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## **Investigation of the Spatial Variation of Soil Resistivity and Conductivity in Ajibode Area, Ibadan**

Emmanuel Oluwagbemi Joshua<sup>a\*</sup>, Florence Yetunde Oljide<sup>b</sup>

<sup>a</sup>*Department of Physics, University of Ibadan, Ibadan, Oyo State, Nigeria.*

<sup>b</sup>*The Nigeria Police Force Education, Del Del, Abuja, Nigeria.*

<sup>a</sup>*Email : emmanuel.joshua@ui.edu.ng*

<sup>b</sup>*Email: sogoolajide@yahoo.com*

### **Abstract**

Electrical resistivity method was carried out investigate spatial variation of soil resistivity and conductivity at a certain depth in Ajibode Area using Miller 400D resistance meters. Three locations were considered with a total of 178 data points. It was observed that the absolute value of the resistivity obtained in location one is  $6428.53 \pm 232.35 \Omega\text{m}$ , location two  $2001.07 \pm 112.07 \Omega\text{m}$ , and location three  $7276.10 \pm 459.87 \Omega\text{m}$ . The absolute value of the conductivity obtained in location one is  $1650 \pm 57.75 \Omega^{-1}\text{m}^{-1}$ , location two  $6002.09 \pm 326.91 \Omega^{-1}\text{m}^{-1}$ , location three  $1704.60 \pm 83.14 \Omega^{-1}\text{m}^{-1}$ . Location two has the lowest resistivity value. Result show that the soil types on the three locations are sandy soil and loose sands.

**Keywords:** Electrical Resistivity; Wenner electrode array; soil conductivity; sandy soil; Ajibode.

### **1. Introduction**

Soil properties are of high importance in many human activities, such as agriculture, forestry, landscaping, environmental protection, recreation, and civil engineering.

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\* Corresponding author.

Soil survey for different applications requires quick and, where possible, non-disturbing estimations of numerous soil properties, such as salinity, texture, stone content, groundwater depth, and horizon sequence in soil profiles. Many of these properties are highly spatially variable yet some are also temporally unstable. An accurate evaluation of soil properties is complicated by the nature of their variability; however, conducting soil measurements with a high sampling density is costly and time-consuming. Conventional methods of soil analysis mostly require disturbing soil, removing soil samples, and analyzing them in a laboratory.

Electrical geophysical methods, on the contrary, allow rapid measurement of soil electrical properties, such as electrical conductivity, resistivity, and potential, directly from soil surface to any depth without soil disturbance. The in-situ methods of electrical conductivity (e.g. four-electrode probe and electromagnetic induction) are routinely used to evaluate soil salinity [1,2,3].

Resistivity methods were originally employed in the petroleum and mining industries, and afterward found useful in archeological, hydrological, environmental, and geotechnical investigations. Development of continuous resistivity measurement techniques in the late 1980s and early 1990s has transformed the basic resistivity method into an effective and efficient tool to assess soil conditions in large agricultural fields.

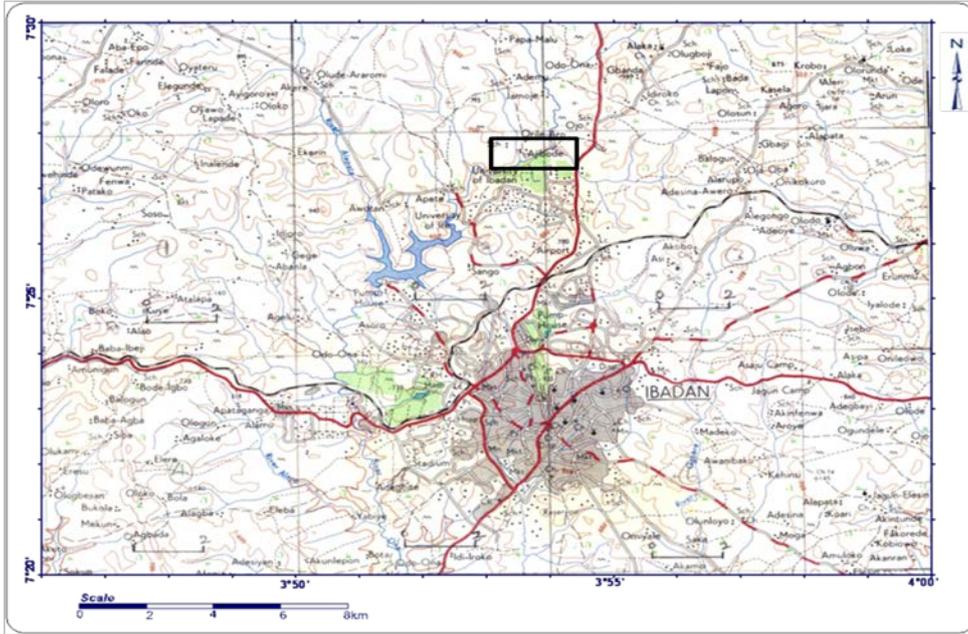
### **1.1. geological background of the area**

The study area, Ajibode is located in the north central part of Ibadan metropolis, Southwestern Nigeria. It shares boundaries with the University of Ibadan and Orogun communities to the south and to the north with the IITA, Ojoo and Shasha communities of Ibadan.(Figure1) The area lies between latitudes 7.476°N to 7.482°N and Longitudes 3.901°E to 3.903°E of the Equator. The area is easily accessible due to availability of effective road network. The UI-Shasha bye-pass links the study area to the surrounding communities.

The geology of the study area, is the subset of the geology of the south western part of Nigeria. The dominated rock types in this region are granite, quartz schist of meta sedimentary series, banded gneiss, granite gneiss, augen gneiss and migmatite complex. Quartzite outcrops as ridges with relatively high elevation with schistose structure. The strike line runs in the NS direction between 340° and 350° consistently dipping eastwards with characteristic cross-cutting features [5].

Field investigations of the study area in Ajibode showed the three main rock types in the study area. They are Banded Gneiss, Granite Gneiss and Augen Gneiss with the presence of fractures along the general strike of the rock. Banded gneiss occurs at the extreme east and west running south-east of the study area. The general strikes of banded gneiss are NNW-SSE while the dips range from 42 to 52 east. The rock is medium grained, crystalline and contorted. Foliation planes are well defined by the mafic and felsic bands.

The Granite gneiss covers the northern part of the area which extended to south where it is in contact with Augen gneiss. The rock is medium grained and appeared pinkish in colour. The trend of the foliation is generally N-S with dip values range from 17 to 42 east. The Augen gneiss outcrop in various parts of the University of Ibadan.



**Figure 1:** Topographic map of Ibadan showing the study area [4]

**1.2. Electrical conductivity**

Electrical conductivity is the measure of the ability of a conductor to carry electric current. It can be calculated as the ratio of the amount of charge passing through a unit area of the conductor (perpendicular to the current direction) per second divided by the electrical field intensity (force on unit charge). The electrical conductivity of a material measures the rate at which charge is conducted through the material per unit cross-sectional area per unit electric field. At any point within a conducting material, the current density **J** is determined by the electric field **E** and the nature of the material. For an isotropic material, **J** is the direction of **E** and can be written as

$$\mathbf{J} = \sigma \mathbf{E} \tag{1}$$

where the positive quantity  $\sigma$  define by this equation is called the conductivity of the material.

$$\rho = \frac{R.A}{L} \tag{2}$$

$$R = \frac{\rho.A}{L} \tag{3}$$

The S.I unit of resistivity is in ohms meter ( $\Omega\text{m}$ )

This resistivity, being a fundamental property of the material is independent of the volume, whereas resistance depends on the shape and size of the material. The true resistivity of an an isotropic homogenous medium is constant. The current **I** is related to the impressed voltages, **V** and resistance, **R** by ohms law which states that when a potential **V**, is applied across a conducting object causes a current, **I** to flow, the ratio of the applied voltage (**V**) to the resulting current flow (**I**) as defined by the well known linear equation from Ohm’s Law [6].

$$V = I \times R$$

$$I = \frac{V}{R} \tag{4}$$

The ground electrical resistivity of various soil types were measured and used to calculate the ground electrical conductivity.

The reciprocal of resistivity gives conductivity and its S.I unit  $\Omega^{-1}m^{-1}$ ,

Electrical conductivity is given by the formula,

$$\sigma = \frac{1}{\rho} \tag{5}$$

## 2. Materials and Methods

This research work was carried out at God’s Foundation group Farmers Association Ajibode Area, Ibadan. The Wenner array in electrical resistivity survey was adopted. The basic field equipment for this study is the MILLER 400D Resistance metre which displays apparent resistivity values digitally as computed from ohm’s law. Three (3) locations were selected. The first location measured 30 by 30 meter, with the electrode spacing of 3 m and the profile spacing was 5 m, the total point sampled was 48 points. The second location measured 50 by 30 meter, with the electrode spacing of 4 meters and profile spacing of 5 meter, with 60 data points. While the third location measured 50 by 35m, with the electrode spacing of 4 meters and profile spacing of 5 meter, the total point sampled was 70 points.

The overall mean soil resistivity was determined as shown below.

$$\rho = \frac{\sum \rho_i}{N} \tag{6}$$

Where;  $\rho$  is the mean resistivity

$\sum \rho_i$ = summation of all sets of resistivity obtained at different location

N = Number of sets of values contained.

To determine the absolute mean resistivity, the standard deviation and standard error were calculated

The overall mean soil conductivities were determined as shown below

$$\sigma = \frac{\sum \sigma_i}{N} \tag{7}$$

Where;  $\sigma$  is the mean conductivity

$\Sigma\sigma_i$ = summation of all sets of conductivity obtained at different location

N = Number of sets of values contained.

To determine the absolute mean conductivity, the standard deviation and standard error were calculated

The standard deviation for each location was calculated using the formula

$$S. D = \frac{\Sigma(\rho_i - \rho)^2}{N-1} \quad (8)$$

$$S. D = \frac{\Sigma(\sigma_i - \sigma)^2}{N-1} \quad (9)$$

Where  $\Sigma(\rho_i - \rho)^2$  is the summation of the square of the difference between each value of resistivity determined, and the mean resistivity value calculated.

$\Sigma(\sigma_i - \sigma)^2$  is the summation of the square of the difference between each value of conductivity determined, and the mean conductivity value calculated.

The standard error for the resistivity and conductivity determined in each location was calculated using the formula;

$$S. E = \frac{S}{\sqrt{N}} \quad (10)$$

Where S = standard Deviation

$\sqrt{N}$  = square root of number of sets of values obtain

### 3. Interpretation of Results

#### 3.1 location one

Figures 2(a-f) showed the variation in resistivity and conductivity values across in each profile. It is observed that profiles 1, 3, 4 and 6 start with highest resistivity values for each profile and decrease towards the end of the profile to the lowest value for each profile while profiles 2 and 5 showed its highest resistivity values on second data points.

Figure 3 showed the contour map and 3-D resistivity variation in location one.

#### 3.2 Location two

Figures 4(a-f) showed the variation in resistivity and conductivity values across in each profile. Generally, all the profiles start with a high resistivity values but attained the highest resistivity value at 20m and 25m of

horizontal distance i.e X- axis. Profile one has a peak at between 15m and 20m horizontal distance while profile three has its peak between 20m to 25m with red colour on the map. Furthermore profile four, five and six start with high resistivity and decrease along the profile and later drops to the lowest resistivity value towards the end of the profiles.

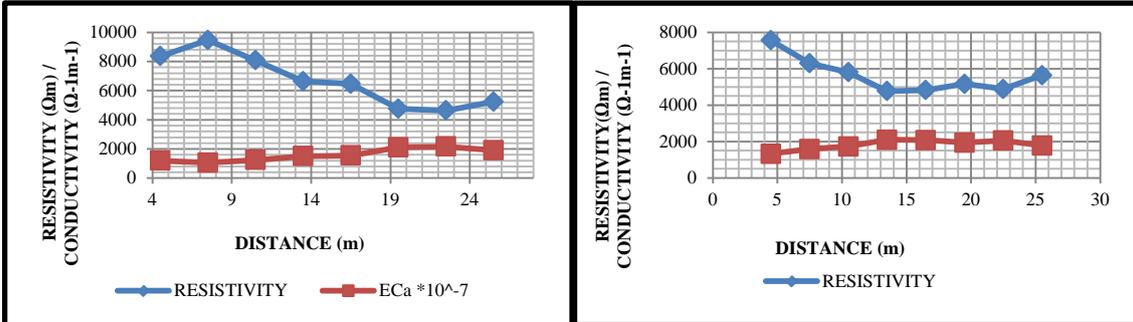


Figure 2a

Figure 2b

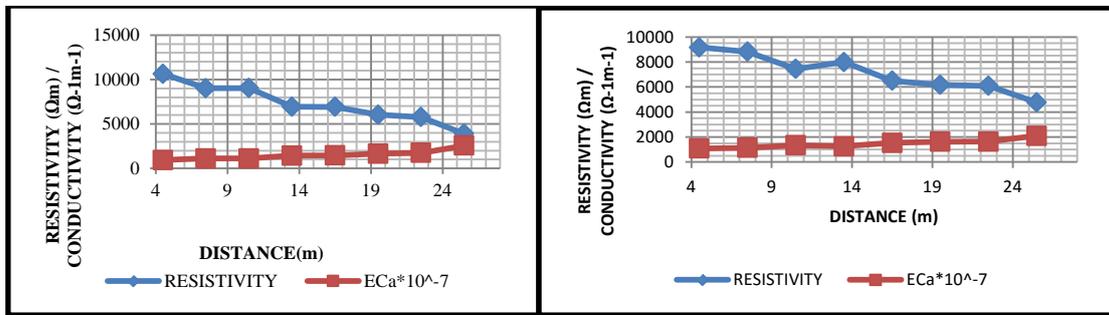


Figure 2c

Figure 2d

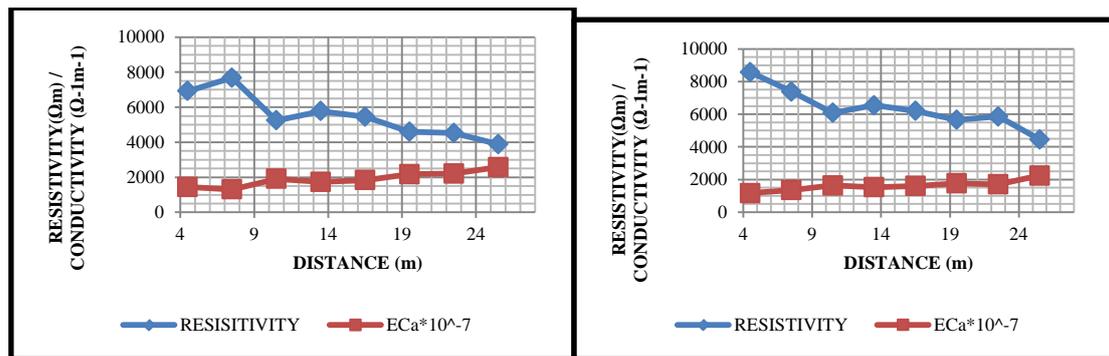


Figure 2e

Figure 2f

Figure 2a–f: Graphs of Resistivity and Conductivity against horizontal distance for location one

Figure 5 showed the contour map and 3-D resistivity variation in location two. The 3-D map is consistency with the graph plotted as it gives a better view of the graph and give better interpretation of the location.

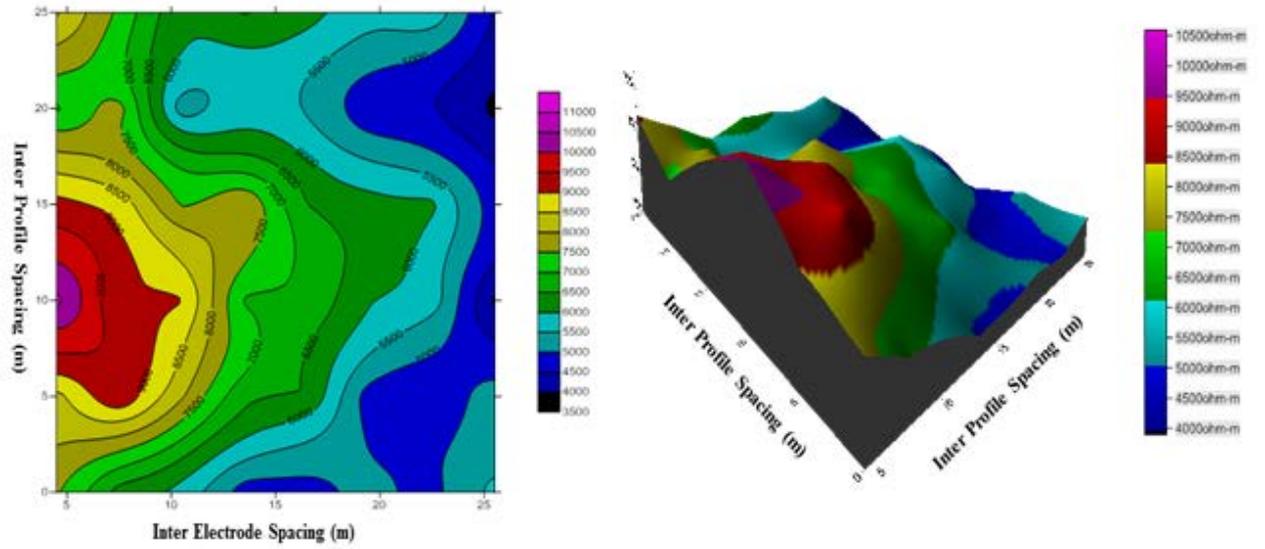


Figure 3: Resistivity contour map and 3-D Resistivity plot for Location one and the colour scale

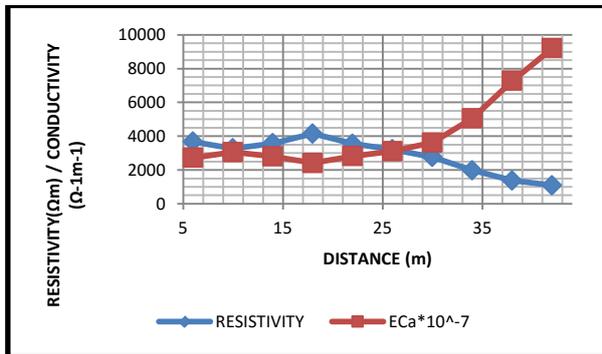


Figure 4a

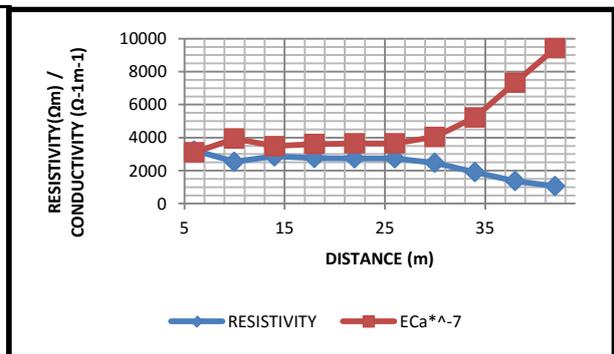


Figure 4b

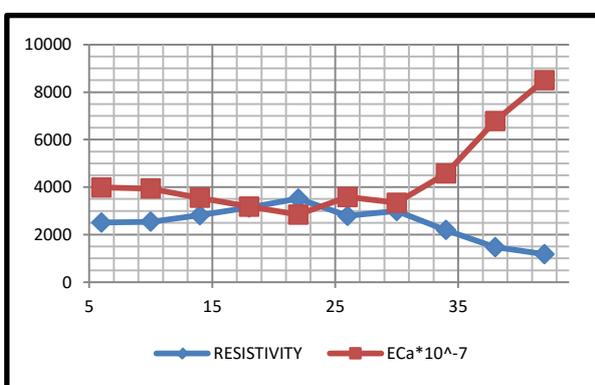


Figure 4c

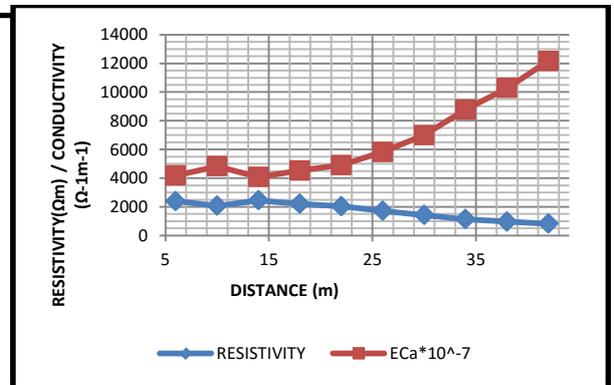


Figure 4d

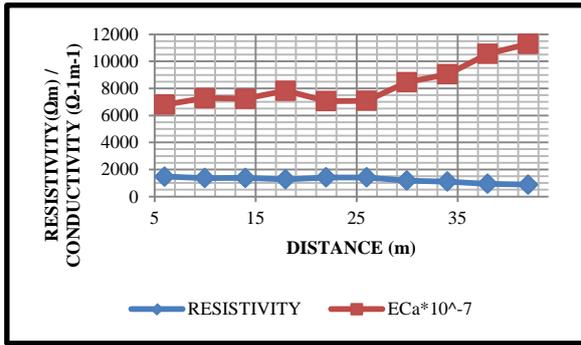


Figure 4e

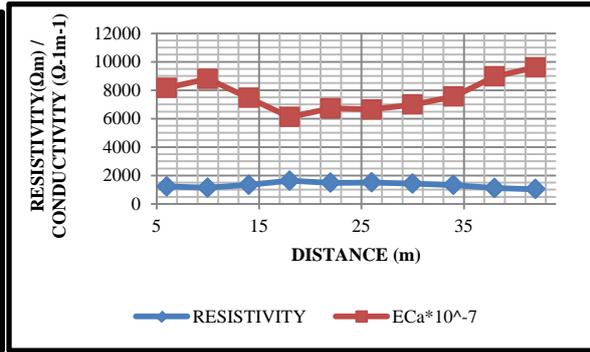


Figure 4f

Figure 4a–f: Graphs of Resistivity and Conductivity against horizontal distance for location two

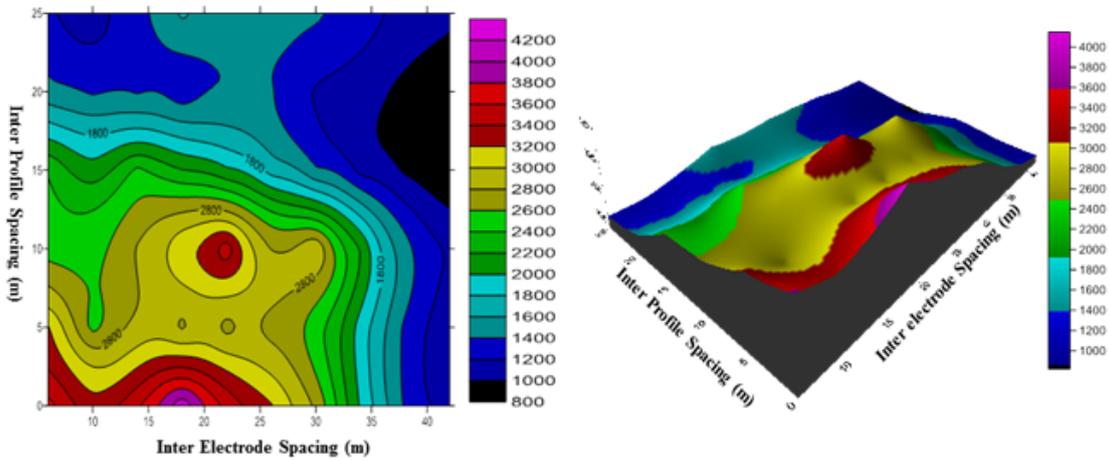


Figure 5: Resistivity contour map and 3-D Resistivity plot for Location two and the colour scale

### 3.3 Location three

Figures 6(a-g) showed the variation in resistivity and conductivity values across in each profile.

Figure 7 showed the contour map and 3-D resistivity variation in location three.

### 3.4. The Standard Deviation And Standard Error In The Three Locations Sampled.

#### Location 1

The mean of the resistivity obtained for location 1 in table 1 can be obtained as

$$\rho = \frac{\sum \rho_i}{N} = \frac{308569.5}{48} = 6428.532 \Omega m$$

$$S.D = \sqrt{\frac{(\rho_i - \rho)^2}{N - 1}}$$

$$S.D = \sqrt{\frac{121509650.7}{47}} = \sqrt{2585312} = 1607.89\Omega m$$

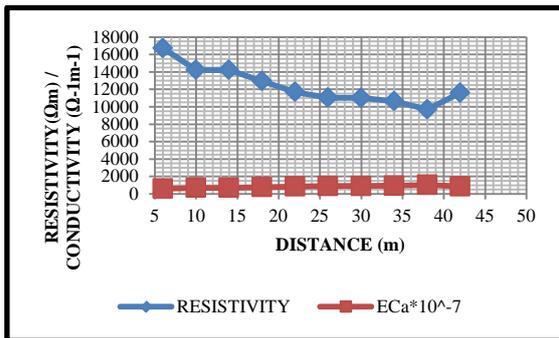


Figure 6a

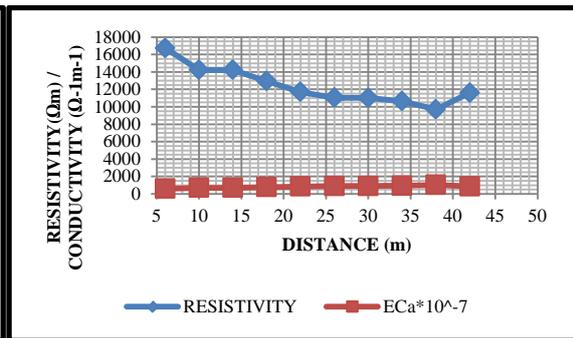


Figure 6b

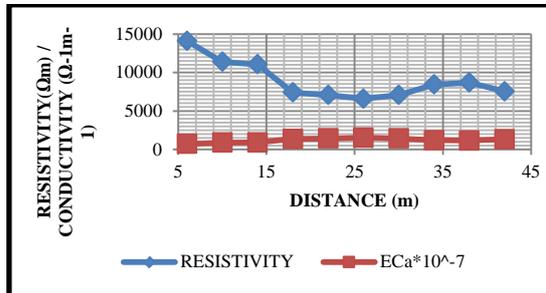


Figure 6c

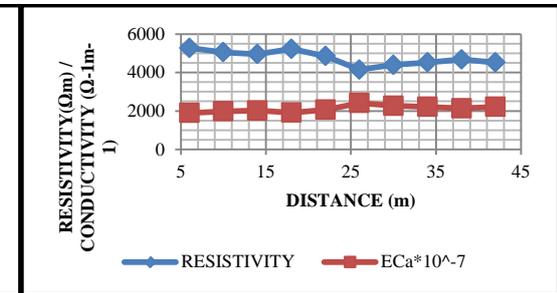


Figure 6d

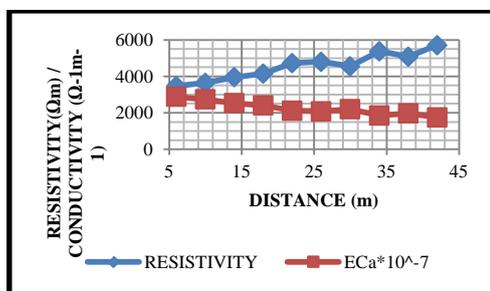


Figure 6e

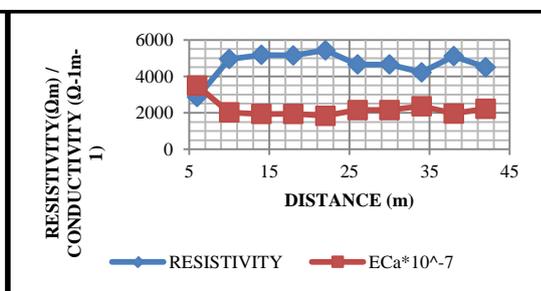


Figure 6f

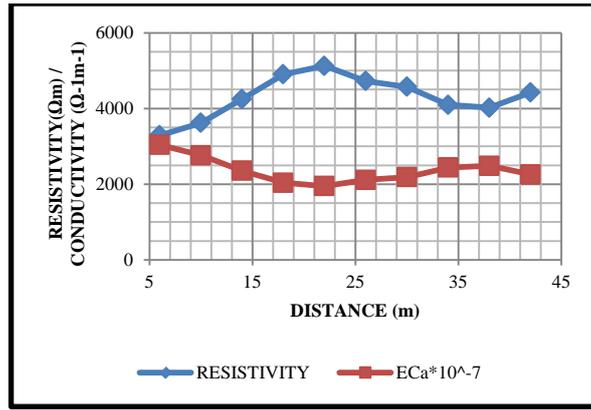


Figure 6g

Figure 6a–g: Graphs of Resistivity and Conductivity against horizontal distance for location three

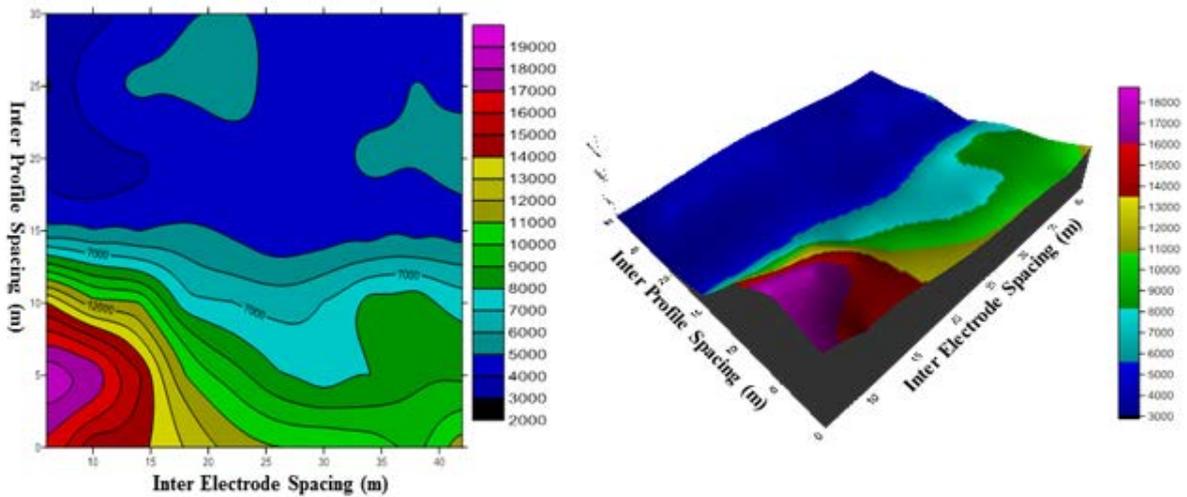


Figure 7: Resistivity contour map and 3-D Resistivity plot for Location three and the colour scale

The standard error

$$S. E = \frac{S. D}{\sqrt{48}}$$

$$S. E = \frac{1607.89}{6.93} = 232.35\Omega m$$

The absolute value of the resistivity obtained in the first location is

$$6428.532 \pm 232.35\Omega m$$

The mean of the conductivity obtained for location one in table one can be obtained as

$$\sigma = \frac{\sum \sigma_i}{N} = \frac{79200.37}{48} = 1650 \Omega^{-1}m^{-1}$$

$$S.D = \sqrt{\frac{(\sigma_i - \sigma)^2}{N - 1}}$$

$$S.D = \sqrt{\frac{7523013.00}{47}} = \sqrt{160064.1} = 400.08 \Omega^{-1}m^{-1}$$

The standard error

$$S.E = \frac{S.D}{\sqrt{48}}$$

$$S.E = \frac{400.08}{6.928} = 57.75 \Omega^{-1}m^{-1}$$

The absolute value of the conductivity obtained in the first location is

$$1650 \pm 57.75 \Omega^{-1}m^{-1}$$

## Location 2

The mean of the resistivity obtained for plot 2 in table 2 can be obtained as

$$\rho = \sum \frac{\rho_i}{N} = \frac{120064.04}{60} = 2001.07 \Omega m$$

$$S.D = \sqrt{\frac{(\rho_i - \rho)^2}{N-1}}$$

$$S.D = \sqrt{\frac{44460998}{59}} = \sqrt{753576.2}$$

$$= 868.09 \Omega m$$

The standard error

$$S.E = \frac{S.D}{\sqrt{60}}$$

$$S.E = \frac{868.09}{7.75} = 112.07 \Omega m$$

The absolute value of the resistivity obtained in the second location is

$$2001.067 \pm 112.07 \Omega m$$

The mean of the conductivity obtained for location 2 in table 2 obtained as

$$\sigma = \sum \frac{\sigma_i}{N} = \frac{360125.75}{60} = 6002.09 \Omega^{-1}m^{-1}$$

$$S.D = \sqrt{\frac{\sum(\sigma_i - \sigma)^2}{N - 1}}$$

$$S.D = \sqrt{\frac{378337169}{59}} = \sqrt{6412494}$$

$$S.D = 2532.29 \Omega^{-1}m^{-1}$$

$$S.E = \frac{S.D}{\sqrt{60}}$$

$$S.E = \frac{2532.29}{7.75} = 326.91 \Omega^{-1}m^{-1}$$

The absolute value of the conductivity obtained in the second location is

$$6002.09 \pm 326.91 \Omega^{-1}m^{-1}$$

### Location 3

The mean of the resistivity obtained for location 3 in table 3 can be obtained as

$$\rho = \sum \frac{\rho_i}{N} = \frac{509326.71}{70} = 7276.10 \Omega m$$

$$S.D = \sqrt{\frac{(\rho_i - \rho)^2}{N-1}}$$

$$S.D = \sqrt{\frac{1021398192}{69}} = \sqrt{14802872} = 3847.45 \Omega m$$

The standard error

$$S.E = \frac{S.D}{\sqrt{70}}$$

$$S.E = \frac{3847.45}{8.367} = 459.86 \Omega m$$

The Resistivity value obtained in the third location is

$$7276.10 \pm 459.86 \Omega\text{m}$$

The mean of the conductivity obtained for location 3 in table 3 can be obtained as

$$\sigma = \sum \frac{\sigma_i}{N} = \frac{119322.184}{70} = 1704.60 \Omega^{-1}\text{m}^{-1}$$

$$S.D = \sqrt{\frac{\sum(\sigma_i - \sigma)^2}{N - 1}}$$

$$S.D = \sqrt{\frac{33382394.06}{69}} = \sqrt{483802.8}$$

$$S.D = 695.560 \Omega^{-1}\text{m}^{-1}$$

*The standard error*

$$S.E = \frac{S.D}{\sqrt{70}}$$

$$S.E = \frac{695.560}{8.367} = 83.14 \Omega^{-1}\text{m}^{-1}$$

The absolute value of the Conductivity obtained in the third location is

$$1704.60 \pm 83.14 \Omega^{-1}\text{m}^{-1}$$

#### 4. Conclusions

The electrical resistivity/conductivity of the soil is essential as it can be used to classify soil because each soil type has its range of value of resistivity/conductivity. Where the electrical resistivity is high electrical conductivity is low and vice versa. The variations in electrical resistivity/conductivity of soil depend the some factors in the soil such as soil salinity, bulk density, temperature, clay content and the moisture content but of all moisture content is the most important which when present will be aid the transportation and exchange of ions which will in turn speed up the electrical conduction of the soil while the resistivity will be low.

It has been shown from this research that electrical resistivity/conductivity of soil varies from location to location but for each location the electrical resistivity/conductivity could be close and form the same shape when measured and plotted as seen in this work. The closeness and the formation of the same shape of electrical resistivity/conductivity in each location could be because the factors that control soil resistivity/conductivity have not varied drastically. The resistivity/conductivity determined at depth could be used to classify the soil type in the locations. From this view, the soil in the three locations belongs to sandy to loose sandy soil (table

1).

**Table 1:** Results of the standard deviation and standard error for the electrical resistivity of the whole field and soil type

<i>Locations</i>	$\sum \rho_i$	$\rho$	<i>S.D</i>	<i>S.E</i>	SOIL TYPE
One	303569.5	6428.53	1607.89	232.35	Sandy soil
Two	120064.0	2001.07	868.89	112.07	Sandy soil
Three	509326.71	7276.10	3847.45	459.86	Sandy soil and loose sands

**Table 2:** Results of the standard deviation and standard error for the electrical conductivity of the whole field

<i>Locations</i>	$\sum \sigma_i$	$\sigma$	<i>S.D</i>	<i>S.E</i>
One	79200.37	1650	400.08	57.75
Two	360125.75	6002.09	2532.29	326.91
Three	119322.184	1704.60	695.56	83.14

Finally, the authors will like to recommend that this type of research work be carried out before planting any crop and be related to crop yield. This will make the work more robust.

### Acknowledgements

The authors would like to thank the God's Foudation Group Farmers Association, Ajibode Area, Ibadan for their valuable contributions to the success of the field survey.

### References

- [1] Halvorson, A. D, and J.D Rhoades (1976) field mapping soil conductivity to delineate dry land saline seeps with four- electrode technique soil sci soc AM.J. 40:571-574
- [2] Chang, C., T.G. Sommerfeldt, J.M. Carefoot, and G.B. Schaalje. (1983). Relationships of electrical conductivity with total dissolved salts and cation concentration of sulfate-dominant soil extracts. Can. J. Soil Sci. 63:79-86. conductance of soil. Soil Sci. Soc. Am. J. 44:925-929.
- [3] Rhoades, J.D., S.M. Lesch, P.J. S house and W.J. Alves. (1989b). New calibrations for determining soil electrical conductivity-depth relations from electromagnetic measurements. Soil Sci. Soc. Am. J. 53:74 79.

[4] Nigeria Geological Survey Agency, (1972).

[5] Olayinka, A.I. and Olayiwola, M.A. (2001). An integrated used of geo electrical imaging and hydrogeochemical methods in delineating limits of polluted surface and groundwater at a landfill site in Ibadan area, Southwestern Nigeria. *Journal of Mining and Geology*. 37.1:53-68.

[6] Nagrath, I.J and Kothari, D., (2001), "Power System Engineering" Tata McGraw-Hill.