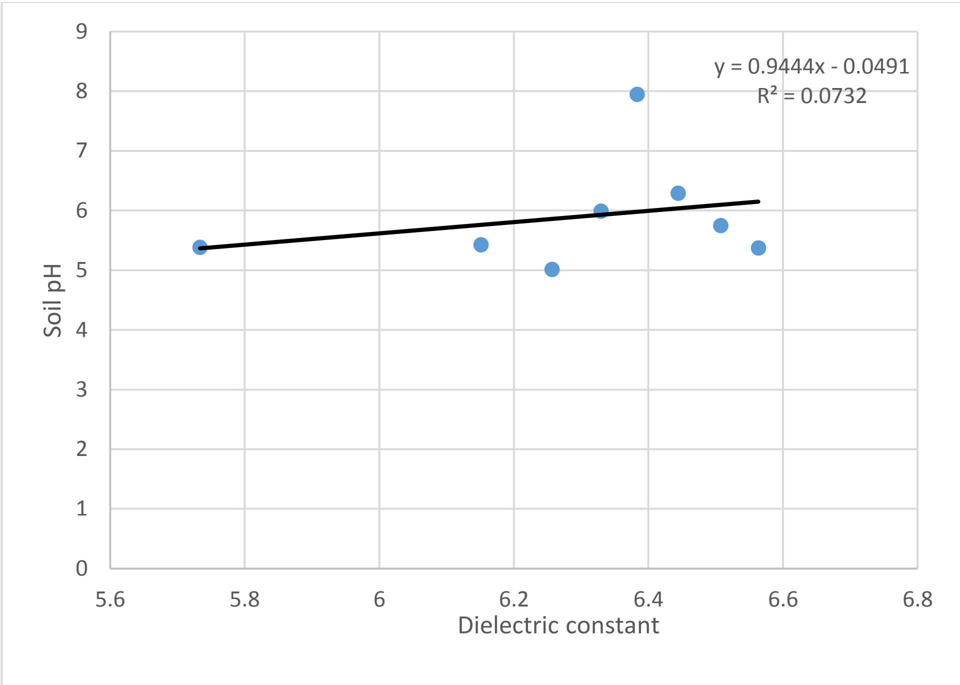

Fig. 2: Correlation between pH and dielectric constant for soil types

CONCLUSION

The mean dielectric constant measurement for all the soil types was found to be within the range of 3.26-25.60, with Arenosols having the highest value of 25.60 while Luvisols has the lowest value of 3.26. Also, the pH measurement for the soil types showed that Arenosols have the highest value of 7.22 which is slightly within the range of alkalinity on the pH scale while Leptosols have the lowest reading of 5.50 which is within the range of acidity on a pH scale. The correlation study indicates the two soil parameters has a positive correlation coefficient of R=+0.30 which is not strong enough to establish a good correlation between the two soil parameters (Pandis, 2016).

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