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Determination of Dielectric Properties of Cultivated and Uncultivated Land at Kafin Hausa LGA, Jigawa State, Nigeria

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Abstract

Improving soil research will boost the Nigerian agricultural productivity. Therefore, the government and other agricultural organization must intervene in experimental soil research. Soil is the most fundamental basic factor that determines a higher or lower agricultural yield. Low or absence of permittivity is one of the major problems that contributes to the agricultural productivity in north eastern part of Jigawa state. Two areas were selected (cultivated and uncultivated land). The soil sample were prepared into pellets and then was characterized using an LCR meter bridge to determine the dielectric constant (Ɛ'), dielectric loss (Ɛ''), and electric conductivity of the soil (б). The results show that the mean dielectric constant, dielectric loss, and electrical conductivity of the cultivated land area at 60 Hz are; 10.43±2.84, 3.7±1.26, 1.61±0.23×$\mathbf{10^{-7}}$ S/m while uncultivated land area at 60 Hz are; 17.54± 8.904 , 6.14±4.43, 2.79±1.78×$\mathbf{10^{-7}}$ S/m . However, the mean dielectric properties of cultivated land at 120 Hz are; 10.66±4.48, 9.90±1.758, 33.001±3.74×$\mathbf{10^{-7}}$S/m, while uncultivated at 120 Hz are; 17.22±9.06, 6.21±3.78, 7.76±0.033×$\mathbf{10^{-7}}$S/m respectively. It can be deduced from the results that the Kafin Hausa uncultivated land area have greater values of dielectric properties than cultivated land and thus is more fertile.

Keywords: Dielectric constant, soil, fertility, Kafin Hausa, electric conductivity

INTRODUCTION

Soil consists of sand, organic and inorganic materials which comprises of living matter and provide support for the growth of plants. Soil has various properties such as chemical, physical and electrical properties (Akhtar *et al.,* 2013). The chemical properties are; organic matter, micro-nutrients, pH, etc., and physical properties are color, bulk density, grain, texture, and water. The electrical properties include dielectric constant, a.c conductivity and permeability of the soil (Sternberg and Levitskaya, 2001). Physical, chemical, electrical and biological components of soil can be considered as the quality of soil and their interaction. Soil health and soil quality is considered in the understanding of soil quality. Therefore, the soil is dominantly engaged in agricultural activities. Structure, nature, and the type of soil play a vital role in agricultural uses (Navarkhele *et al.,* 2009).

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The dielectric constant is also called the permittivity. Dielectric constant can be defined as the ratio of the capacitance of the capacitor filled with given dielectric to that of the same capacitor having only a vacuum as dielectric. The dielectric between the plate of say, a parallel plate capacitor always increases its capacitance as the plates are separated by vacuum which brings the ability of the capacitor to store opposite charge on the plates. Thus, the permittivity and the dielectric constant K, in the cgs system are identical; both of them are dimensionless numbers. The measured capacitance between the parallel plates can be used to calculate the dielectric constant Ɛ, and dissipation factor, D. The capacitance of a parallel plate capacitor is directly proportional to the dielectric constant of the insulator separating the conductors and the conductor's area, A, and inversely proportional to the distance, d, between the conductors $C=\frac{A\varepsilon}{d}$ (James and Dale, 2011).

Many factors contribute to the agricultural productivity but permittivity is one of the major factors that contribute to the agricultural productivity in Nigeria. Permittivity of the soil increases with increase in fine particle of the soil with high surface area and also, increases with increase in soil moisture contents irrespective of zones, soil type and geological variation of the area (Kayode and Oludare, 2011). Dielectric constant increases with depth of the soil likewise increases with resistivity of the soil (Nwanko *et al*, 2013). Also, dielectric constant can be used to predict the soil fertility (Patel *et al.,* 2018). The presence of micronutrients in the soil increases as the dielectric constant of the soil increases (Sahu, *et al.,* 2020). Dielectric constant increases slowly with increase in fertilizer concentration (Jaiswal, *at al,* 2019). Exact soil p H, electrical conductivity of the soil and organic matter are essential to ensure optimal plant growth and crop yield because it predicts available nutrients in the soil for the plants to absorbed (Alam, 2020). The research finding show that the moisture is the function causing the variation in the ground of soil electrical conductivity. Many factors affect the dielectric properties of soil and these include, soil classes (i.e. the proportion of sand, silt and clay), and temperature of the soil because the dielectric of other materials varies with frequency (Kabir, *et al.,* 2020).

Haris (2015) carried out a study on the dielectric properties of soil with organic and inorganic matter at J-band microwave frequency. The results showed that the value of Ɛ' and Ɛ'' increases with increase in organic matter as well as inorganic matter. In a similar work, Dhiware, *et al.* (2017) investigated the correlation between physiochemical characteristics with dielectric constant of soil from Nasik region. The results revealed that availability of micronutrients in the soil show the variation of dielectric properties of the soil. Another study was carried out on the complex dielectric behavior of soil from Nasik region at X-band microwave frequency and it was concluded that dielectric loss is directly proportional to the ac conductivity of the soil and dielectric constant increases with increase in moisture contents (Dhiware, *et al,* 2016). Low yields per unit land is one of the major problems of agricultural productivity in Nigeria, especially in the northeastern part of Jigawa state. Every year, farmers are experiencing low yield of agricultural products. The aim of this work is to determine the dielectric properties of the soil in Kafin Hausa, Jigawa State Nigeria.

METHODOLOGY

Study Area

Kafin Hausa is the study area selected from the eastern part of Jigawa state, Nigeria. Jigawa state is one of the North-western state of Nigeria. It lies between latitude 11.00^0 N to 13.00^0 N and longitude 8.00^0 E to 10.15^0 east, with land mass of 22.140km^2 and with 27 local government areas. According to National population Commission (NPC, 2006). The number of people living in the area is estimated to reach 4.3 million. Kafin Hausa is a local government area of Jigawa state located at Latitude 12.14′27.6″N and longitude $9^0$54′ 46.8E. It headquarter are in the town of Kafin Hausa. It has an area of 1,38km^2 and a projected population of 357,200 as at 21th, 2016 (NPC & NBC, 2017). 12^0.39, 27.04″N and longitude 10^0.28′ 10.60′E.

Sample Collection

A total of ten samples were collected from different location of the study area. Five (5) samples from the land that is frequently cultivated and five (5) samples from the land that has never been cultivated. Before sampling, 15mm top soils were removed, and the samples were collected at 20cm in zigzag pattern across the required area. Five pits were dug for each sample. A composite of about 2kg were taken through mixing and designated as one soil sample. The soil samples were sieved first by a greater sieve shaker to approximately 2mm spacing and all the coarser particles were removed. The sieved samples were dried and all trace of moisture contents were removed according to the procedure described by Dhiware, *et al* (2018).

Sample Preparation

The soil sample is pounded with help of mortar and pestle into a fine grain of 250μm size. 2g of the sample were weighed using analytical weighing balance, six drops of the liquid binder were added (toluene compound). The pellet was pressed to push out the live pelleting sample structure.

LCR Meter Measurement

The set up consist of test cell, four connecting cables and programmable LCR (HM 8118) meter. The test cell is made up of box housing electrode; anode and the cathode, were all connected to the LCR meter bridge through the connecting cables as described by Lawal *et al,*. (2019). The pellet sample was inserted in to the test cell and the electrode was closed by the micro screw of the test cell until it touches the pellet slightly and the value of the capacitance, resistance and tangent loss were displayed by the digitals interface of the meter. Two frequencies were used (60 and 120 Hz) and effect of different frequencies were observed on the measured samples. Dielectric constant Ɛ′, electrical conductivity б, dielectric loss Ɛ″ relaxation time τ were calculated using a combination of the following equations

$$\varepsilon' = \frac{C_a}{C_o} \qquad 1$$

$$C_o = \frac{A \times \varepsilon_o}{t} \qquad 2$$

$$\rho = \frac{R \times A}{L} \qquad 3$$

$$б = \frac{1}{\rho} \qquad 4$$

$$T = \frac{\varepsilon''}{2\pi f \varepsilon'} \qquad 5$$

where A is the area, Ɛ′ is the dielectric constant of the material, Ɛ″ is the dielectric loss of the material, C_a is the capacitance of the of the material, C_o is the capacitance of the free space, ε_o is the permittivity of the free space, R is the resistance of the material and τ is the relaxation time

RESULTS AND DISCUSSION

Table 1 shows the measured permittivity properties of Kafin Hausa cultivated land at 60 Hz. The results show that each sample has different permittivity properties. This may be due to the presence of micronutrient in the soil. The results is in agreement with results of Dhiware, *et al,*. (2017), who revealed that the presence of micronutrients in the soil shows in the variation of dielectric properties of the soil. Also, the results show that dielectric loss increases with increase in ac conductivity of the soil as depicted by Dhiware, (2016).

Table 2 presents the measured permittivity properties of Kafin Hausa cultivated land at 120 Hz. The results show that the dielectric properties slightly decrease with increase in frequency in some areas. This is likely due to the proportional relation between electrical conductivity of the soil and physiochemical parameters present in the soil. Dospatliev, *et al*,. (2014) showed that increase or decrease in dielectric constant or ac conductivity in soil depends on the frequency or content of the soil.

Table 3 shows the permittivity properties of Kafin Hausa uncultivated land area at 60 Hz. The result shows the permittivity properties of Kafin Hausa uncultivated land have greater values of dielectric properties than the cultivated land area at 60 Hz. This may be due to the presence of organic and inorganic matter in the soil. It is likely that organic and inorganic matter has been deposited in the soil with time, since the land has never been cultivated, thus increasing the soil dielectric properties. The results is in agreement with result of Harris (2015).

Table 4 shows the measured permittivity properties of Kafin Hausa uncultivated land at 120 Hz. The result similarly shows that the permittivity properties of uncultivated land have the greater values of dielectric properties than the cultivated area.

Table 1: Measured Permittivity Properties of Kafin Hausa Cultivated area at 60Hz

Soil samples	ε′	ε″	6 (S/m)	Latitude	Longitude
A	7.90	2.90	1.61x1010^{-7}	12.25475	10.042565
B	8.70	2.02	1.515x10^{-7}	12.221025	9.857193
C	8.75	1.950	1.477x10^{-7}	12.197525	9.8278483
D	14.50	4.65	1.44x10^{-7}	12.217243	9.846483
E	12.30	4.33	2.004x10^{-7}	12.182905	9.922546

Table 2: Measured Permittivity Properties of Kafin Hausa Cultivated area at 120 Hz

Soil samples	ε′	ε	6 (S/m)	Latitude	Longitude
A	7.84	2.08	1.181×10^{-7}	12.24025	9.857193
B	8.63	1.81	1.068×10^{-7}	12.221025	9.857193
C	8.68	1.83	9.69×10^{-7}	12.197525	9.8278483
D	9.54	2.82	1.272×10^{-7}	12.217243	9.846483
E	18.62	5.96	1.790×10^{-7}	12.182905	9.922546

Table 3: Measured Permittivity Properties of Kafin Hausa Uncultivated Land at 60 Hz

Soil samples	ε′	ε″	6 (S/m)	Latitude	Longitude
A	17.77	6.503	2.894×10^{-7}	12.102502	9.916353
B	30.32	12.78	1.784×10^{-7}	12.267634	10.07891
C	21.27	7.27	1.928×10^{-7}	12.2496433	9.9308367
D	9.60	2.22	1.554×10^{-7}	12.236416	9.8883127
E	8.76	1.94	1.486×10^{-7}	12.1777433	9.9079283

Table 4: Measured Permittivity Properties of Kafin Hausa Uncultivated Land, at 120 Hz

Soil samples	Ɛ′	Ɛ″	6 (S/m)	Latitude	Longitude
A	17.40	6.0	2.23×10^{-7}	12.102502	9.916353
B	30.16	12.07	1.855×10^{-7}	12.267634	10.07891
C	21.17	7.20	1.842×10^{-7}	12.2496433	9.9308367
D	8.69	2.89	1.448×10^{-7}	12.236416	9.888127
E	8.69	2.89	1.450×10^{-7}	12.1777433	9.9079283

The grid maps (figures 1 and 2) contain a contour map layer and color relief map layer overlaid. The grid file used for the two map layers is the same and includes latitude as the X values, longitude as the Y values and the color relief described the Z values which is the dielectric constant of the four locations in the study research area. Also, it is possible for the map to predict low or high of dielectric constant of the area and other location not visited. The dielectric constant shown on the map is increasing as the contour level increases and vice versa.

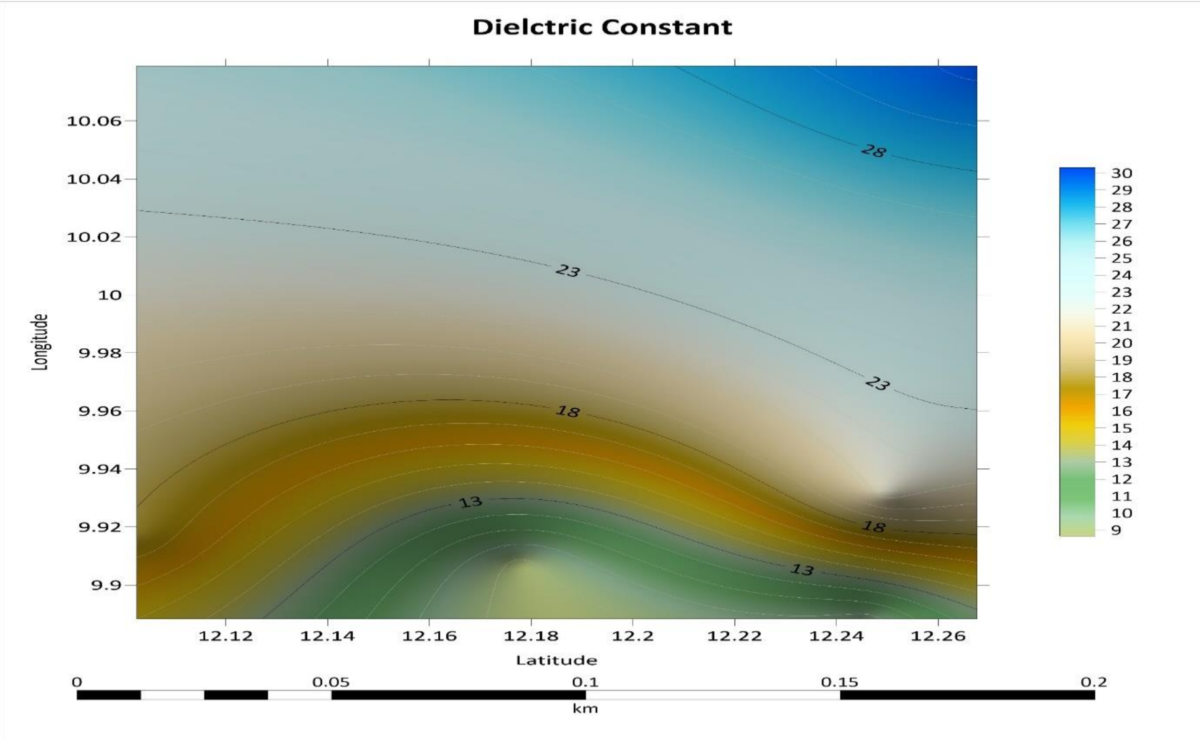

Figure 1 Dielectric of Kafin Hausa cultivated soil

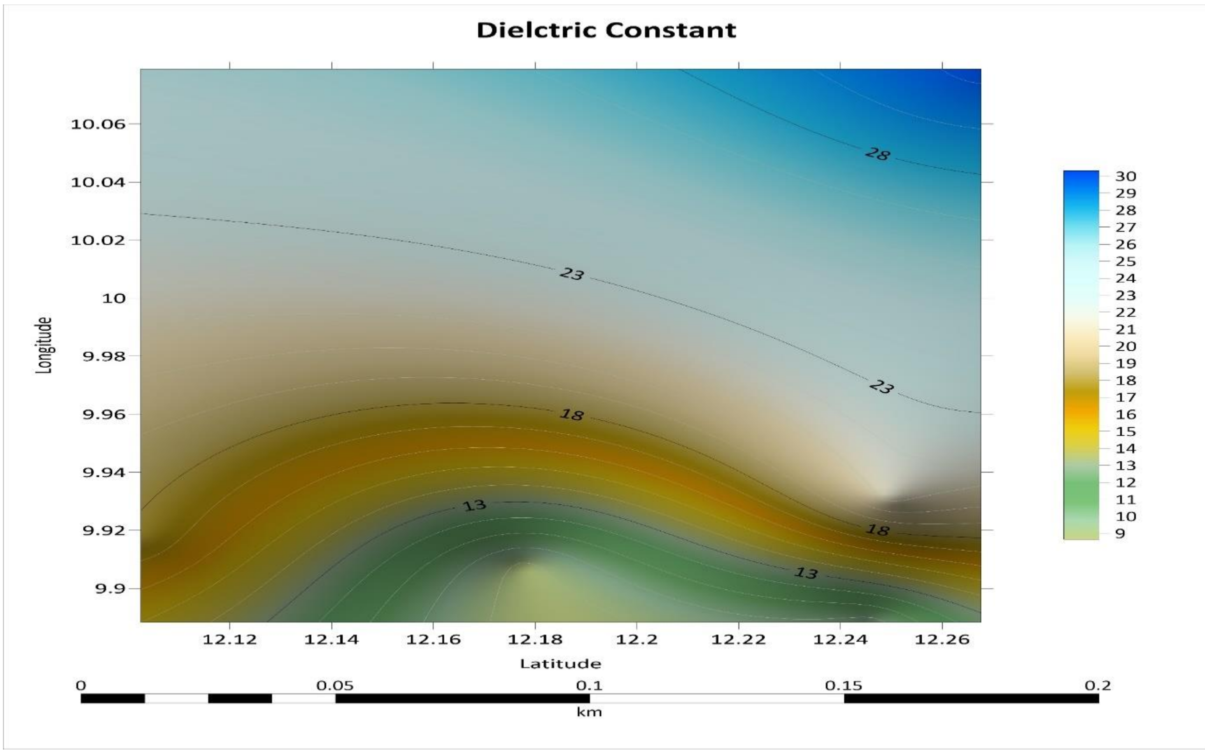

Figure 2 Dielectric constant of Kafin Hausa Uncultivated soil

CONCLUSION

The dielectric constant values of Kafin Hausa uncultivated land and cultivated land at 60 Hz and 120Hz is investigated. The results show that the uncultivated land at both frequencies have greater values of dielectric constant compared to the cultivated land. Therefore, uncultivated land areas have greater soil fertility than the cultivated land areas. Also, the result show that the dielectric constant decreases in some areas as the frequency increases. Dielectric loss and a.c conductivity of the soil increases as the dielectric constant increases.it also, shows that in some areas dielectric properties decreases as the frequency increases.

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