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Application of Electrical Resistivity Method in Monitoring Influence of Soil Properties on the Growth of *Cucumis Sativus*

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Abstract: *Randomized Complete Block Design (RCBD) field experiment was carried out at the Teaching and Research farm of Federal University of Technology, Akure, Southwestern Nigeria. The Research is aimed at monitoring soil water dynamics and evaluating the impact of soil properties such as soil pH, soil electrical conductivity and soil salinity on the growth and yield of Cucumber (Cucumis sativus) using 2D-Electrical Resistivity Tomography (ERT) method. Results from various surveys conducted were subjected to statistical correlation in order to determine existing statistical relationships between measured soil properties as they influence the growth and yield of the crop, as well as analyzing electrical resistivity responses from the soil properties and their significance in improving plants' yield Data collected on plants includes vine length at 2 weeks, 3 weeks and 4 weeks after planting, number of fruits per plant, fruit length, and fruit diameter, which were subjected to analysis of variance (ANOVA) and mean separation. The inverted electrical resistivity response, laboratory soil parameters and crop yield were correlated using regression analysis, while coefficient of correlation generated and mathematical models were interpreted in terms of plants growth and yield.*

Keywords: *Electrical resistivity, Cucumis Sativus, Soil Salinity, Tomography, Poultry manure, Crop Yield*

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I. Introduction

Promoting sustainable agriculture in developing countries is a key to achieving food security, improve governance of global agricultural trade, and increase productivity while conserving the natural resource base. According to [1], the food security situation deteriorated sharply in 2016 in parts of sub-Saharan Africa, South-Eastern Asia and Western Asia, and that the most recent estimates indicate that global hunger increased in 2016 and now affects 815 million people. It was estimated that the the percentage of the global population suffering from hunger also increased in 2016, while situation is especially urgent in Eastern Africa, where one-third of the population is estimated to be undernourished where the subregion's prevalence of undernourishment (PoU) increased from 31.1 percent in 2015 to 33.9 percent in 2016 [1], It is therefore pertinent that people's diets will change, shifting to increased proportions of vegetables, fruits and livestock production, thus there is a need for continuous focus on optimizing agricultural output in conjunction with conserving the natural resources base via improved crops and crop management system [1]. In the light of the recorded the number of chronically undernourished people in the world estimated to have been increased to 815 million, up from 777 million in 2015 as presented in [1], there is a need for researches in the area of optimizing agricultural output in conjunction with conserving the natural resources through improved crops and crop management systems. In other to achieve this, a proper understanding of agricultural soil and soil properties such as soil moisture content and soil salinity that may significantly affect plants growth and crop yields is necessary.

Traditionally, deficiencies in soil nutrients are assessed by visual crop observation. This traditional technique of visual crop observation is fast and economical, but its major disadvantage is that plants would have been damaged or low yield would have been recorded before they are detected [2]. In recent times, Geophysical methods have found varieties of relevance in agro ecosystem and their uses have been proven in literatures for detecting and monitoring the variations in soil properties before they can have detrimental effects on plants [3]. Among areas of application includes; measurement of soil salinity ([4], [5], [6]), soil water content [7], mapping of contaminant plumes associated with elevated chloride, sulfite and nitrate levels ([8], [9]), clay content measurement [10], determination of soil cation exchange capacity and exchangeable Ca and Mg [11], depth to clay pans [12], field-scale leaching rates of solutes [13], spatial groundwater recharge ([14], [15]) and yield [16], etc. These studies were successful because the parameters of interest either influenced a soil property (e.g., water content) that affects the electrical resistivity or its inverse - electrical conductivity (ECa), obtain directly or because the parameter is associated with pedogenic processes that create properties that affect ECa [17]. Soil Moisture Content (SMC) is a key control on plant growth and health, and controls important physical, chemical and biological processes such as plant growth, solute transport, rainfall runoff, erosion, and ultimately pedogenesis [2].

Natural geologic processes can cause soil variations and associated water-holding capacity to vary significantly over a short or wide distances. As a consequence, a continuous and precise spatially and temporal follow-up of the soil physical and chemical properties is required in order to have maximum yield.

Soil salinity on the other hand is basically the amount of major dissolved inorganic solutes present in the soil aqueous phase, which consists of soluble and readily dissolvable salts. Soil salinity tends to increase over time due to various factors which are either natural or artificial. The natural factors include processes such as mineral weathering and saline water intrusion, while artificial factors include practices such as irrigation, application of fertilizers and other anthropogenic activities. Salinity limits water uptake by plants by reducing the osmotic potential and thus making it difficult for plants to extract water from the soil. Consequently, this results in low yield or complete destruction of plants [18]. Soils salinity may cause specific ion toxicity thereby upsetting the nutritional balance of plants. Also, the salt composition of the soil water influences the composition of cations on the exchange complex of the soil particles and consequently influences soil permeability [3]. Apart from limiting crop yield and adversely affecting soil hydraulic parameters, soil salinity can negatively impact groundwater system as well as causing damages to infrastructures in the area through corrosion.

This paper addresses the use of geophysical methods in monitoring variation in soil properties and their effective association with yield of agricultural produce, especially the influence of soil moisture content and soil salinity on the growth of Cucumber (*Cucumis sativus)* using 2D electrical resistivity Tomography in complete randomized blocks system. The study demonstrates that geoelectrical resistivity imaging as an effective tool in mapping the spatial variability of soil water dynamics of farm land for precision agricultural planning.

II. Site Description And Geologic Settings

The research was carried out within the teaching and research farm of the Federal University of Technology, Akure, which lies in a typical crystalline terrain in the tropical rainforest region. The University Campus (Fig. 1) is situated on the northwestern flank of Akure, which is the capital city of Ondo State, Nigeria. The University, which occupies an area of about 5 km^2, lies between Latitudes 7°17' 0" N – 7°19' 0" N and Longitudes 5°7' 0" E - 5°9' 0" E. It is easily accessible through Akure - Ilesha highway. There are network of roads and foot paths within the campus. The mid-annual rainfall in the study area ranges between 1000 mm and 1500 mm, with the relative humidity during rainy and dry seasons varying between 37.4% and 95.3 % respectively. The mean minimum and maximum ambient temperature of 22.3 ^{0}C and 31.5 ^{0}C are observed within study area according to the metrological reports from the Department of Metrology and Climate Science of the Institution in 2016.

The geology of the study area as shown in Fig. 1, comprise of crystalline rocks of the Basement Complex area of Nigeria, with major rock types being undifferentiated granite, Charnockite and migmatite gneisses ([19], [20]). These rocks occur mostly as outcrops of granites and the migmatite gneisses, with the charnockitic rocks intruded into the migmatite gneiss quartzite complex and the older granite, forming discrete bodies in some parts of the study area.

III. Material And Methodology

3.1 Experimental Blocks Design

Experimental blocks of six rectangular wooden boxes, filled with humus soil, with a thickness of 30 cm from the base to maintain a nearly homogenous soil texture, were constructed within the Teaching and Research farm with dimension shown in Fig. 2. Each of the wooden boxes has a dimension of length 360 cm, breadth 60 cm and height 45 cm i.e. (360 X 60 X 45) cm^3 and used as soil profile boxes. . Geophysical survey was conducted on the designed experimental blocks packed up with humus soil. Dipole-dipole electrode configuration with minimum spacing of 0.1m was used for resistivity data measurement, with maximum expansion factor of 5 translating to maximum depth of investigation of approximate 0.3 m at every phase of investigation along the profiles of the investigation. The minimum electrode spacing and expansion factor used ensures that the effective depth of investigation is confined to the base of the root zone of the crop plants. Forty-eight (48) random soil samples, limited to the top soil within 10 cm range, were collected from the experimental blocks (twelve samples at pre-planting, planting, flowering and harvesting stages of the plants) and were analyzed in the laboratory. The base of each box was covered by a 2-layered thick carpet to prevent contact with the ground in other to maintain the same soil type and prevent the upward migration of water from the ground into the soil profile boxes. Thus, reducing leakages of water out of the soil profile boxes and regulating the soil temperature. This also ensures availability of enough water to dissolve soil nutrients for plants intake, strengthening the root system of the crop plants and improving its entire growth.

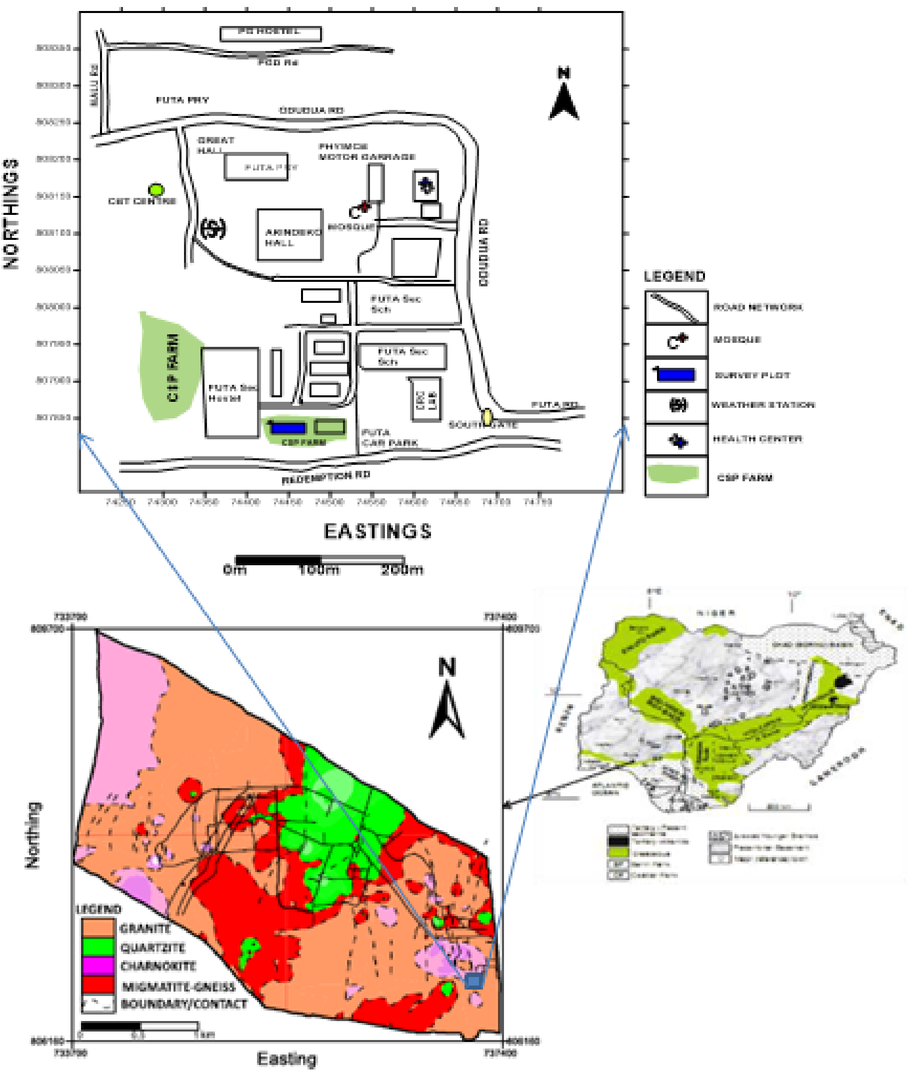


Figure 1: Geological map of the Federal University of Technology, Akure (left below, after [20]) showing the location of research farm (upper figure) within the geological map of Nigeria

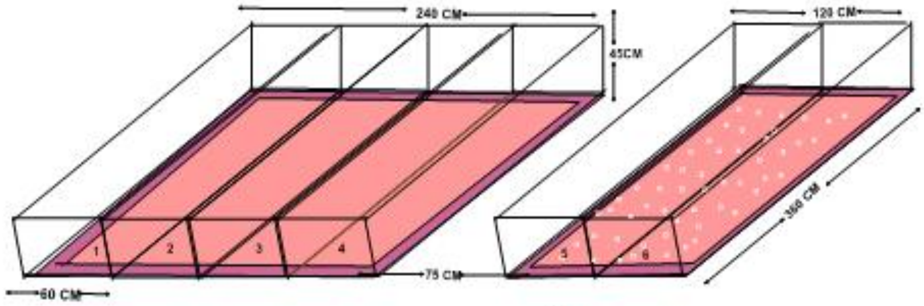
Boxes labelled 1 and 2 were used as a control (i.e. neither organic manure was applied nor any pore space created on the first layer of the base carpet), boxes labelled 3 and 4 were used as treatment with application of poultry manure before and after planting, while several pore spaces were created on the first layer of the base carpet for boxes labelled 5 and 6 in order to create some channels for water to leak out of the box thus, providing a relatively low moisture for plants in both profile boxes compared to others. The experiment was conducted between 1st April and 30th June, 2017.

Mechanical soil analysis of the experimental soil showed that it had **56.6 %** sand, **26.32%** clay, **17%** silt, thus classified as Sandy Clay Loam in the textural class. The field was cropped with Cucumber (*Cucumis sativus*). The investigation was carried out in stages, spanning a period of 11 weeks between 4th April, and 29th July 2017, corresponding to the background measurements at the pre-planting, planting, flowering and harvesting stages.

3.2 Laboratory Measurement

A total of forty – eight (48) samples (twelve samples at each stage) were collected from the experimental blocks and analysed in the laboratory. The soil samples were collected at the onset, 3rd week during the planting of crops, 7th week, and 11th week of the study. The soil samples were limited to the top soil within 10 cm range. The samples were dried to determine the moisture content in the soil samples. During the laboratory testing, distilled water was used in every step that involved liquid.

(a)



(b)

Figure 2: The design of the (a) experimental Soil Profile Box (b) constructed randomized Experimental Blocks

The beakers, measuring cylinder and spatulas were washed with distilled water and dried so as to remove traces of ions and water molecules present in the apparatus. The laboratory conductivity meter was calibrated using solution 1413 μS/m so as to sterilize the sensing part of the conductivity meter. The JENWAY 4510 conductivity meter which applies an alternating current (I) at a specific frequency to two active electrode and measures the potential (V) was used for determining the conductance.

The conductivity meter then uses the conductance and cell constant to determine the conductivity displayed. The salinity meter was used to measure the salinity level in the samples. The conductivity and salinity meters were re-calibrated after each reading before using it for the next sample. The conductivity of the samples was measured in micro-Siemen per meter μS/m, while the salinity is measured in parts per meter (ppm).

3.3 Geophysical Survey

Geophysical survey was conducted on the surface of the soil within the experimental blocks of six wooden boxes each of length 3.6 m as an in-situ measurement of the soil property. The 2D-geoelectrical resistivity profiling were conducted with the aid of ABEM Terrameter (SAS 1000/4000 series) using Dipole-dipole electrode configuration with minimum spacing of 0.1 m for data measurement, with a data level of 5. Maximum electrode spacing of 0.3 m was achieved in each of the profiles at every phase of the investigation. The minimum electrode spacing and data level reached allow the effective depth of investigation to be confined to the root zone of the crop plants. Care was taken to minimize electrode positioning error in the measurements throughout the survey. The measurements were stacked to ensure good quality and minimise error in the data collection. The root-mean square error up to 0.5% or higher were reject and readings repeated after ensuring that the electrodes were in good contact with the ground. The observed apparent resistivity data sets on each profile were later processed with Dipro^{TM} for Window (Version 4.0) and Surfer^{TM} (Version 13) software. The inverted resistivity values at respective point of observations are presented along with the analyses from the water chemistry of the soil samples on which the plant was cultivated (Tables 1- 4). The laboratory observations showed that the salinity and conductivity levels of the soil were generally within the limit for normal soil for plant growth.

Table 1: Inverted ER data and Laboratory Sample Analyses Results at Phase I (Before Planting)

Block	Sample	ER (Ohm-m)	MC (%)	Cond(μS/m)	pH_H2O	SS (ppm)
1	A_1 (S1)	302	8.3	203	9.3	291
1	B_1 (S2)	319	8.1	213	9.4	315
2	A_2 (S3)	214	10.0	230	9.2	230
2	B_2 (S4)	328	8.1	193	9.3	311
3	A_3 (S5)	492	7.4	185	9.3	208
3	B_3 (S6)	209	10.0	242	9.3	336
4	A_4 (S7)	422	7.8	219	9.1	185
4	B_4 (S8)	243	9.7	190	9.2	330
5	A_5 (S9)	285	9.2	219	9.4	230
5	B_5 (S10)	368	8.1	188	9.3	185.5
6	A_6 (S11)	207	10.0	233	9.4	332
6	B_6 (S12)	253	9.5	214	9.1	129.3

Table 2: Inverted ER data and Laboratory Sample Analyses Results at Phase II (Planting stage)

Block	Sample	ER (Ohm-m)	MC (%)	Cond (μS/m)	pH_H2O	SS (ppm)
1	A_1 (S1)	112	20.8	291	9.1	182
1	B_1 (S2)	161	14.8	243	9.0	217
2	A_2 (S3)	115	18.1	250	9.3	310
2	B_2 (S4)	163	14.2	238	9.1	380
3	A_3 (S5)	149	17.3	255	9.3	368
3	B_3 (S6)	133	17.8	280	9.2	385
4	A_4 (S7)	192	14.1	237	8.9	399

4	B_4 (S8)	150	16.2	285	8.8	430
5	A_5 (S9)	191	11.9	226	9.0	233
5	B_5 (S10)	202	10.3	207	9.0	110
6	A_6 (S11)	162	12.1	243	9.1	212
6	B_6 (S12)	153	15.3	250	8.6	250

Table 3: Inverted ER data and Laboratory Sample Analyses Results at Phase III (Flowering stage)

Block	Sample	ER (Ohm-m)	MC (%)	Cond(μS/m)	pH_H2O	SS (ppm)
1	A_1 (S1)	18	74.1	345	7.6	450
1	B_1 (S2)	35	71.2	324	7.5	410
2	A_2 (S3)	33	71.4	341	7.8	415
2	B_2 (S4)	31	73.0	350	7.8	402
3	A_3 (S5)	12	81.6	389	7.7	713
3	B_3 (S6)	14	79.5	372	7.9	666
4	A_4 (S7)	38	67.9	297	8.0	515
4	B_4 (S8)	48	65.2	284	7.9	385
5	A_5 (S9)	48	54.5	230	7.9	304
5	B_5 (S10)	53	51.2	264	7.9	256
6	A_6 (S11)	59	50.0	214	8.1	351
6	B_6 (S12)	60	46.7	210	8.0	230

Table 4: Inverted ER data and Laboratory Sample Analyses Results at Phase IV (Harvesting stage)

Block	Sample	ER (Ohm-m)	MC (%)	Cond(μS/m)	pH_H2O	SS (ppm)
1	A_1 (S1)	117	40	320	8.0	153
1	B_1 (S2)	156	38.2	362	7.9	555
2	A_2 (S3)	125	38.8	308	7.8	1289
2	B_2 (S4)	80	42.0	302	7.8	680
3	A_3 (S5)	75	43.6	529	7.8	1793
3	B_3 (S6)	64	45.3	545	7.8	1612
4	A_4 (S7)	77	42.5	321	7.9	1408
4	B_4 (S8)	115	40.0	432	7.5	842
5	A_5 (S9)	161	36.0	302	7.9	1002
5	B_5 (S10)	78	34.2	320	8.0	830
6	A_6 (S11)	276	31.0	234	7.5	615
6	B_6 (S12)	144	38.8	295	7.6	519

3.4 Seed collection and Crop cultivation

Seed of proven variety of Cucumber were obtained at the Akure main market. They were sown on the plots at the rate of 3seeds/stand at a spacing of 0.45 m × 0.6 m and at a depth of 3 cm. However, the seedlings were later thinned to 1 seedling/stand, giving an average plant population of 10 plants / box. Boxes labelled 1 and 2 were used as control, while poultry manure was applied on boxes labelled 3 and 4 before planting at 2 weeks after planting (WAP), i.e., 5^{th} week of study at a standard rate of 5tons / hectare. Several holes were created at the base carpet of boxes labelled 5 and 6 in order to create some channels for water to flow out of the box at a steady rate, thus providing relatively low moisture for plants in both boxes compared to other boxes (Fig. 2). Weeding was conducted twice throughout the entire planting process by manual uproot of weeds at 2WAP and 4WAP.

3.4.1 Plants Growth Monitoring

Data collected were vine length (cm), fruit length (cm), and fruit diameter (cm). The result obtained is presented in Tables 5 - 9. The vine length was measured at 2WAP, 3WAP and 4WAP using tape rule from the base to the growing tip of the plant. The numbers of fruits/plants were determined by direct counting. Fruit length and diameter were measured using tape rule. At the later stage of the study, data collected and plants' yield were subjected to descriptive and analyses of variance (ANOVA) of mean using Minitab^{TM} (version14.14) and IBM SPSS^{TM} (version 23) statistical analyses software.

Table 5: Vine Length at 2WAP

	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	
TR1 (Box 1)	23.0	20.0	21.0	22.6	22.0	21.3	21.8	23.0	24.0	21.0	
TR2 (Box 2)	19.8	20.0	21.5	23.0	20.0	22.3	20.8	20.7	21.0	22.0	
TR3 (Box 3)	23.3	19.8	23.0	23.0	22.4	22.1	24.0	24.6	24.0	25.2	
TR4 (Box 4)	25.0	24.6	26.0	24.3	24.0	24.4	25.0	25.0	27.4	28.0	
TR5 (Box 5)	20.0	21.8	21.0	19.4	20.0	19.0	19.5	19.4	19.0	22.0	
TR6 (Box 6)	19.3	19.8	21.0	21.3	21.0	21.0	19.5	21.0	19.8	21.5	

Table 6: Vine Length at 3WAP

	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	
TR1 (Box 1)	62.4	61.3	65.8	60.2	61.4	59.0	58.2	63.0	58.0	58.0	
TR2 (Box 2)	59.0	62.0	62.1	60.6	61.0	63.0	59.8	60.4	65.0	60.0	
TR3 (Box 3)	68.0	65.0	64.3	65.1	62.0	62.0	64.0	63.2	67.0	62.4	
TR4 (Box 4)	65.4	65.0	63.0	62.0	63.0	62.1	65.1	64.0	63.6	63.0	
TR5 (Box 5)	59.0	60.0	60.0	61.0	61.0	57.0	56.0	62.0	58.0	56.0	
TR6 (Box 6)	59.4	60.5	59.8	62.0	58.5	55.0	60.4	57.0	60.1	59.0	

Table 7: Vine Length at 4WAP

	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10
TR1 (Box 1)	109.5	105.2	99.5	107.0	104.3	101.0	103.3	109.0	113.8	99.5
TR2 (Box 2)	93.8	94.8	102	109	101.8	105.7	98.6	98	99.5	104.3
TR3 (Box 3)	110.4	118.5	112	109	106.2	104.7	113.8	116.6	112.8	119.4
TR4 (Box 4)	118.5	116.6	123.2	115.2	113.8	115.6	118.5	118.5	120.0	124
TR5 (Box 5)	94.8	93.8	99.5	91.9	94.8	90.1	92.4	91.9	90.1	98.6
TR6 (Box 6)	91.5	93.8	88.2	96.2	95.5	98.8	92.4	92.4	91	90.3

Table 8: Fruits Length measured at 11th week of Study

	FRUIT LENGTH (CM)										
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	
TR1 (Box 1)	15.0	13.0	14.9	16.4	14.3	14.5	15.4	17.0	16.2	14.6	
TR2 (Box 2)	15.0	14.0	15.2	14.0	15.8	14.0	14.6	14.0	16.0	16.0	
TR3 (Box 3)	15.8	16.0	13.0	16.0	15.2	16.7	15.2	16.3	15.0	16.7	
TR4 (Box 4)	13.0	15.0	16.2	17.5	15.5	17.0	16.0	17.0	16.0	14.0	
TR5 (Box 5)	15.0	14.0	14.0	15.5	15.0	16.5	18.4	14.0	14.0	12.0	
TR6 (Box 6)	17.0	14.3	13.0	14.5	15.0	16.8	15.8	16.0	14.5	13.0	

Table 9: Fruits Diameter measured at 11th week of Study

	FRUIT DIAMETER (CM)									
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10
TR1 (Box 1)	3.8	3.2	3.2	3.4	3.5	3.6	3.6	3.7	3.4	3.5

TR2 (Box 2)	3.1	3.4	3.5	3.7	3.3	3.5	3.7	3.6	3.6	3.6
TR3 (Box 3)	3.6	3.5	3.5	3.6	3.6	3.4	3.5	3.8	3.7	4.0
TR4 (Box 4)	3.6	3.6	3.8	3.6	3.4	3.6	3.5	3.6	3.6	3.8
TR5 (Box 5)	3.2	3.1	3.3	3.5	3.4	3.5	3.4	3.4	3.6	3.7
TR6 (Box 6)	3.6	3.6	3.3	3.4	3.2	3.1	3.3	3.5	3.6	3.3

3.5 Agro-meteorological data measurement

Amount of rainfall and soil temperature were recorded to monitor the effect of atmospheric factors that significantly influence soil resistivity and other soil properties. These parameters were recorded at FUTA Meteorological station situated at about 300 m away from the study area. These agro-meteorological data were recorded between April 1st, 2017 and June 30th, 2017, which covers the entire period of pre-planting to the harvesting stages of the study. An automatic rain gauge and three soil thermometers buried at 10 cm, 20 cm and 30 cm below the subsurface were used for monitoring the frequency and volume of precipitation (Table 10), and the corresponding soil temperatures (Fig. 3) of the environment respectively.

Table 10: Amount of Rainfall recorded during the study

Date	Amount of Rainfall		Date	Amount of Rainfall		Date	Amount of Rainfall
	Phase I-Phase II (mm)			Phase II-Phase III (mm)			Phase III-Phase IV (mm)
6-Apr	16.6		28-Apr	65.6		29-May	3.9
8-Apr	22.3		1-May	35.4		30-May	4.8
9-Apr	9.0		3-May	12		2-Jun	14.8
11-Apr	1.6		6-May	29.4		5-Jun	6.6
13-Apr	14.4		11-May	47.2		7-Jun	4.0
15-Apr	64.2		16-May	22.6		12-Jun	75
20-Apr	10.0		19-May	31.4		13-Jun	5.8
23-Apr	10.0		22-May	75		16-Jun	47
			23-May	45.2		19-Jun	18.2
						26-Jun	51.6
						29-Jun	7.2
Total	**148.1 mm**			**363.8 mm**			**238.9 mm**

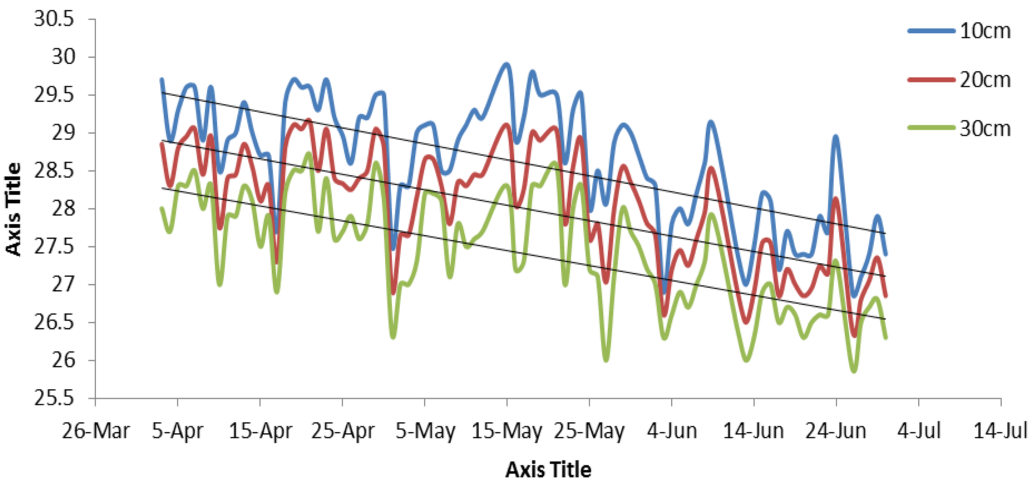


Figure 3: Recorded soil temperature during the period of study

IV. Results And Discussion

In order to assess the existing relationships between the laboratory derived soil parameters and effectiveness of the in-situ surface geophysical method to map or image the spatial distribution of the soil parameters, the results obtained from the various techniques were presented in a suitable forms that allows statistical analyses and inferences on the reliability of the approach adopted.

4.1 Electrical Resistivity Imaging

The results of resistivity survey show a significant contrast in the resistivity values across each stage of the investigation, as shown in the inverted resistivity imaging of the measured soil resistivity. These contrasts were suspected to result from the variation in soil properties and atmospheric weather condition especially precipitation from rainfall which influenced the soil moisture content. In addition to that, different treatments applied to the humus soil may have also contributed to the resistivity variation among other factors. Thus, there is a need to test the significance difference associated with fluid content and other physic-chemical properties of the soil. The geophysical survey results are presented in 2D structural resistivity models (or resistivity images) of the subsurface geology (Fig. 4 - 7).

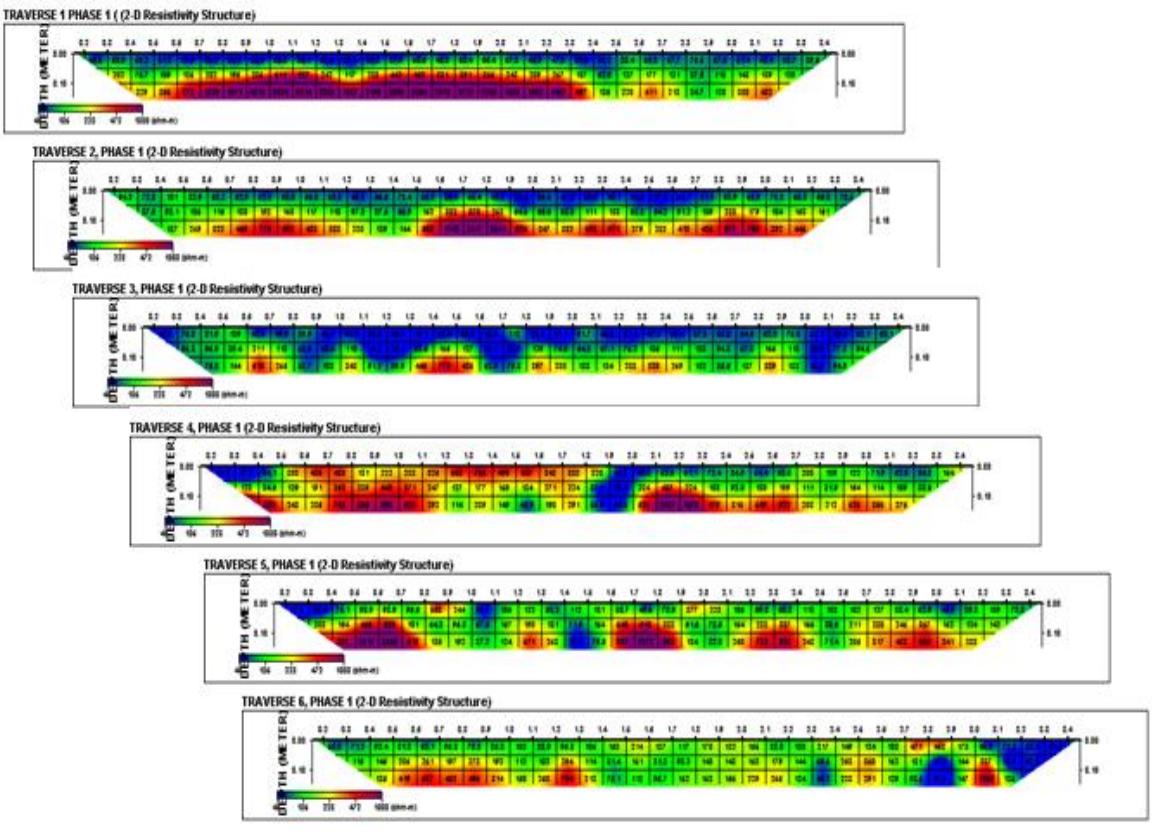


Figure 4: Resistivity imaging of the subsoil from the inverted ER data across the centre of each survey box at the onset of the study (Phase I)

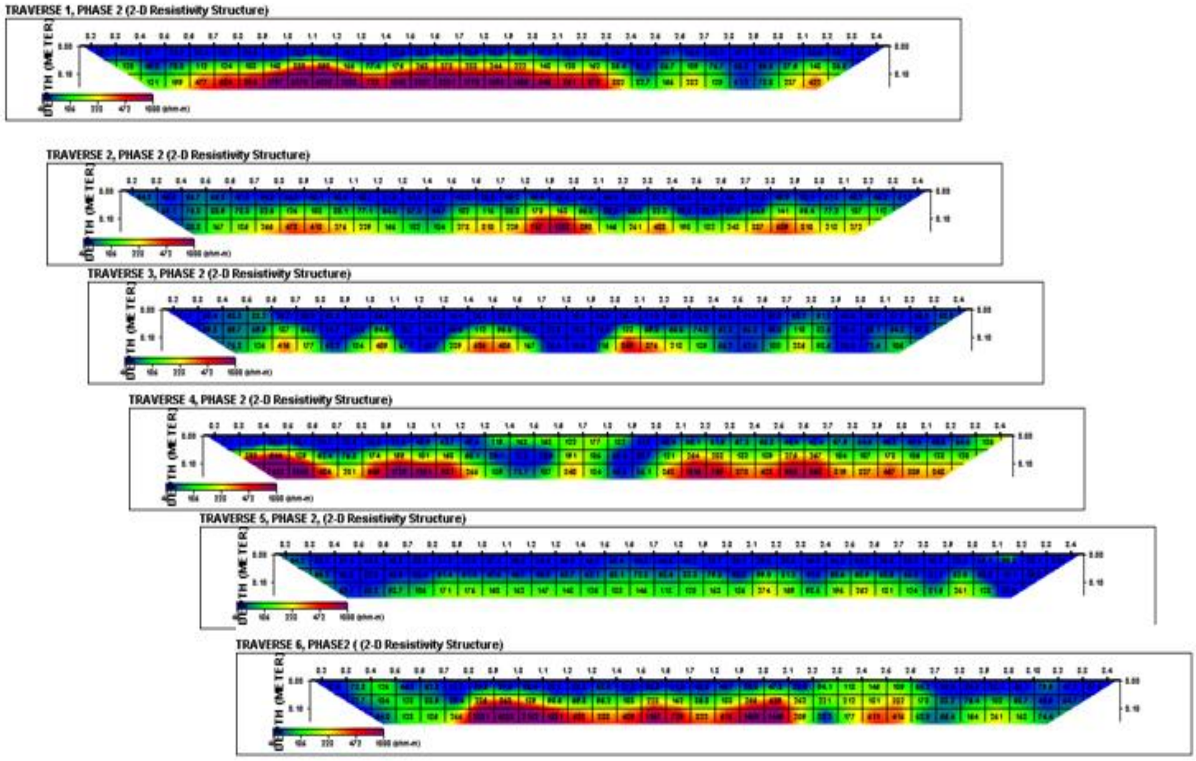


Figure 5: Resistivity imaging of the subsoil from the inverted ER data across the centre of each survey box at the planting stage (Phase II), 5th Week of the study

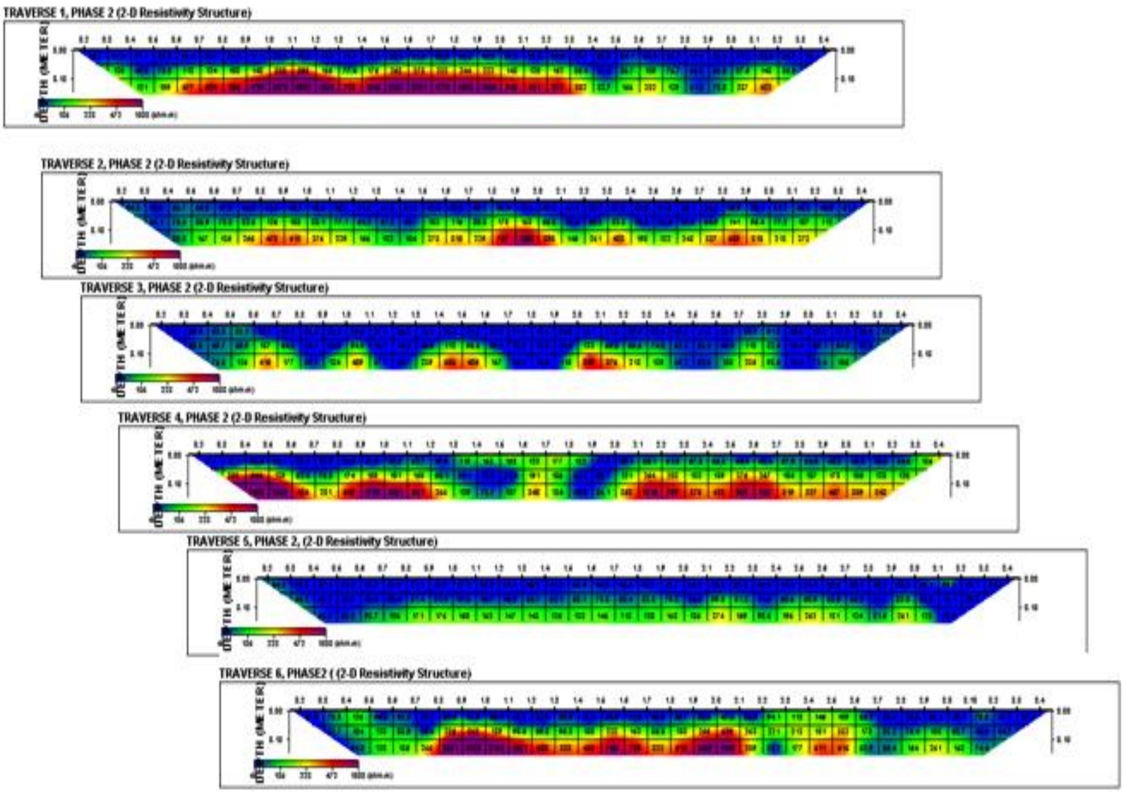


Figure 6: Resistivity imaging of the subsoil from the inverted ER data across the centre of each survey box 2 weeks after planting stage (Phase III), 7th Week of the Study

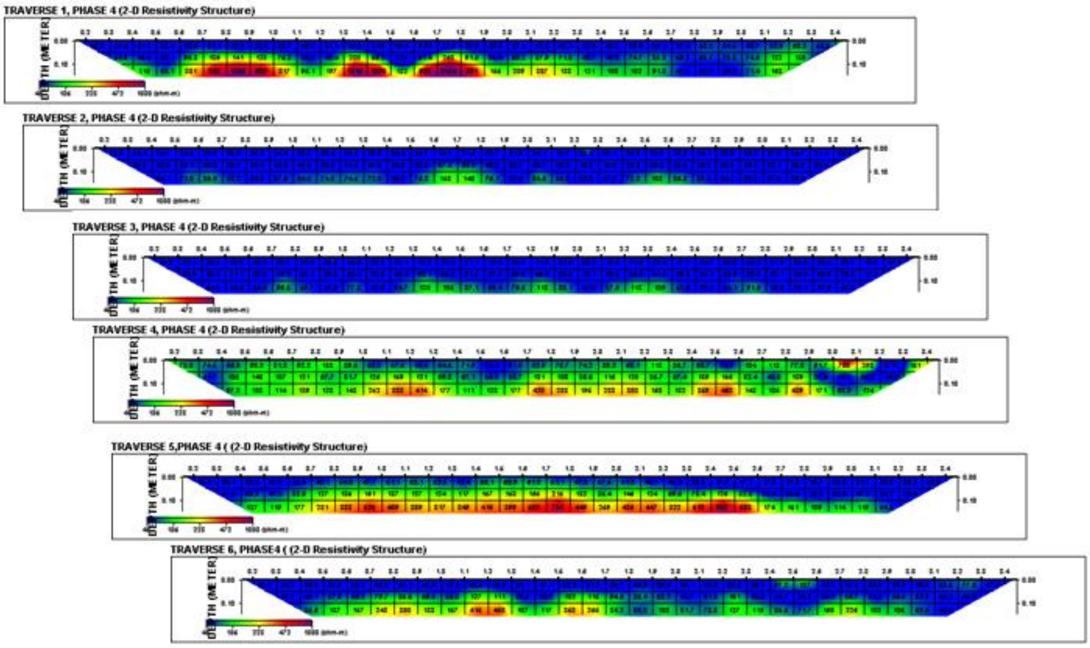


Figure 7: Resistivity imaging of the subsoil from the inverted ER data across the centre of each survey box at the harvesting stage (Phase IV), 11th Week of the study

The descriptive and paired sample test conducted on the inverted in-situ soil resistivity from the geophysical survey (Tables 11 & 12) reveal progressive variation in the in-situ soil resistivity through Phase I to Phase IV, showing effective changes in the average resistivity of soil before planting and planting stage, a period of 3 weeks interval, and further impacts of increase interplay between other soil properties. The results obtained at Phase I (Pre-planting/ background stage) of the investigation indicated relatively high resistivity values (low conductivity) for the dry condition of the humus soil at the onset of the research (Fig. 4). The resistivity values range between 207 ohm-m and 492 ohm-m, depicting the resistance to current flow by a unit thickness of the soil with unit cross sectional of the soil.

Table 11: Descriptive Statistics for the inverted ER Data

	Mean (ohm-m)	Min (ohm-m)	Max (ohm-m)	SD (ohm-m)
Phase_I	303.50	207	492	89.1286
Phase_II	156.92	112	202	28.5672
Phase_III	37.42	12	60	16.7357
Phase_IV	122.33	64	276	58.9735

Table 12: Paired Sample Statistics from the inverted ER Data

Group	Phase	Correlation					t-test		
		Paired Difference		R	Std Error mean (ohm-m)	sig (2-tailed)	t	df	Sig (2-tailed)
		Mean (ohm-m)	SD (ohm-m)						
Pair 1	Phase I & II	146.5822	81.8207	0.406	23.6196	0.191	6.206	11	0.000
Pair 2	Phase II &III	119.50	24.2243	0.533	6.9930	0.075	17.089	11	0.000
Pair 3	Phase III& IV	-64.9167	51.1637	0.578[a]	14.7697	0.049	-5.749	11	0.000
Pair 4	Phase I& III	266.0833	95.8839	-0.325	27.6793	0.303	9.613	11	0.000

Pair 5	Phase I& IV	181.1667	128.9128	-0.494	37.2139	0.102	4.868	11	0.000
Pair 6	Phase II& IV	34.5433	65.1759	0.014	18.8147	0.966	1.838	11	0.000

a. Correlation is significant at the 0.05 P level (2 tailed).

Progressive reduction in the resistivity values (112 – 202 Ohm-m) can be observed arising from increase in the mobility and exchange of ions in the soil with time, as shown in the inverted resistivity sections across the six profiles (Fig. 5). This is possibly as a result of increased rate of precipitation during this stage; 148.1mm of rainfall was recorded between Phase I & II.

From the statistics, a wide spread of resistivity values within the soil is evident, with significance difference in mean, except between phase II and Phase III where the correlation in the ER values is significant at 0.01 probability level ($p < 0.01$) for 2-tail t-test. The attributed general low resistivity pattern (12 – 60 Ohm-m at Phase III) is a reflection of ionic exchange due to fluid flow within the soil materials at particular point in the soil arising from increase in mobility of ions and electrolytic actions that can be attributed to increase in the moisture content. The resistivity sections show low resistivity distribution at effective depth if 0.1m, 0.2 and 0.3m (Fig. 6), a pattern that can be attributed to the saturation of the soil from precipitation (average amount of 363mm) between Phase II & III. Between Phase III and IV, there is notable increase in the inverted resistivity values (64 – 276 Ohm-m) as shown in the resistivity sections at the end of the study (Phase IV) as shown in Fig. 6, compared to that of phase III, but relatively lower compared to the period between phase I & II. At this stage, the rate of water consumption by the plants would have reached optimum level of demand for water by the plants from the flowering stage to the harvesting stage, so little is expected of further increase in the soil moisture during the development of the fruits between stages III and IV. It was also observed that recharge from rainfall decreased during this period as shown in Table 10. This is the maturity stage of the plant whereby leaves are being shed and amount of water intake via the roots of the plant has reduced drastically, though raining season has not seized.

4.2 Statistical Evaluation of relationship between geophysically derived Soil Electrical Resistivity and other Physio-chemical Soil Parameters

Statistical operations were performed on the paired inverted electrical resistivity data obtained through geophysical survey and the soil parameters using a series of regression analyses to determine the empirical relationship between the laboratory' determined soil parameters and the derived geophysical soil parameter. Considering the units of measurements, scale and variability in the range of measured properties, it was observed that simple linear relationship may not hold in establishing the existing relationships.

The simple regression equation, is of the form:

$Y = Mx + C + \xi$ (1)

where Y = dependent parameter, x = the independent variable, m is the slope (factor of linearity), C = non-linear or constant in the relationship, and ξ = error term, expressing the departure of the predicted values from the estimated values.

The observed moisture content, conductivity, salinity, and water pH from the analysed soil samples were paired with the corresponding inverted resistivity values as presented in Table 1 - 4. The regression equations from the scatter plots and the degree of correlation in terms of obtained coefficient of correlation **R** for the various paired parameters are presented as Tables and Figures. A modified classification of the correlation table by [21] shown in Tables 13 was adopted for expressing the degree of correlation of the paired data on the basis of regression curves obtained.

Table 13: Modified Range of Coefficient of Correlation (after [21])

Range of Coefficient of Correlation (R)	Classification
0 to 0.25 (or 0 to –0.25)	weak or no linear relationship
0.25 to 0.5 (or –0.25 to –0.5)	fair degree of linear relationship
0.50 to 0.75 (or –0.5 to –0.75)	moderately strong linear relationship

> 0.75 (or -0.75)	very strong linear relationship
1 or –1	perfect linear relationship – deterministic relationship

4.2.1 Paired Parameters Statistics

4.2.1.1 Soil Moisture Content Vs ER

Table 14 and Fig. 8 show the regression models adopted in establishing the relationship that exist between the Soil moisture content (MC) and the geophysical derived soil electrical resistivity (ER) . Logarithmic relationship appears to be the best regression model with coefficient of correlation of 0.94 against that of linear and power models standing at 0.80 and 0.90 respectively. From the regression curves, the soil moisture content decreases with increasing resistivity of the soil as expected ([16], [22], [23]), however the seasonal effects can be observed in the distribution of data, despite using appropriate scales for their representation. The power or exponential regression curve appears to present the best trend in the scatter plots, and presumed to have expressed the relationship existing between soil moisture content and geophysically derived earth resistivity using four electrode system with dipole-dipole array as used in this study. The empirical relationship is strong between the paired parameters, while the ANOVA test shows that the variation in the means of the data set is significant different from zero at 0.5 probability level ($p < 0.05$ 2 tailed), thus there is significant correlation (linearly) between the data sets.

Table 14: Paired Parameter Regression Correlation between Laboratory determined Moisture Content and geophysically derived Electrical Resistivity

Regression Model		ANOVA					Model Summary			Model Equation $Y = Mx + C + \xi$
Linear		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
										MC =(58.2582 ± 3.56) - (0.1680 ± 0.02)ρ
	Regression	16409.421	1	16409.421	80.59	0.000	0.798	0.637	14.629	
	Residual	9366.298	46	203.615						
	Total	25775.719		47						
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	-0.168	0.019	-0.798	-8.977	0.000				
	(Constant)	58.258	3.559		16.370	0.000				
Logarithmic		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	22527.005	1	22527.005	318.970	0.000	0.935	0.874	8.404	MC = (149.5965 ± 6.68) - (24.7949 ± 1.39)ln(ρ)
	Residual	3248.714	46	70.624						
	Total	25775.719	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	Ln(ER)	- 24.795	1.388	- 0.935	-17.860	0.000				
	(Constant)	149.597	6.684		22.381	0.000				

Table 14 Contd.'

Power		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	24.384	1	24.384	186.117	0.000	0.895	0.802	0.362	MC = 1141.1317 ±328.51)$\rho^{-(0.8158\pm0.06)}$
	Residual	6.027	46	0.131						
	Total	30.410	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	Ln(ER)	-0.816	0.060	-0.895	-13.642	0.000				
	(Constant)	1141.132	328.513		3.474	0.001				

MC = Soil Moisture Content, ρ = resistivity

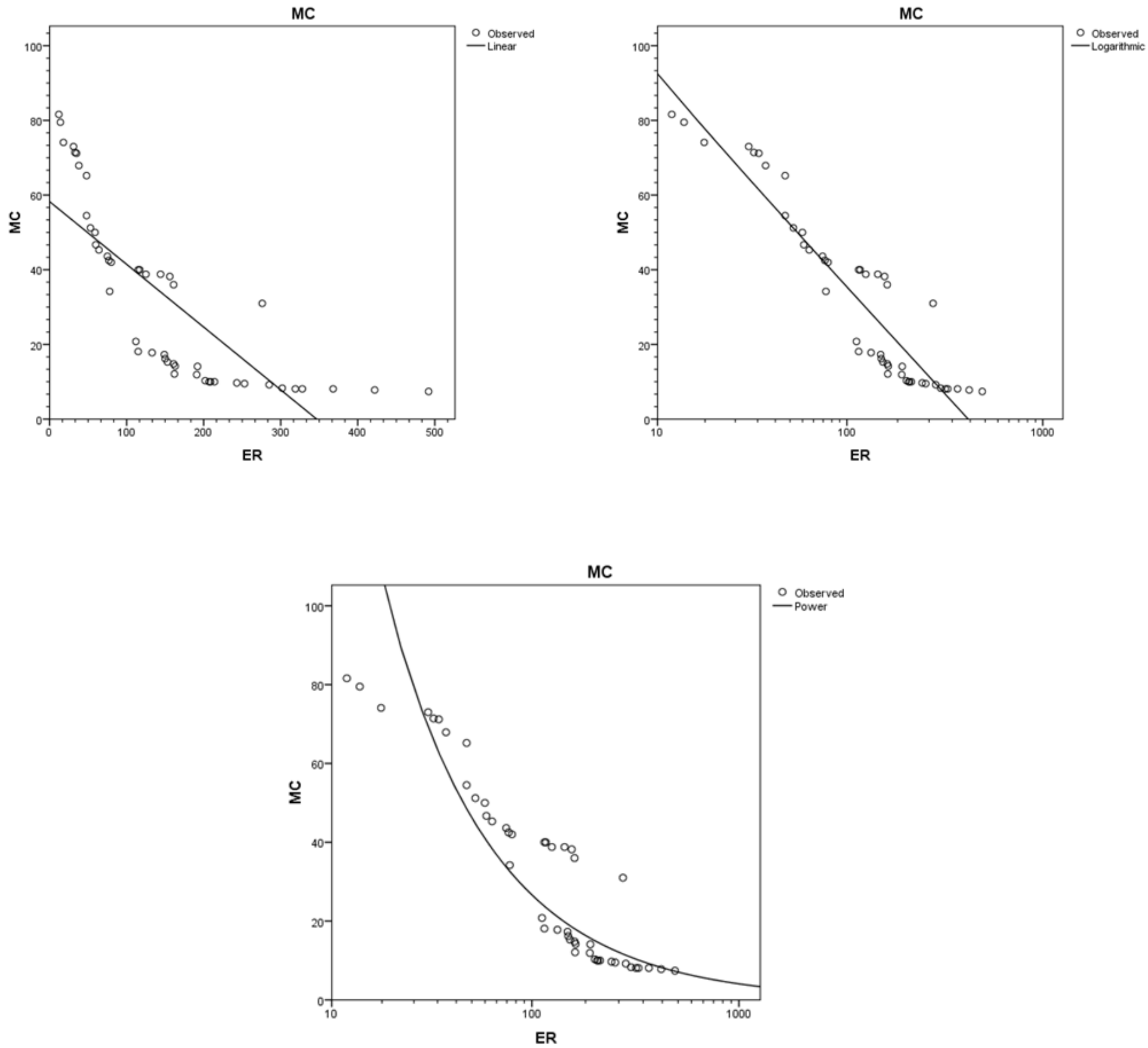


Figure 8: Paired data correlation between laboratory determined Moisture Content and geophysically computed resistivity at same point within the soil; a) Linear, b) Logarithmic and c) Power regression curves

4.2.1.2 Conductivity Vs ER

Similar pattern to that of relationship described between MC and ER above is observed in the case of laboratory determined conductivity and field data of electrical resistivity from the geophysical survey. The conductivity of soil is the inverse of its resistivity, however, the existing relationship is not a direct inverse relationship, but depends on other factors as described by Diarchy's relationship. Other factors are the soil matrix, sorting, fluid content and cementation (or compaction) factors among several others. As shown in Table 15, the ANOVA test shows that the variation in the means of the data set is also significant different from zero at 0.5 probability level ($p < 0.05$ 2 tailed), thus there is correlation between the data sets. For the humus soil used, the best derived relationship between the laboratory determined conductivity and in-situ electrical resistivity from the geophysical survey assumed power (exponential) regression model in a very strong relationship with degree of correlation, R of 0.90 against 0.60 and o.62 for the linear and quadratic models depict moderately strong relationship (Fig. 9).

Table 15: Paired Parameter Regression Correlation between Laboratory determined Conductivity and geophysically derived Electrical Resistivity

Regression Model		ANOVA					Model Summary			Model Equation $Y = Mx + C + \xi$
Linear		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	\`106806.315	1	106806.315	25.810	0.000	0.600	0.359	64.328	
	Residual	190354.352	46	4138.138						$\sigma = -(0.4287 \pm 0.084)\rho + (346.1369 \pm 16.04)$
	Total	297160.667	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	-0.429	0.084	-0.600	-5.080	0.000				
	(Constant)	346.137	16.044		21.575	0.000				
Quadratic		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	113275.594	2	56637.797	13.860	0.000	0.617	0.381	63.924	$\sigma = (367.2710 \pm 23.16) - (00.7374 \pm 0.26)\rho + (0.00074 \pm 0.001)\rho^2$
	Residual	183885.073	45	4086.335						
	Total	297160.667	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	-0.737	0.259	-1.031	-2.844	0.007				
	ER^2	0.001	0.001	0.456	1.258	0.215				
	(Constant)	367.271	23.158		15.859	0.000				
Power		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	24.384	1	24.384	186.117	0.000	0.895	0.802	0.362	
	Residual	6.027	46	0.131						$\sigma = (1141.13 \pm 328.51)\rho$
	Total	30.410	47							
		Unstandardized		Standardized						

		Coefficients		Coefficients						(-0.8158 ± 0.060)
		M	Std. Error, ξ	Beta	t	Sig.				
	Ln(ER)	-0.816	0.060	-0.895	-13.642	0.000				
	(Constant)	1141.132	328.513		3.474	0.001				

σ = conductivity, ρ = resistivity

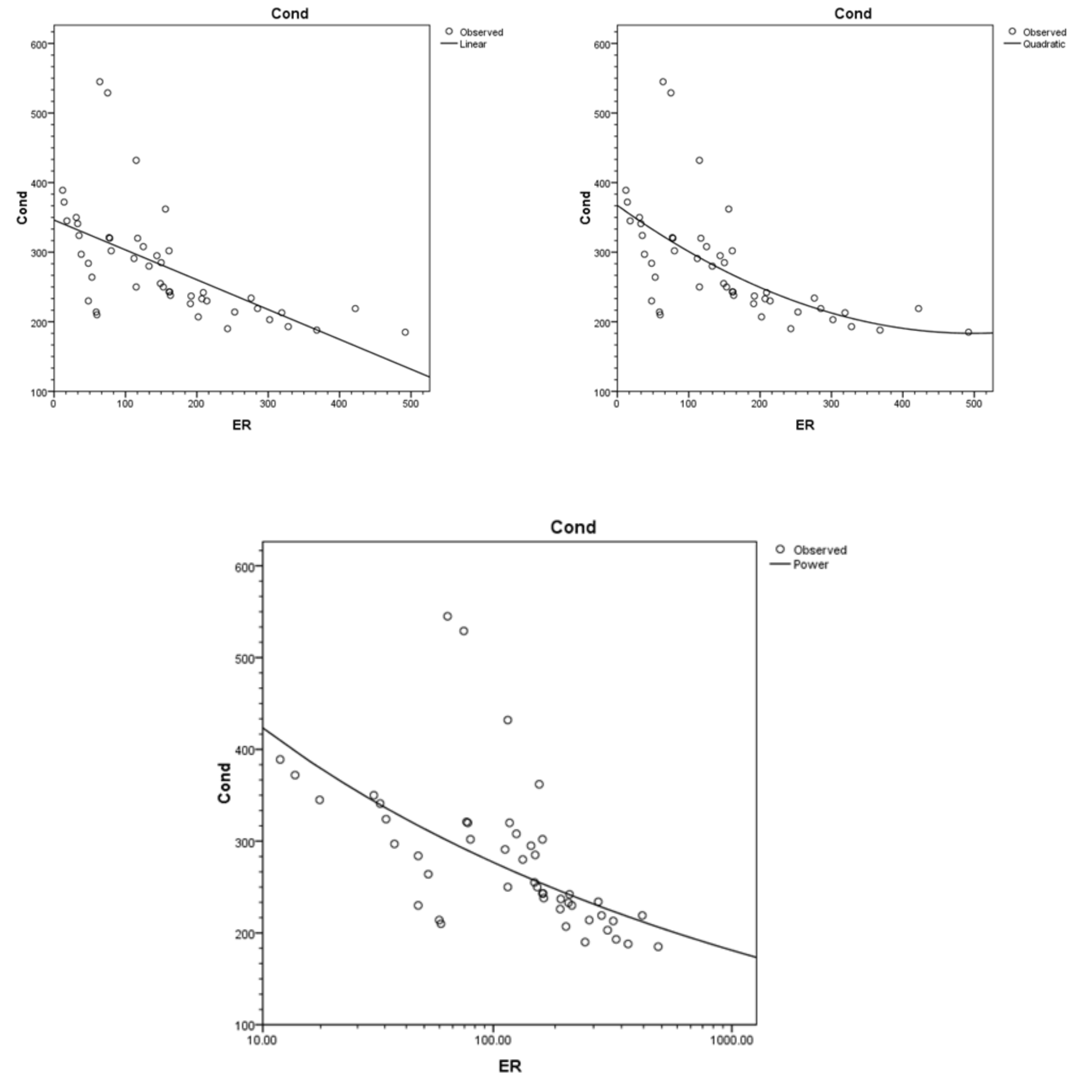


Fig. 9: Paired data correlation between laboratory determined conductivity and geophysically computed resistivity at same point within the soil; a) Linear, b) Quadratic and c) Power regression curves

4.2.1.3 Soil Salinity Vs ER

The ANOVA test on the relationship between the paired soil salinity and electrical resistivity data shows lack of good relationship with degree of correlation ranging from 0.361 – 0.404 for a linear model and power (exponential) models (Table 16). The degree of correlations depict that the relationship between soil salinity, which is a measure of salt contents of the humus soil used and electrical resistivity is more complex in this case. The regression models show a generally fear relationship between salt content (salinity) and resistivity arising from chedmical composition of the applied salt. However, increase in salinity is observed with decrease in electrical resistivity as expected, since application of organic manure increases the salinity from the compositions of the organic manure applied to the soil in blocks 3 and 4. Though the correlation between the two data sets is significant different from zero at $p < 0.05$, there is fairly linear relationship, and the exponential relationship model presents the best relationship between the soil salinity and geophysically derived electrical resistivity as shown in Fig. 10.

Table 16: Paired Parameter Regression Correlation between Laboratory determined Soil Salinity and geophysically derived Electrical Resistivity

Regression Model		ANOVA					Model Summary			Model Equation $Y = Mx + C + \xi$
Linear		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	875151.705	1	875151.705	6.914	0.012	0.361	0.131	355.764	
	Residual	5822129.234	46	126568.027						
	Total	6697280.939	47							$SS = (668.4740 \pm 88.73) - (1.227 \pm 0.47)\rho$
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	- 1.227	0.467	- 0.361	- 2.630	0.012				
	(Constant)	668.474	88.728		- 2.630	0.000				
Quadratic		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	887414.788	2	443707.394	3.437	0.041	0.364	0.133	359.316	
	Residual	5809866.151	45	129108.137						
	Total	6697280.939	47							
		Unstandardized Coefficients		Standardized Coefficients						$SS = (697.5720 \pm 130.17) - (1.652 \pm 1.46)\rho + (0.001 \pm 0.003)\rho^2$
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	- 1.652	1.457	-0.487	- 1.134	0.263				
	ER^2	0.001	0.003	0.132	0.308	0.759				
	(Constant)	697.572	130.171		5.359	0.000				
Power		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	3.154	1	3.154	8.983	0.004	0.404	0.163	0.593	
	Residual	16.151	46	0.351						
	Total	19.305	47							
		Unstandardized Coefficients		Standardized Coefficients						$SS = (1535.732 \pm 723.76)\rho^{-(0.293 \pm 0.098)}$
		M	Std. Error, ξ	Beta	t	Sig.				
	Ln(ER)	-0.293	0.098	-0.404	- 2.997	0.004				
	(Constant)	1535.732	723.762		2.122	0.039				

SS = Soil Salinity, ρ = resistivity

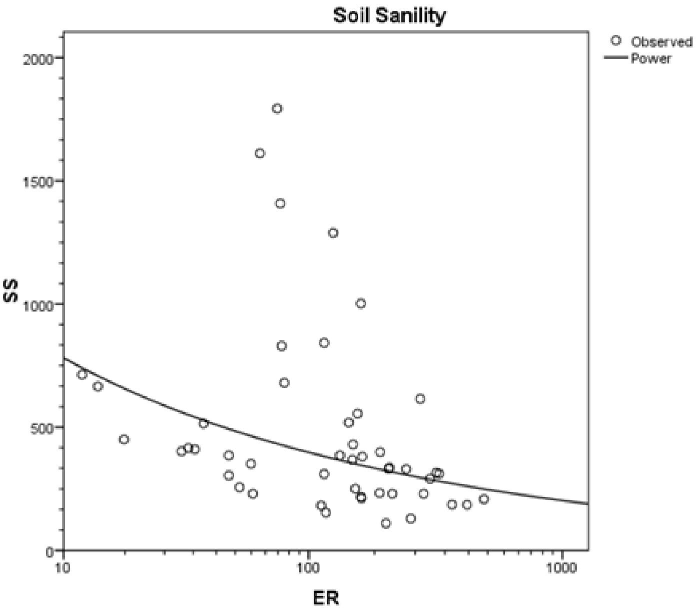


Figure 8: Paired data correlation between laboratory determined Soil Salinity and geophysically computed resistivity at same point within the soil; a) Linear, b) Quadratic and c) Power regression curves

4.2.1.4 pH Vs ER

The modelled relationship between the pH of the soil and the electrical resistivity (Table 17) shows positive slope, i.e., increase in the pH corresponds to increase in the electrical resistivity. In Fig. 11 the quadratic equation assumes the best regression model for the relationship with R = 0.745, while the logarithmic and linear models have R = 0.71 and 0.69 respectively, a good relationship. However, the logarithmic model appears to describe the best trend in the existing relationship, using the appropriate scale and units of measurements. The regression curves shows the impact of seasonal variation in the pH data, with the soil saturation resulting in the pH values between 7.5 and 8.1 for the wet soil and between 8.6 – 9.4 for the dry soil.

Table 17: Paired Parameter Regression Correlation between Laboratory determined pH and geophysically derived Electrical Resistivity

Regression Model		ANOVA					Model Summary			Model Equation Y = Mx + C + ξ
Linear		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	11.031	1	11.031	42.187	0.000	0.692	0.478	0.511	pH = (0.004 ± 0.001) - (7.810 ± 0.13)ρ
	Residual	12.028	46	0.261						
	Total	23.060	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std.	Beta	t	Sig.				

			Error, ξ							
	ER	0.004	0.001	0.692	6.495	0.000				
	(Constant)	7.810	0.128		61.238	0.000				
Quadratic		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	12.783	2	6.391	27.987	0.000	0.745	0.535	0.478	pH = (7.462 ± 0.17) - (0.009 ± 0.002)ρ - (0.000012) ρ^2
	Residual	10.2777	45	0.228						
	Total	23.060	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	ER	0.009	0.002	1.498	4.869	0.000				
	ER^2	$1.216X10^{-5}$	0.000	-0.835	-2.769	0.008				
	(Constant)	7.462	0.173		43.103	0.000				
Logarithmic		Sum of Squares	df	Mean Square	F	Sig	R	R^2	Std. Error of the Estimate	
	Regression	11.609	1	11.609	46.638	0.000	0.710	0.503	0.000	pH = (5.820 ± 0.40) - (0.563 ± 0.08) ln(ρ)
	Residual	11.451	46	0.249						
	Total	23.6060	47							
		Unstandardized Coefficients		Standardized Coefficients						
		M	Std. Error, ξ	Beta	t	Sig.				
	Ln(ER)	0.563	0.082	0.710	6.829	0.000				
	(Constant)	5.820	0.397		14.668	0.000				

pH = Hydrogen Index, ρ = resistivity

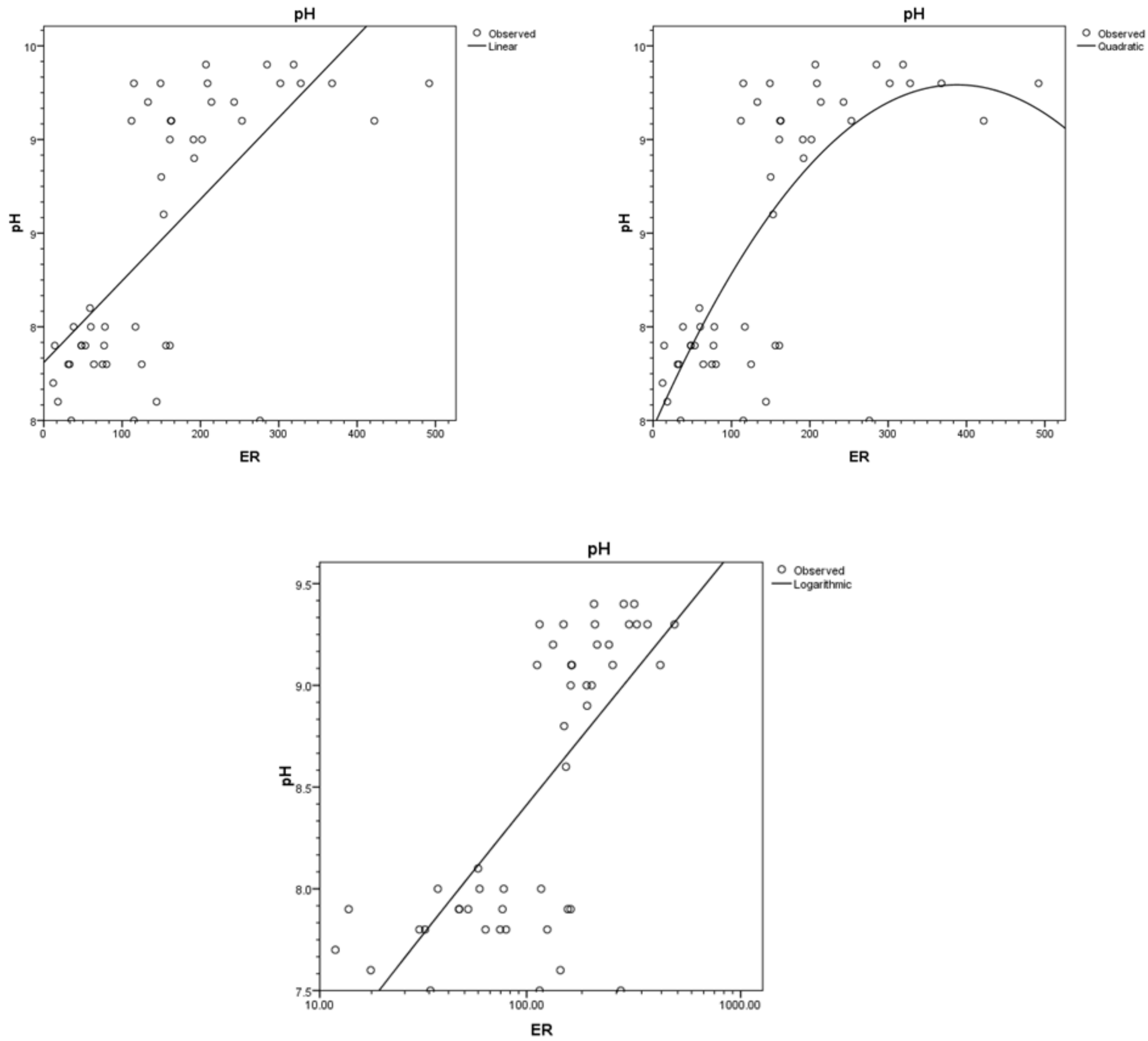


Figure 9: Paired data correlation between laboratory determined pH and geophysically computed resistivity at same point within the soil; a) Linear, b) Quadratic and c) logarithmic regression curves

4.2.1.5 Crop Yield Analysis

It was observed from the result that plants with highest vine length were mostly recorded on box 3 and 4, depicting the influence of the poultry manure with corresponding low resistivity values indicating that electrolytic activities increases within the block corresponding to others. The least length of vines was observed in the control boxes 5 and 6, where the rate of flow of water was moderated to drain the blocks (Tables 5 -7 & 18). The non-marketable fruits were insignificant and were not counted with the result presented in Tables. Significant differences were observed in the growth and yield parameters of the crop across the treatments except for fruit length with no statistical difference (Table 18). The analysis of Variance and mean separation of the parameters shows that the best plants and fruits were produced on plots with addition of poultry manure. It was observed that the manure significantly improved the soil conditions for crop establishment as well as released adequate nutrient elements for yield enhancement. This is in harmony with the reports of [24], [25], [26], and [27], which indicated that higher rates of manure increases crop yield.

Table 18: Number of fruits per plant and ANOVA Test for the Yield.

	NUMBER OF FRUITS PER PLANT									
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10
TR1 (Box 1)	4	3	4	3	2	2	4	3	4	3
TR2 (Box 2)	4	4	4	3	5	3	3	2	4	4
TR3 (Box 3)	4	4	5	5	4	4	3	4	3	3
TR4 (Box 4)	5	4	5	4	5	4	3	3	4	3
TR5 (Box 5)	3	3	3	2	3	2	3	2	2	2
TR6 (Box 6)	2	3	3	2	2	2	4	3	3	2

Treatment	Vine length (cm)			Number of Fruits	Fruit Length (cm)	Fruit Diameter (cm)
	2WAP	3WAP	4WAP			
T1	21.97bc	60.73c	105.21c	3.20ab	15.13a	3.49ab
T2	21.11cd	61.29bc	100.75c	3.60a	14.86a	3.50ab
T3	23.14b	64.30a	112.34b	3.90a	15.60a	3.62a
T4	25.37a	63.62ab	118.39a	4.00a	15.72a	3.61ab
T5	20.11d	59.00c	93.79d	2.50b	14.84a	3.41ab
T6	20.52cd	59.17c	93.01d	2.60b	14.99a	3.339b

ANOVA	Vine length 2WAP	Vine length 3WAP	Vine length 4WAP	Number of Fruits	Fruit Length	Fruit Diameter
TRT	38.41	49.04	1027.27	4.16	1.44	0.09
Error	1.44	3.99	16.73	0.55	1.71	0.03
P-value	0.00	0.00	0.00	0.00	0.52	0.02

V. Conclusion

This study has demonstrated that geophysical applications can enhance agricultural practices and reduce cost by providing a fast and cost effective means of monitoring soil properties for high yields. Generally, it was observed that there is significant correlation between the in-situ resistivity of the soil and laboratory determined soil properties that allow the geophysical resistivity survey provided a quick and affordable means of monitoring the soil properties. These properties in turn have significant roles in improving crop yield. Since measurement of in-situ electrical resistivity provide direct imaging of the water content of the soil as well as tomographic display of distribution of properties that revealed the nutrient in the soil. The approach to this research involved measurement of time lag electrical resistivity on the experimental blocks, continuous evaluation of the soil properties from the control sample points through laboratory test, monitoring of the growth and yield rate of the crop plants within the blocks and monitoring of the agro-meteorological data (rain fall and soil temperature) within the study area. The geophysically acquired in-situ electrical resistivity data provides subsurface resistivity imaging that can be deployed in effective mapping and assessment of the spatial variability of soil-water dynamics in the farm land for precision agricultures. It provides spatial information for use in site-specific soil and crop management. The observed low resistivity could be attributed to the increase in salinity in the soil as well as increasing moisture content in the soil. In addition, presence of organic matter applied as treatment to selected plots improves electrolytic actions within the soil and thereby also reduced the resistivity of the soil further. Electrical resistivity thus provides a direct approach to monitoring water content in the soil and a viable means of characterising some soil properties that influence agricultural crop yield. The degree of reliability of the subsoil characterisation can be achieved using the resistivity techniques as well as other geophysical methods such as induced polarization and ground penetrating radar and which are equally sensitive to these parameters.

REFERENCES

[1] FAO, The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. FAO, IFAD, UNICEF, WFP and WHO. Rome, FAO, 2017.

[2] D.S. Eyinla and A. Oladunjoye, Improving Quality Agricultural Practices in Tropical Environments through Integrated Geophysical Methods, *IOSR Journal of Applied Geology and Geophysics, 2(5)*, 2014, 28-139.

[3] D. L. Corwin, Past, Present, and Future Trends of Soil Electrical Conductivity Measurement Using Geophysical Methods, in B. J. Allred, J.J. Daniels, and M. R. Ehsani (Ed), *Handbook of Agricultural Geophysics*, (New York: CRC Press, Taylor & Francis, 2008), 17- 44.

[4] D. R. Cameron, E. de Jong, D.W.L. Read, and M. Oosterveld, Mapping salinity using resistivity and electromagnetic inductive techniques, *Canadian Journal of Sciences, 61(66)*, 1981,

[5] S.M. Lesch, J.D. Rhoades, L.J. Lund, and D.L. Corwin, Mapping soil salinity using calibrated electromagnetic measurements, *Soil sci. Soc. Am. J.*, 1992, 540-548.

[6] J.D. Rhoades, and D.L., Corwin, Determining soil electrical conductivity – Depth relations using an inductive electromagnetic soil conductivity meter, *Soil Sci Am. J, 45*, 1981, :225-260

[7] R.G. Kachanoski, E.G. Gregorich, and I.J. Van-Wesenbeeck, Estimating spatial variation of soil water content using non contacting electromagnetic inductive methods, *Can, J. Soil Sci., 68*, 1988, 715-722.

[8] D.J. Drommerhausen. D.E. Radcliffe, D.E. Brune, and H.D. Gunter, Electromagnetic methods to map contaminant migration, *Ground Water Monitoring Rev. 3(2)*, 1995, 47-59.

[9] J.P. Greenhouse, and D.D. Slaine, The use of reconnaissance electromagnetic methods to map contaminant migration, *Ground Water Monitoring Rev. 3(2)*, 1983, 47-59.

[10] B.G. Williams, and D. Hoey, The use of electromagnetic induction to detect the spatial variability of the salt and clay contents of soils, *Aust. J. Soil Res., 25*,1987, 21–27, 1987.

[11] R.A. McBride, A.M. Gordon, and S.C. Shrive, Estimating forest soil quality from terrain measurement of apparent electrical conductivity, *Soil Sci. Soc. Am. J., 54*, 1990, 290-293.

[12] J.A. Doolittle, K. A. Sudduth, N. R. Kitchen, and S. J. Indorante, Estimating depths to clay pans using electromagnetic induction methods. *J. Soil and Water Cons.,49*, 1994, 572–575.

[13] P.G. Slavich, and J. Yang, Estimation of field scale leaching rates from chloride mass balance and electromagnetic induction measurements, *Irrig. Sci 11*, 1990, 7-14.

[14] P.G. Cook, G.R. Walker, G. Buselli, I. Potts, and A.R. Dodds, The application of electromagnetic techniques to groundwater recharge investigations, *J. Hydrol., 130*, 1992, 201-229.

[15] P.G. Cook, G.R. Walker, G. Buselli, I. Potts, and A.R. Dodds, The application of electromagnetic techniques to groundwater recharge investigations, *J. Hydrol., 130*, 1992, 201–229.

[16] D.B. Jaynes, J.M. Novak, T.B. Moorman, and C.A. Cambardella, Estimating herbicide partition coefficients from electromagnetic induction measurements, *J. Environ Qual., 24*, 1995, 36-41.

[17] B.J. Allred, M.R, Ehsani, and D, Saraswat, The impact of temperature and shallow hydrologic conditions on the magnitude and spatial pattern consistency of electromagnetic induction measured soil electrical conductivity, *Trans. ASAE, 48*, 2005, 2123-2135.

[18] D.L. Corwin, and S.M. Lesch, Application of soil electrical conductivity to precision agriculture: Theory, principles, and guidelines, *Agron. J., 95*, 2003, 455–471.

[19] O.A. Ademeso,Field and petrographic relationships between the charnockitic and associated granitic rock, Akure Area, Southwestern Nigeria, *Int. J. Environ. Ecol. Geol. Mining Eng., 4*, 2010, 49–53

[20] G.M. Olayanju, and O. Ojo, Magnetic Characterization of Rocks Underlying FUTA Campus, Southwestern Nigeria‖, *Journal of Environment and Earth sciences, 5(14)*, 2015, 113-127.

[21] T. Colton, Statistics in medicine (Little Brown and Company, New York, NY, 1974)

[22] C.K. Johnson, K.M. Eskridge, and D.L. Corwin, D.L., Apparent soil electrical conductivity: Application for designing and evaluating field-scale experiments, *Comput, Electron. Agric., 46*, 2005, 181-202.

[23] J. Doolittle, M. Petersen, and T. Wheeler. 2001. Comparison of two electromagnetic induction tools in salinity appraisals, *J. Soil and Water Cons., 56*, 2001, 257–262

[24] L. Aliyu L, The effects of organic and mineral fertilizer on growth, yield and composition of pepper (Capsicum annum L.), *Biol. Agric Hort. !8*, 2000, 29-36.

[25] A.O. Adekayi and S.O. Ojeniyi, Evaluation of tomato growth and soil properties under methods of seedling bed preparation in an Alfisol in the rainforest zone of southwest Nigeria, *Bioresource Technol., 96*, 2002, 509-516.

[26] E. Mangila, F.P. Tabiliran, M.R.AS. Naguit, and R. Malate, Effects of Organic Fertilizer on the Yield of Watermelon, *Threshold, 2, January-December*, 2007, 27-35.

[27] T.M. Agbede, S.O. Ojeniyi, and A.J., Adeyemo, Effect of Poultry Manure on Soil physical and chemical properties, growth and grain yield of sorghum in Southwest, *Nigeril, AM. – Eurasian J. Sustain. Agric 2(1),* 2008, 72-77.

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