Application of Electro- Geophysical and laboratary methods in soil quality assessment for lowland rice production in Obubra local government area, cross river state

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Abstract

Maintenance and monitoring of soil fertility is a key issue for sustainable lowland soil management. Vital ecosystem processes may be affected by management practices that change the physical, chemical, and biological properties of the soil. This study used Electrical resistivity (ER) as a nondestructive nor non-invasive method to rapidly determine lowland soil properties in the field. The study explored the correlation between ER and lowland soil properties on twenty plots of rice paddies soil in Obubra. ER measurements were used to determine soil-sampling locations and samples were analyzed in the laboratory for pH, EC, organic matter content (OM), Total Nitrogen (TN), Available phosphorus, Ca, Mg, K, Al^3, H, ECEC, BS, Mn, Fe, Sand, Silt, Clay, Bulk density (BD) and texture. Even though the magnitude of correlation was modest, we were able to assess variation in soil properties, having chemically analyzed the sample, which is confirmatory to ER results. The sampling design based on an ER survey allowed us to map basic soil properties with a small number of samples. The result showed that there is a strong positive correlation between Electrical Resistivity and soil properties as R^2 = 0.775 and the Correlation between ER and individual soil properties are ECEC (0.69), Ca (0.66), Mg (0.64), clay (0.64), Zn (0.59), Bs (0.53), H (0.4) and Organic Matter (0.46), while Total Nitrogen (TN) (0.25), Available Phosphorus (AP) (0.39), Na (0.30), K (0.26), Al (0.30), Mn (0.30), Cu (0.04), Silt (0.08) and pH (-0.13), Mn (0.30), Cu (0.04), Silt (0.08) and BD (0.17) were weakly correlated with ER. Negative correlation existed between ER and pH (-0.13), EC (-0.06), Fe (-0.12) and sand (0.67). Juxtaposing the Electrical resistivity and statistical results with that of the analyzed samples, it is obvious from the ER sections that the soils are made up of sand, clay, and shale which are sources of the physicochemical parameters obtained from the laboratory analysis.

Keywords: Electrical Resistivity, physicochemical properties, lowland soil, Rice production.

Introduction

As the quest to diversify the Nigeria economy increases so as to reduce the dependence on oil revenue, Agriculture becomes one of the viable alternatives for the diversification. This can be observed from the growing agricultural programmes for the states and federal government, a recent policy trust implemented through one of federal Government Agencies (FADAMA) is the emphasis on Cassava and Rice production. This is because this two crops have been identified as a major source of stable food for the populace and such it importation, especially rice has been on the increase from the Asian countries. But looking back home it is a known fact that Nigerians have had a long contact with the growing of rice although mostly at subsistence scale, it is therefore not new to build the capacity to improve rice production, among the capacities to be built includes soil quality assessment and management, this is because from a preliminary assessment of the local farmers outputs, it is obvious that the soil fertility is far declining. It therefore becomes pertinent to develop criteria and indicators for the assessment of soil fertility's for sustainable rice production (Shoenholtz et. al., 2000; Agbor et. al. 2013; Ekpo et. al. 2013; Osang et. al. 2017 and Uquetan et. al.2017).

Maintenance of soil fertility is an essential component in the protection of soil resources. Fertility encompasses a range of soil properties: physical (compaction and erosion), chemical (biodiversity and biological activity) (Doelman & Eijsackers, 1998; Shoenholtz et al., 2000). Thus the fertility of the soil play a critical role in food production, climate regulation and maintenance of biodiversity. Studies have shown that it is a critical component in many environmental and economic issues in any nation. The proper management of the soil fertility determines the balance between environmental and economic viability of any nation. (Sanchez, 2002; Filip, 2002; Pekene et. al. 2015; Fixen, 2005; Osang et. al. 2013, 2016; Uzoho et al., 2007 and Egor et. al. 2017).

Soil quality is a concept developed to characterize the usefulness and productivity of soils (Lindert, 1996; Sanchez, 2002; Struif Bontkes & Van Keulen, 2003; Nortchiff, 2003). Soil quality is the capacity or fitness of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem (Larson & Pierce, 1991; Lar, 1993; Doran & Parkin,; Udoimuk et. al. 2014; Ushie et. al. 2014; Gregorich et al., 1994; Ewona et. al. 2014 and Andrew et al., 2004). Soil quality has emerged as a unifying concept to address the large issues of sustainability of ecosystem, and provides a near precise basis for evaluating the different options which land can be used, it affords government, agricultural organizations, farmers and individuals the opportunity to optimally allocate land for different purposes like conservation programmes, crop production and plantation agriculture (1996; Karlen et al., 2001; Ushie et. al. 2014; Uquetan et. al. 2016 & 2017).

Soil quality can be changed by the level of crop production without replenishing biocontamination and unsustainable farming practices, in such scenarios are used, the land becomes degraded and this has serious implications on the soil fertility. The remediation of the quality of most soils by improving the fertility is of utmost importance to the agricultural subsectors and the numerous stakeholders as this will lead to increase production with minimal loses occasioned by poor yield which hitherto has been due to poor soil quality (Uquetan et. al. 2016; Ewona et. al. 2013 and Egor et. al. 20116).

Rice farming is one of the largest simple landuse types for producing food in Asia and sub-Saharan Africa (Yoshida, 1981; IRRI, 2003; WARDA, 2008). Rice is an important crop to the Obubra people because it has become a major food source as well as a source of income, its availability enhances food security within the area, the state and the country at large (Akande, 2003; Olaf et al., 2003; Obi et. al. 2017; Adeosun et al, 2005).

Rice yield in the area under study have been on the decline over the years, efforts by local farmers to improve the yield by using the traditional methods of shifting cultivation is not paying off due to the growing population which hardly allow the soil enough time to regain its fertility. On the basis of this declining soil fertility, this paper is to unravel the causes of this decline by the application of quick, easy statistically relevant, non destructive sampling methods and electrical resistivity method to assess the properties of the soil that might be responsible for the declining fertility of the Obubra soils. The electrical resistivity is used in this work as a tool for the assessment. This is because there is a relationship between electrical resistivity and soil properties as reported by Friedmand (2005), Samouelian et al., (2005), Corwin & Lesch, (2005a). Roade et al (1999) reported a correlation between many soil properties and electrical resistivity like; salinity and nutrients, water content and preferential direction of water flow (Michot et al., 2003; Ewona et.al. 2016). Texture related properties like sand, clay, depth to clay pans or sand layers (Corwin et al, 2003), bulk density (Corwin & Lesch, 2005c) and other indirectly measured soil properties like organic matter (Fedotove et al., 2005).

The use of the soil resistivity makes it possible to measure, mapped out, assess and monitor soil properties without muchdestruction on the soil ecosystem and without intensive sampling (Tabbagh et al, 2000; Osang et. al. 2013), hence the electrical resistivity method us justified as a tool for assessment and monitoring soil fertility (Conwin et al, 2006, Ettema & Wartle, 2002 stein & Ettema, 2003; Ojar et. al. 2014; Obi et. al. 2013, 2016).

Location and geology of the study area

The study area is Obubra Local Government Area of Cross River State, Nigeria. The area is bounded in the North by Ikom and Yala Local Government Areas, to the East by Akamkpa Local Government and to the West by Ebonyi State. The area lies between longitude $8^0 15'$ and $8^0 20'$E and latitude $5^0 59'$ and $6^0 15'$N of the equator. It occupies a total land area of 1086.2227km^2 (see **Fig. 1**).

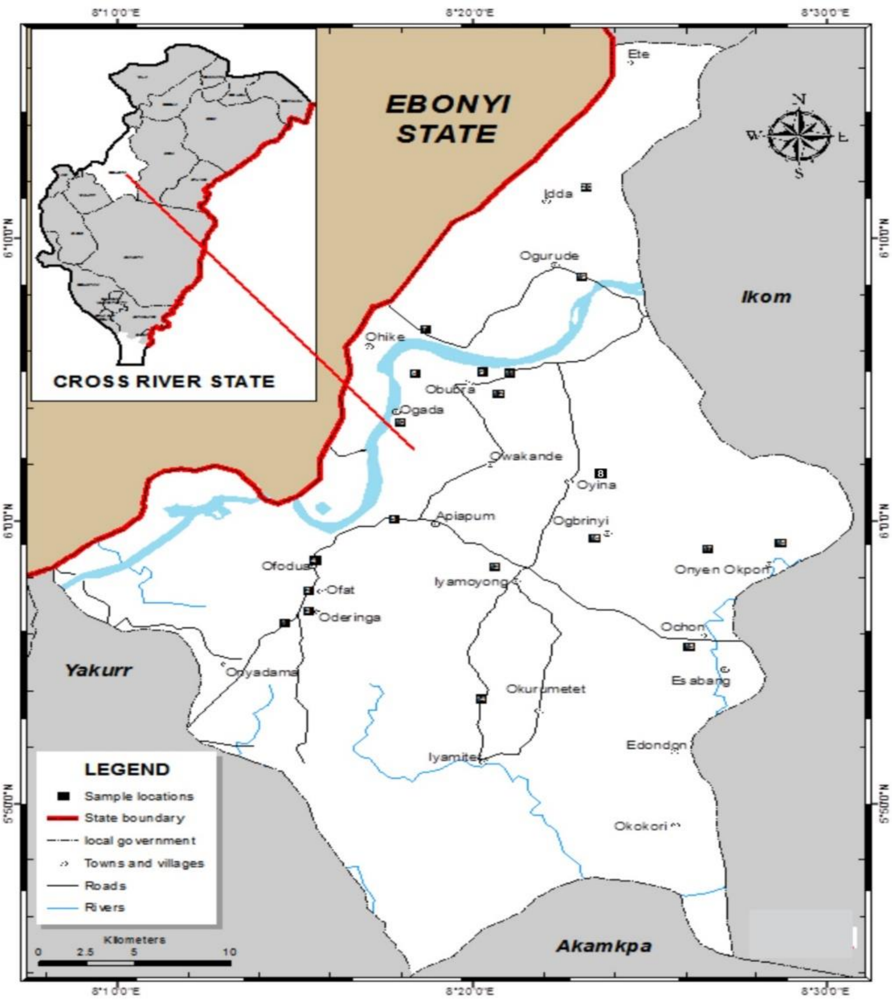


Fig 1: Map of Obubra Local Government Area showing study locations.

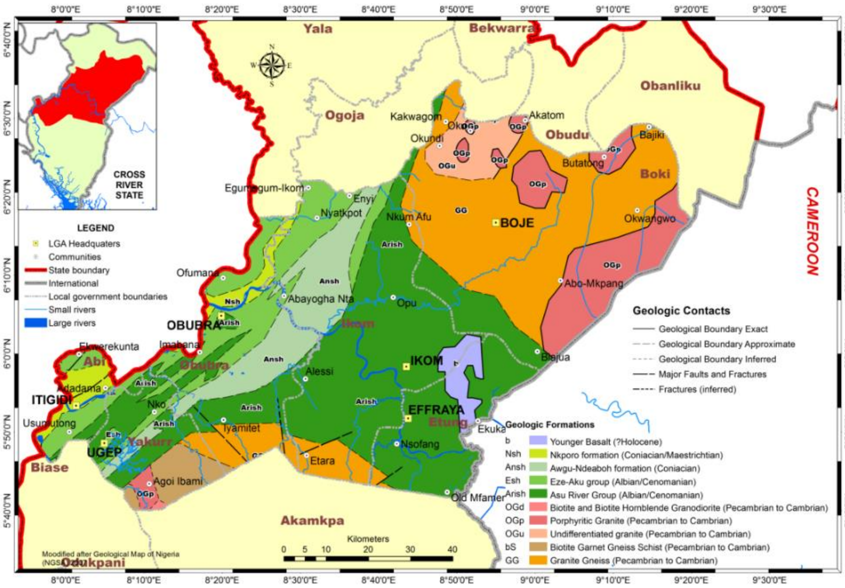
The area has a tropical humid climate, the rainfall patterns are double maxima with peaks in June and October. It has an annual rainfall range of 2000 to 22000mm. the rainy season lasts for 8 months between April to October while the dry season starts in November and ends in March lasting for four months (Akpan-Idiok & Antigha, 2006). Rainfall is the major source of water for all the streams and rivers of the area, seasonal flooding of paddy fields is a common phenomenon year after year

The mean annual temperature ranges from 26.0^{O}C to 35.0^{O}C with some months recording temperature as low as 24.^{O}C as observed during field investigation. The recorded relative humidity is between 60 to 70 percent for the months of January to July and 75.90 to 83.0 percent for the months of November to March. The wind speed ranges from 11.42 to 29.33 knots at the beginning and at the end of the rainy season.

Atmospheric pressure recorded a mean value of 747.3mmHg (Eshett, 1985; CRADP, 1992; Amalu, Esu & Nwulu, 2001). The peak of the dry season is between December and March while the coldest month is August. The dry season is the period of harvest while the rainy season is the season of farming (planning of crops).

Geologically the study area is part of the geological entity called Ikom-mamfe embayment. This entity is made up of Precambrian basement rocks which area overlain by three major cretaceous lithostratigraphic units comprising the Asu River Group (ARG), Eze Aku Group (EAG) and the Post-Samtonian Nkporo-Afikpo shale formation (NASF). The Albian ARG is the oldest sedimentary rocks in the study area. They are basically non-marine to marginal marine in character. The sediments within the ARG consists of impervious shales, limestones with some sandstone intercalations and ammonites (NGSA, 2006; Odigi and Amajor, 2007) Obianu, Egbor & Okiwelu, 2015 (see fig 2)

Fig. 2: Geological map of the study area



Source: Modified after Geological Map of Nigeria – NGSA, (2006).

Materials and method

The method of data acquisition was in two phases, the first phase involves the use of Electrical resistivity tomography (ERT) or resistivity imaging and vertical electrical sounding (VES) method. The VES was carried out using the Schlumberger array and 2-D ERT was executed with Wenner array.

The vertical electrical sounding was executed using the Schlumberger array to obtain information about the vertical variation in resistivity of subsurface in 20 VES points, minimum current electrode spread at all the stations was 2m while lack of space and the depth of interest seriously constrained the maximum current electrode to vary from 120m to 200m. The potential electrodes were kept fixed while the current electrode spacing was expanded symmetrically about the centre of the spread.

Following the limitation of the electrical resistivity sounding to take into account horizontal changes in the subsurface resistivity, electrical resistivity tomography using wenner array was applied to complement VES procedure. To ensure that a good quality data was generated, measurements in the field were carried out in a systematic manner so that, as far as possible, all the necessary measurements are made, for the first measurement, the first current electrode along the profile was designated as C_1, the second electrode was designated as the first potential electrode P_2 while the fourth along the profile was designated as second current C_2, switching between the electrode and different electrode separations was manually performed. For the second round of measurement, electrode 2, 3, 4 and 5 are used for C_1, P_1, P_2 and C2 respectively. This was repeated to the end of the profile line until the last sets of electrodes are used. After completing the first sequence of measurement where "a" has a minimum of 3m, the second sequence of measurement with electrode separation of 2a was performed. The separation was later increased to 3a, 4a, …, *n*a where *n* was equal to eleven (11). In all the rounds of measurements, the original position of C_1 was always preserved. It was observed that as the spacing between C_1, P_1 and C_2 increases, the number of measurements from the preceding ones decreases three (**Fig. 3)**.

In all, three ERTs with profile lengths of 102m for ERT1 and 100m for ERT2 and ERT3 were carried out. The lengths were dependent on the length of the rice plots. The IGIS resistivity meter was used in acquiring the VES data while the ABEM Terrameter SAS 100 was used for ERT data acquisition. All distances were measured using measuring tapes. A portable Garmin made GPS map 76 model GPS was used in measuring the coordinates of the survey station.

The results obtained from ERT were interpreted as a resistivity sections and mapped Soil samples were collected using a stainless auger at each of the anger foonts measurements was carried out.

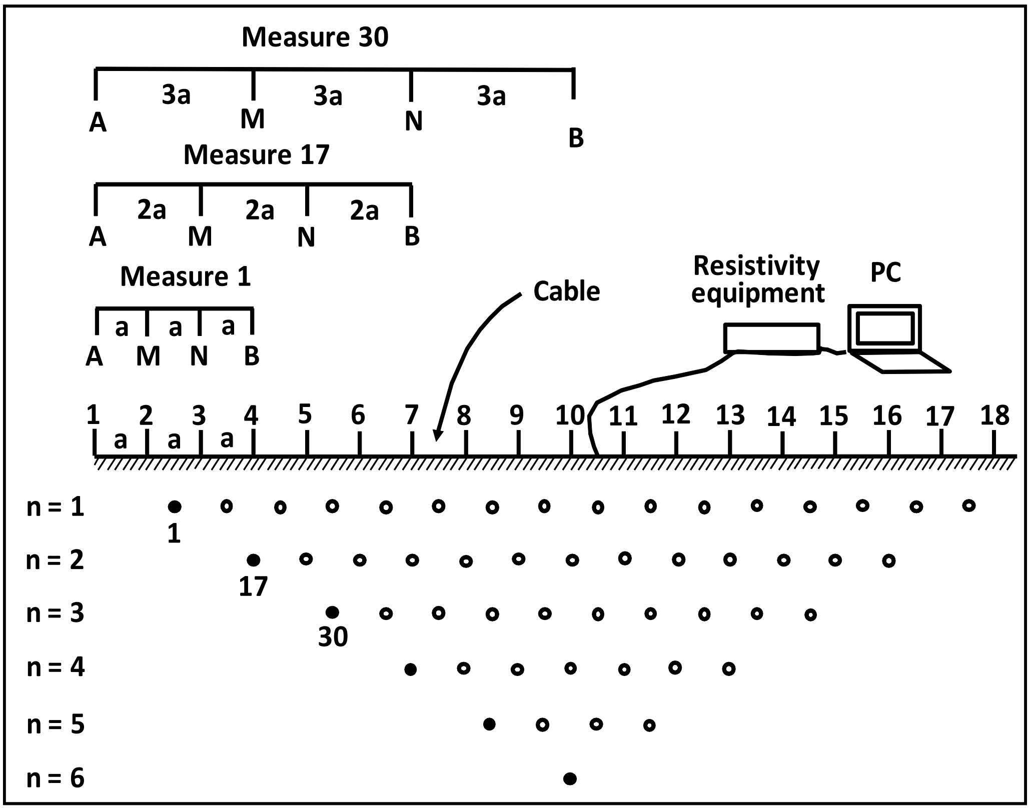


FIG 3: The Arrangement of Electrodes for a 2-D Electrical Survey and the Sequence of Measurements used.

At each auger point the following morphological features were recorded: soil texture, colour, drainage, structure, consistency, horizon boundary, relief and vegetation cover. The soil samples were taken to the laboratory for preliminary analysis of soil pH, available Nitrogen, Potassium, Phosphorus, exchangeable bases micro-nutrients being routine laboratory analytical procedures.

. Bulk density determination was done using the core method by Blake (1965). The bulk density rings containing the collected soils samples were weighted, oven dried to a constant weight at 105^{O}C for about 24 hours and later re-weighed and noted of the respective weights in grains. The bulk density was then calculated using the formulae:

$$B.D\left(\frac{g}{cm^3}\right) = \frac{\text{Weight of Oven} - \text{dry soils (g)}}{\text{Volume of Core } (cm^3)}$$

Morphological properties like soil colour was determined using Munsel soil colour chart, while soil structure and consistency was determined by noting the resistance of the aggregates when they are gently crushed. Chemical properties such as soil pH were determined potentiometrically with a glass electrode pH meter in water at 1:25 soil/water suspension (IITA, 1979). The electrical conductivity (EC) was determined using the conductivity meter model (WTWFL 90), organic matter was determined by Walkley and Blak dichromate oxidation method (Nelson & Sommers, 1982). Total nitrogen was determined by Macro Kjeldahl method as described by Bremmer & Mul Vaney (1982) Available phosphorus was determined by extraction with Bray P-1 extractant and phosphorus in the solution determined by the method of Reley and Murphy (1961). Micro-nutrients (Mn, Fc, Cu, Zn) copper and zine in the soil were extracted by the standard sodium carbonate fusion technique (Jackson, 1960, Black, 1965) and further determine using atomic absorption spectrometer (model 6405uv). Extraction of iron was determined following the methods described by Mckeaque and Day (1966) while easily reducible manganese was determined following methods described by Udo et al (2009).

RESULTS AND DISCUSSION

Textual characterization was carried out on the soil samples, the results revealed that soils across the study area are made up of sandy loam to sandy clay loam, these points to the fact that stand and shale are the probable parent materials thereby associating the soils to similar lithological origin (Obaje, Nzebuna, Moumouni & Ukaonu, 2005).

The textual characterization is corroborated by the findings made with Electrical Resistivity (ER), which captured some geoelectric layers eventually correlated with borehole lithology log as being composed of loose top soil, clay sandstone and shale.

The particle size distribution of the soils as shown in table 1. 11 indicated that sand fraction ranged from 24.80 to 56.70 percent, with a mean value of 40.10 percent. The dominance of sand in these soils reflects the nature of parent materials of the soils. Silt fraction ranged from 14.03, to 21.4 percent with a mean value 17.70 percent, clay fraction ranging from 22.57 to 42.33 percent with a mean value of 33.13 percent, this revealed a picture of low clay content on the surface horizons. This could be attributed to sorting of soil materials by biological and agricultural activities, clay migration and surface erosion (Ojanuga, 1975; Essoka, 2008). From the ERT resistivity section, a visual inspection revealed the presence of clay at depth, according to Idoga and Azugaku (2005), increase in clay with depth may be the result of illuviation processes as well as contributions of the underlying geology through weathering.

Silt/clay ratio ranged from 0.37 to 0.94 with a mean of 0.59, since the ratio is less than unity, it means low values, interpreted as low values with implications of high weather ability of the soils and pedogenisies (Essoka, 2008, Nwaka & Kwari, 2000). The results of this study showed that all the soils have silt/clay ratios above 0.37, which indicates high pedogenesis under intensive landuses.

Bulk density varies from 1.25 to 1.38gcm^{-3} with a mean of 1.31gcm^{-3}, the mean value is adjudged to be low and therefore favourable for agronomic use, because it implies root penetration, good aeration and infiltration (Uquetan, 2014, Essoka, 2008). Another reason for low values of bulk density in the study area could be due to crop intensification, high organic matter conversion ad increasing litter fall. The bulk density values indicated that the soils were not compacted and non-saline.

Soil chemical properties variations

Arising from the laboratory analysis of the soil samples, some soil chemical properties were analysed and presented in Table 1. The soil pH was slightly acidic, it varied from 4.98 to 5.75 and a mean value of 5.3. The acidic condition of the soil may be due to the dissociation of strongly acidic functional groups in the organic matter and the redox products of ferrolysis that is common is slowly permeable soils. Low pH of the soil might also be due to heavy leaching, heavy rainfall in the area, effect of cultivation (Esu, 2010), such conditions can induce phosphate fixation and reduce the ability of soil microorganisms to fix atmospheric nitrogen. (Uquetan, 2017).

Optimum pH for rice is about 6.0 to 6.6, at this values more nutrients are available for rice (Opeke, 2006; Lal, 1994). The average value of the pH realized in this work suggests that soil pH might not be favourable for rice farming because aluminum toxicity arising from soil acidity play a vital role in rice growth and gain yield.

Electrical conductivity (EC) varied between 0.11 to 0.67dsm^{-1} with a mean value of 0.31dsm^{-1}, the values are low and are within the allowable limits set by Food and Agricultural Organization (FAO, 1996; Mirase et al, (2000). Soil organic matter content varied from 0.52 to 1.89 percent, the percentage of soil organic matter is observed to be moderate, a situation that is attributed to the soil management practices like burning of rice paddies during the dry season, removal of crop residues, continuous and prolonged cultivation and level of soil puddling, also slow decomposition rate of litter phase under waterlogged conditions can also lead to the low values (Landon, 1991 NMSU, 2000). The implication of the low percentage of organic matter content is that the level of organic matter cannot sustain gainful rice farming for the period greater than five years, application of suitable fertilizer can be a solution for enhanced crop yield.

Total nitrogen varied between 0.14 to 0.6 percent with an average of 0.33 percent, the values were slightly moderate to high, there is significant variation, although moderate, it does not mean nitrogen sufficiency. The low response of the soil to Nitrogen fixation could be attributed to flooding, leading to rising water level, continuous cropping practices without measures to build up soil nutrient reserves (Enwezor et al., 1989; Lal, 1990; Okusami & Rust, 1992). Plant available Nitrogen (N) and Phosphorus (P) were low, the low total available nitrogen is associated with low organic matter content (Fisseha, 1992; Deckers et al., 2001), Eylachew (2001) blamed this on the characteristics of the soil on one hand and loss of N as a result of removal of excess water on the other hand. Furthermore, denitrification due to water logging is also implicated for loss of nitrogen.

Available Phosphorus (P) varied from 3.99 to 9.73mgkg^{-1} with a mean of 6.68mgkg^{-1}. The value is low when compared with the FAO standards, which puts P for productive tropical soils at 15mgkg^{-1} (FAO, 1976; FPDD, 1989). According to Bubba, Avias & Briix (2003) deficiency of P in tropical soils is as a result of intensive rainfall, high weatherability of the soils and absorption reaction. Low P availability causes stunted growth of rice plants, development of few tillers, narrow short dirty green leaves and delay ripening panicles which produce high percentage of empty grains (Bubb et al., 2003; Mukho-Padhyay et al., 2008).

Exchangeable bases (Ca, Mg, Na and K) showed variability across the study area. Ca varied between 2.6Cmolkg^{-1} to 5.4Cmolkg^{-1} with a mean of 3.83Cmolkg^{-1}. These values are slightly greater than the critical limit of 4.0Cmolkg^{-1} set by FAO (FAO, 1976; FPDD, 1989). From the comparison, it is clear that Ca cannot be a limiting factor to rice or any arable crop production in these soils because most of the calcium values are above the FAO critical value which is regarded as the lower limit of fertile soils (FAO, 1976; Kyuma et al., 1985). The content of exchangeable magnesium (Mg) ranged from 1.37 to 2.5Cmolkg^{-1} with an average value of 0.3-1.0Cmolkg^{-1} recommended by FAO (FAO, 1976, Landon, 1991). From the foregoing analysis, there is high predominance of calcium and magnesium in the soils under study. Sodium (Na) had values between 0.14 to 1.13Cmolkg^{-1} with a mean value of 0.66Cmolkg^{-1}. The concentration of sodium is below the critical value 0.1Cmolkg^{-1} (FAO, 1974). This is optimum as the soils will not develop sodicity problem and the sodium will not be harmful to plant roots and does not inhibit plant growth.

The content of exchangeable potassium (K) ranged between 0.18 to 0.31Cmolkg^{-1} with a mean value of 0.24Cmolkg^{-1}. Potassium is a key element in fertilization of rice. It is one of the cations lost in large quantities due to leaching. The concentration of K in all the soils in the study area is suitable enough for rice growth. The mean value was more than the critical values of 0.16 to 0.20Cmolkg^{-1} for different land uses in Nigeria as reported by Isirimah et al., (2003). The content of Aluminum was between 2.17 to 3.94Cmolkg^{-1} with a mean value of 2.83Cmolkg^{-1}. These values were below the critical value of 4.0Cmolkg^{-1}. (Holland et al., 1989; FAO, 1979; FPDD, 1989). Going by this analysis, Al may be injurious to rice crop as aluminum toxicity increases soil reaction and decreases the rate of microbial activities in the soil, which plays a major role in organic matter build up. Exchangeable Hydrogen (H^+) carried from 1.87 to 3.13Cmolkg^{-1} with a mean value of 2.51Cmolkg^{-1}. This concentration is not a limitation of rice production because of the change in soil nutrient chemistry during flooded conditions (Ezeaku & Anikwe, 2006). Effective cation exchange capacity ECEC) varied from 8.47 to 14.12 and a mean value of 11.6Cmolkg^{-1}, level of ECEC was considered suitable for tropical soil (FPDD, 1990). According to Fagbami and Ajayi (1990) values below 10Cmolkg^{-1} are considered marginally adequate while values above 20Cmolkg^{-1} are adjudged to be highly suitable for wetland rice production. If others (weather, farm management, crop variety) are favourable. The mean value of ECEC reported in this study is indicative of low capacity of these soils to retain nutrient elements due to insufficient amount of organic matter and soil pH. This renders the soils slightly suitable for intensive rice cultivation when compared to rice paddies in Vietnam, Bangladesh, Malaysia and Sirilanka (Abe et al., 2010; Ogban & Babalola, 2003).

Base saturation (BS) values ranged from 52.22 to 58.18 percent and a mean value of 54.97 percent. These values are below the critical value of 60 percent establish for ecological zone (Holland et al., 1989), this implies that the soils has a slightly low base saturation, this could be due to the presence of weatherable minerals in soil in the study area, an indication of availability of basic ions in soil solution for rice crop absorption.

The concentration of Zinc (Zn) was between 3.33 to 4.68mgkg^{-1} with a mean value of 4.04mgkg^{-1} these values are above the critical unit of 2.0mgkg^{-1} required for rice production. This result indicates that the levels of zinc in the soils may not constitute a major constraint to rice production in the study area. Available manganese (Mn) was between 28.15 to 48.186 mgkg^{-1} and a mean value of 39.18mgkg^{-1}. These resulting values suggests that the levels of available Mn in these soils appeared to be adequate and even high in some locations. The concentration of iron (Fe) ranged from 103.18 to 128.30mgkg^{-1} with a mean value of 114.47mgkg^{-1}. The results showed that there is high concentration of iron. These ranges are higher than the limits obtained by Aghimien, Udo & Ataga, (1988). The values one higher than these obtain by Udo (1980) in some hydromorphic soils in Nigeria. This is in tandem with the findings of Mohr et al., (1972) who opined that the lower horizons of hydromorphic soils are usually enriched with iron (Fe) due to the deposition of Fe compounds.

TABLE 1: Summary of physico-chemical properties variations of lowland soils in Obubra.

Location	Loc CODE	pH	EC Soil	Organic Matter	Total Nitrogen	Avail P mgrg	Ca	Mg	Na	K	Al	H	ECEC	BS	Zn	Mn	Fe	Cu	Sand	Silt	Clay	BD
OYADAMA	1	5.08	0.11	0.52	0.22	6.01	5.40	1.88	0.72	0.24	2.75	3.13	14.12	58.09	4.68	48.86	128.32	4.68	48.17	17.03	34.80	1.25
OFAT	2	5.58	0.23	1.74	0.35	3.99	4.57	1.37	0.47	0.26	2.41	2.41	11.48	58.18	4.21	46.18	107.95	8.85	52.53	17.97	29.50	1.27
ODERIGA	3	4.98	0.67	1.89	0.14	4.43	2.60	1.38	0.14	0.31	2.17	1.87	8.47	52.22	3.75	28.15	103.63	13.28	56.03	21.40	22.57	1.38
OFODUA	4	5.75	0.24	0.97	0.60	9.73	2.73	1.88	0.94	0.18	2.47	2.55	10.76	53.44	3.33	29.17	126.73	17.52	39.62	18.05	42.33	1.31
APIAPUM	5	5.15	0.14	1.30	0.30	8.88	3.48	2.50	1.13	0.20	3.94	2.64	13.89	52.50	4.33	44.94	103.18	7.41	48.13	14.03	37.83	1.36
OBUBRA	6	5.28	0.12	5.63	0.15	8.01	4.32	2.52	0.29	0.24	3.82	2.31	13.49	54.40	4.44	29.00	132.15	7.36	37.00	19.80	43.20	1.34
OHIKE	7	5.30	0.29	0.68	0.33	5.06	2.80	1.79	0.19	1.17	2.41	5.25	26.05	47.44	3.87	26.97	101.63	13.70	46.47	21.67	31.87	1.36
OYINA	8	4.58	0.25	2.21	0.18	4.61	3.87	1.95	0.12	0.14	2.45	1.69	10.29	58.00	3.82	30.61	140.37	7.13	36.53	27.27	36.20	1.50
OWAKWANDE	9	5.20	0.20	3.95	0.39	4.61	6.10	3.83	0.21	0.18	2.86	1.72	14.90	67.94	3.98	25.44	105.23	7.84	41.13	17.03	41.83	1.23
OGADA	10	5.12	0.08	1.40	0.35	6.14	10.50	5.20	0.26	0.25	3.69	2.41	22.32	72.54	5.70	42.81	99.13	7.51	39.70	17.40	42.90	1.25
OFUMBONGHA_1	11	5.28	0.24	2.01	0.49	9.80	12.03	3.32	1.18	0.45	4.44	5.91	27.33	61.97	6.74	54.45	112.15	7.41	35.67	22.03	42.30	1.38

OFUMBONGHA_3	12	4.88	0.32	1.36	0.20	7.33	10.37	2.88	1.42	0.26	4.17	4.71	23.80	62.51	5.10	48.03	101.37	5.86	32.43	17.40	50.17	1.37
IYAMONYONG	13	5.78	0.28	4.37	0.49	5.37	8.08	3.95	0.88	0.26	2.34	2.54	18.05	74.05	5.03	43.48	127.97	14.18	39.80	19.10	41.10	1.42
IYAMETET	14	3.98	0.47	2.18	0.24	7.06	9.37	2.47	0.88	0.25	2.71	3.24	18.85	68.56	4.22	38.02	107.93	8.92	47.17	18.80	34.03	1.68
ESABANG	15	5.38	0.29	2.13	0.28	6.34	3.93	1.82	0.49	0.24	2.75	2.37	11.60	55.69	3.86	35.70	114.07	10.46	43.90	17.93	38.17	1.37
OGBRINYI	16	5.17	0.50	7.46	0.55	9.94	13.12	4.83	1.59	0.67	1.94	6.34	28.49	70.74	6.61	56.77	102.47	24.87	40.57	16.47	42.97	1.32
OCHON	17	5.27	0.25	6.18	0.33	8.86	8.00	2.68	0.82	0.54	2.03	3.95	18.02	66.97	6.27	46.20	120.43	9.94	35.67	22.00	42.33	1.47
ONYEN	18	5.10	0.41	7.31	0.51	6.71	8.50	5.23	0.23	0.35	2.29	3.46	20.06	71.48	4.64	50.45	140.23	9.02	36.60	20.40	43.00	1.47
OGRUDE	19	5.28	0.36	7.04	0.20	8.12	9.60	4.20	0.13	0.36	1.96	5.47	21.72	65.97	5.30	42.43	122.48	15.10	35.37	19.37	45.27	1.41
IDDA	20	5.22	0.38	3.83	0.38	7.26	10.93	3.93	1.13	0.36	3.01	4.53	23.90	68.46	5.73	47.18	111.22	15.56	31.63	18.27	50.10	1.56

(Source: Author's fieldwork, 2017).

Copper (Cu) concentration ranged from 4.68 to 17.52mgkg^{-1} with a mean value of 10.56mgkg^{-1}. This result showed that these values are greater than the critical unit of 1.0 mgkg^{-1} (Holland et al., 1989, FAO, 1976; FPDD, 1989). The concentration of Cu fluctuates, having increasing values in the dry season than in the wet season. This is in agreement with the findings of Amalu et al., (2001), Enwezor, (1989). Soils in the study area were rated adequate in providing copper for good growth and yield of rice and other related crops.

Analysis of the variation in soil quality and electrical resistivity

(i) Bivariate correlation analysis was used to examine the strength of the relationship between soul quality (physico-chemical properties) and electrical resistivity, the result is recorded in table 2 which contains the correlation matrix of relationship between soil quality and electrical resistivity the table indicated that strong positive correlation was recorded for ECEC(0.69), Ca(0.66), Mg(0.64), Clay(0.64), Zn(0.59), Bs(0.53), H(0.47) and Organic Matter (0.46) with electrical resistivity. Total Nitrogen – Tn(0.25), Availebla phosphorus – AP(0.39), Na (0.30), K(0.26), Al(0.30), Mn(0.30), Cu(0.04), Silt(0.08) and BD (0.17) were weakly correlated with ER. Negative correlation was recorded for pH (0.13), EC (-0.06), Fe(-0.12) and Sand (-0.67) with electrical resistivity (ER). The results from the matrix further shows that Ca, Mg. ECEC, Zn, sand and clay were significant at $P \leq 0.01$ while OM, H and BS were significant at $P \geq 0.05$.

(ii) Multiple regression analysis of variation in soil quality (physico-chemical properties of lowland soils on electrical resistivity (ER)

Multiple regression equation

Electrical resistivity (ER) = 4.167 + (0.120ECEC) – (0.022sand) + (0.062Ca) + (0.000clay) – (0.159Mg) – (0.003Zn) – (0.025BS) –(0.410H) + (0.110Organic Matter)

Table 3 contain regression summary of soil quality (physico-chemical properties variation on electrical resistivity. Tables 3 and 3 showed the model summary and the regression coefficients of the variations from table 3. It was observed that R is 0.881, R^2 is 0.776 and adjusted R^2 is 0.574, while the standard error of the estimate associated with the model is 0.30302. The model indicated that soil quality (physico chemical peroperties of low land soils in Obubra such as Effectice Cation Exchange Capacity (ECEC), Calcium (Ca), Clay, Zinc (Zn) and organic matter (OM), had a direct positive relationship with electrical resistivity in different locations in the study area. This implies that given a unit increase in dependent variable (Electrical resistivity), while holding physico-chemical properties of lowland soils constant, ECEC, Ca, Clay, Zn and OM will increase by magnitude of 0.120, 0.062, 0.000, 0.0603, and 0.110 respectively.

Similarly, sand, magnesium (Mg), Electrical conductivity, bas saturation (BS) and exchangeable hydrogen (H) decrease by a magnitude of 0.022, 0.159, 0.060, coefficients are indicative that the degree of scattering of observation point is wide, depicting that the relationship between soil quality properties and electrical resistivity would predict results similar to the test locations. The percentage contribution of the independent variables (ECEC, Sand, Ca, Clay, Mg, BS, H and OM) to the variation in electrical resistivity indicated as 18.15(ECEC), 7.67(Sand), 3.68(Ca), 3.35(Clay), 4.01(Mg), 0.21(Zn), 13.12(BS), 11.88(H) and 2.98(OM). This further reflects the fractional contributions of one unit of each independent variable to the variation in Electrical resistivity.

Table 3 showed the analysis of variance (ANOVA), it revealed that the means squares due to regression (Explained mean squares) is equal to 0.353, and the error mean square (unexplained mean square) is equal to 0.092, while the F_{cal} at P>0.05 equal to 3.846 and is greater than F_{crit} 3.02 meaning that the F_{value} is significant.

The R^2 value of 0.776 implied that 77.60 percent of the variation in electrical resistivity are explained by variation in soil quality (physico chemical) properties of the lowland soil, while 22.40 per cent was unexplained by the model. The results revealed that soil quality (physico chemical) properties significantly influenced electrical resistivity.

The graph in fig 4 and study concludes that a significant larger proportion of the variation in electrical resistivity was due to variation in soil quality properties of the lowland.

The scattered plots represented on Fig 5 to 7 were used to buttress the strength of relationship between soil quality, physico chemical properties and electrical resistivity.

Table 2: Correlation matrix of Electrical Resistivity against physico-chemical properties of Obubra lowland soils

	Electrical Resistivtv	***pH***	***Ec***	***Organic Matter***	*Total Nitrogen*	***Available P***	***Ca***	***Mg***	***Na***	***K***	***Al***	***H***	***ECEC***	***BS***	***Zn***	***Mn***	***Fe***	***Cu***	***Sand***	***Silt***	***Clay***	***Bulk Density***
Electrical Resistivy	1.00																					
pH	-0.13	1.00																				
eC	-0.06	-0.31	1.00																			
Organic Matter	0.46	0.10	0.28	1.00																		
Total Nitrogen	0.25	0.50	-0.01	0.21	1.00																	
Available P	0.39	0.10	-0.04	0.31	0.38	1.00																
Ca	0.66	-0.17	0.18	0.45	0.32	0.43	1.00															
Mg	0.64	0.04	0.03	0.62	0.45	0.27	0.76	1.00														
Na	0.30	0.02	0.09	-0.02	0.40	0.65	0.51	0.13	1.00													
K	0.26	0.12	0.22	0.12	0.18	0.09	0.10	0.04	0.04	1.00												
Al	0.30	-0.10	-0.48	-0.40	-0.13	0.25	0.17	0.03	0.30	-0.25	1.00											
H	0.47	0.02	0.27	0.31	0.27	0.56	0.65	0.35	0.50	0.66	0.02	1.00										

ECEC	0.69	-0.05	0.12	0.29	0.35	0.41	0.80	0.62	0.44	0.61	0.19	0.87	1.00									
BS	0.53	-0.11	0.11	0.56	0.37	0.10	0.80	0.83	0.21	-0.16	-0.12	0.19	0.46	1.00								
Zn	0.59	0.06	0.01	0.45	0.29	0.53	0.86	0.61	0.52	0.26	0.19	0.69	0.74	0.59	1.00							
Mn	0.30	0.04	0.04	0.28	0.34	0.44	0.73	0.47	0.63	0.06	0.15	0.58	0.56	0.51	0.78	1.00						
Fe	-0.12	0.10	-0.17	0.34	0.03	0.02	-0.19	0.00	-0.29	-0.30	-0.26	-0.24	-0.34	0.05	-0.17	-0.06	1.00					
Cu	0.04	0.32	0.53	0.41	0.50	0.32	0.21	0.24	0.28	0.42	-0.56	0.43	0.30	0.14	0.19	0.08	-0.13	1.00				
Sand	-0.67	-0.07	0.18	-0.45	-0.22	-0.45	-0.57	-0.56	-0.24	0.03	-0.23	-0.39	-0.48	-0.47	-0.51	-0.27	-0.33	-0.05	1.00			
Silt	0.08	-0.22	0.18	0.07	-0.22	-0.24	-0.14	-0.21	-0.43	0.19	-0.23	-0.03	-0.09	-0.13	-0.05	-0.28	0.47	-0.11	-0.20	1.00		
Clay	0.64	0.16	-0.26	0.42	0.31	0.55	0.62	0.64	0.42	-0.10	0.33	0.40	0.52	0.52	0.53	0.38	0.13	0.10	-0.91	-0.22	1.00	
Bulk Density	0.17	-0.57	0.47	0.21	-0.15	0.09	0.24	0.02	0.11	0.01	-0.17	0.14	0.13	0.25	0.06	0.07	0.22	0.06	-0.24	0.39	0.07	1.00

Source: Author's fieldwork (2011).

Table 3:Multiple Regression analysis of effect of variation in soil quality (physico-chemical) properties of lowland soil on Electrical Resistivity

a. Model summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of Estimate**
1	0.881	0.776	0.574	0.30302

b. Regression Coefficient

Coefficients[a]

Model	**Unstandardized Coefficients**		**Standardized Coefficientst**		**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	4.167	2.803		1.487	.168
ECEC	.120	.043	1.589	2.809	.018
Sand	-.022	.027	-.317	-.805	.440
Ca	.062	.087	.459	.717	.490
Clay	.000	.029	.006	.014	.989
Mg	-.159	.156	-.428	-1.015	.334
Zn	.003	.150	.006	.017	.987
BS	-.025	.029	-.424	-.850	.415
H	-.410	.179	-1.288	-2.296	.045
Organic Matter	.110	.058	.553	1.887	.088

c. Analysis of Variance:

Effect	**DF**	**SS**	**MS**	**F**	**P**
Regression	9	3.178	0.353	3.846	0.24
Residual	10	0.918	0.92		
Total	19	4.096			

P > 0.05Source: Author's field

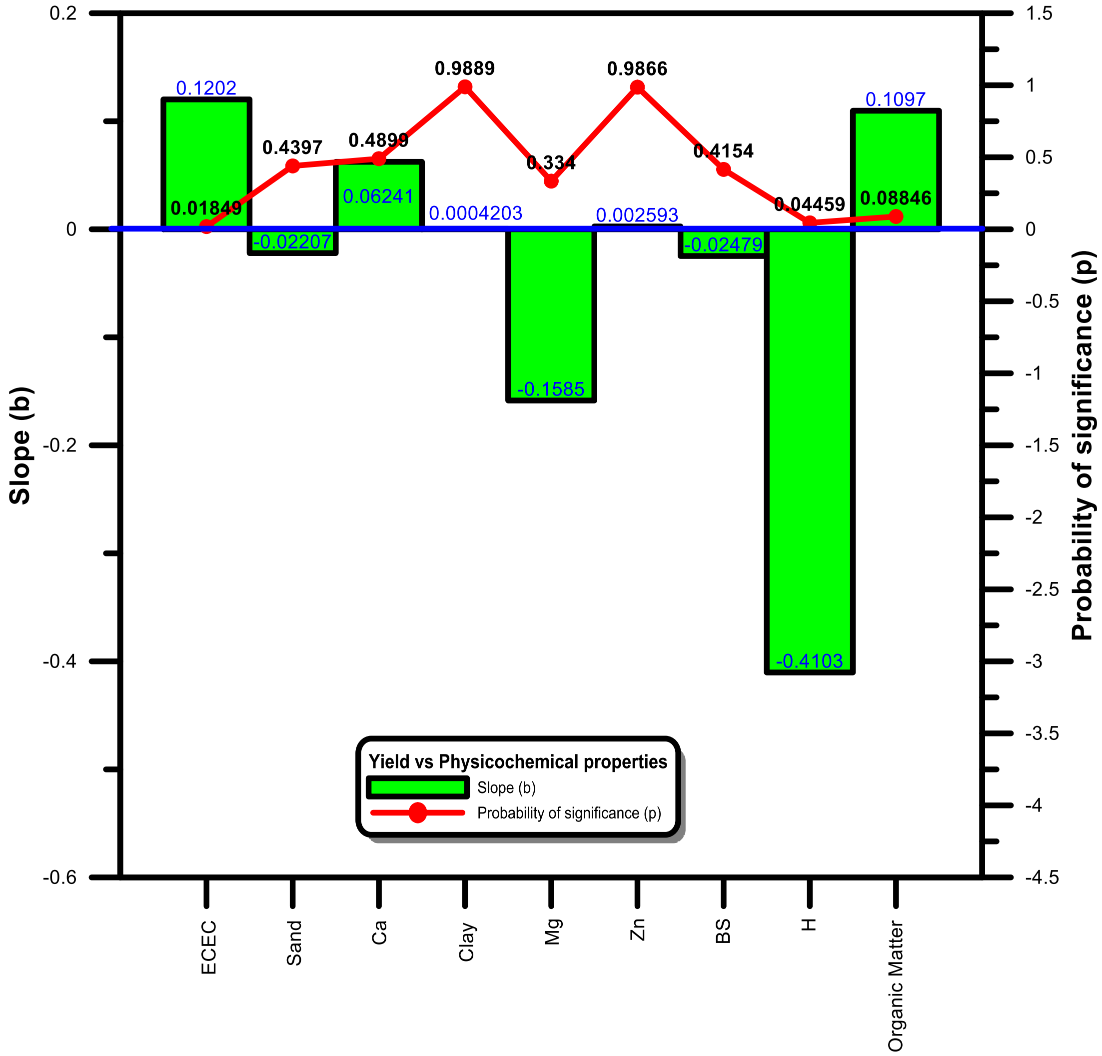


Fig. 4: Electrical Resistivity against physico-chemical properties

Source: Author's fieldwork (2017).

Figure 4 shows the slope of ER against physcico-chemical properties in a multiple regression model. The slope represented here is unstandardized, it was observed that ECEC has the highest level of significance with a probability of significance of 0.018 and a slope of 0.12, clay recorded the least probability of significance of 0.98 and a slope of 0.004. In all H^+ and ECEC had a probability of significance less than or equal to 0.05. The model indicated that four variables (sand, Mg,Bs, H^+) has an inverse relationship with ER constituting A4 percent of the mine independent variables used in the model while five variables (ECEC, Ca, Clay, Zn, Om) have direct relationship with ER constituting 55.55 percent of the total variables used in the mode

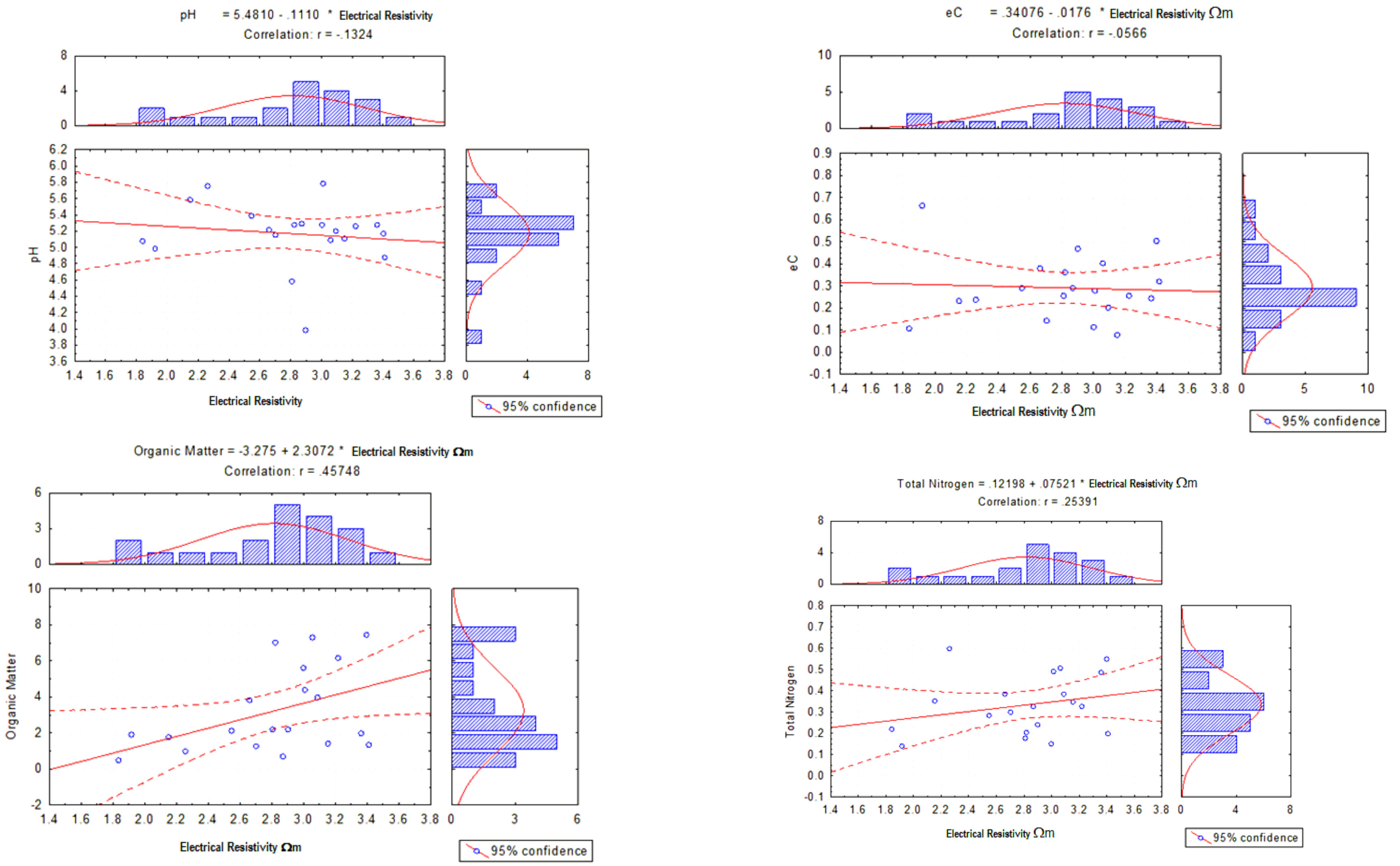

pH = 5.4810 - .1110 * Electrical Resistivity
Correlation: r = -.1324
pH
Electrical Resistivity
95% confidence
eC = .34076 - .0176 * Electrical Resistivity Ωm
Correlation: r = -.0566
eC
Electrical Resistivity Ωm
95% confidence
Organic Matter = -3.275 + 2.3072 * Electrical Resistivity Ωm
Correlation: r = .45748
Organic Matter
Electrical Resistivity Ωm
95% confidence
Total Nitrogen = .12198 + .07521 * Electrical Resistivity Ωm
Correlation: r = .25391
Total Nitrogen
Electrical Resistivity Ωm
95% confidence

Fig. 5

Electrical resistivity variation

From the VES analyzed presented in table 4, the data it is crystal clear that there are variations in the electrical resistivity from one plot to another. Considering the first layer resistivity variation in all the twenty locations, it obvious that apart from Owakande, Iyamitet, Ochon, Onyen and Idda where the first layer resistivity is high, ranging from 120Ωm to 311 Ωm, other location have moderately low to resistivity ranging from 3 Ωm to 87 Ωm which can be classified as clays, unconsolidated wet clay or marls. This inference is as a result of comparing the field values with that of Telford et al (1990)

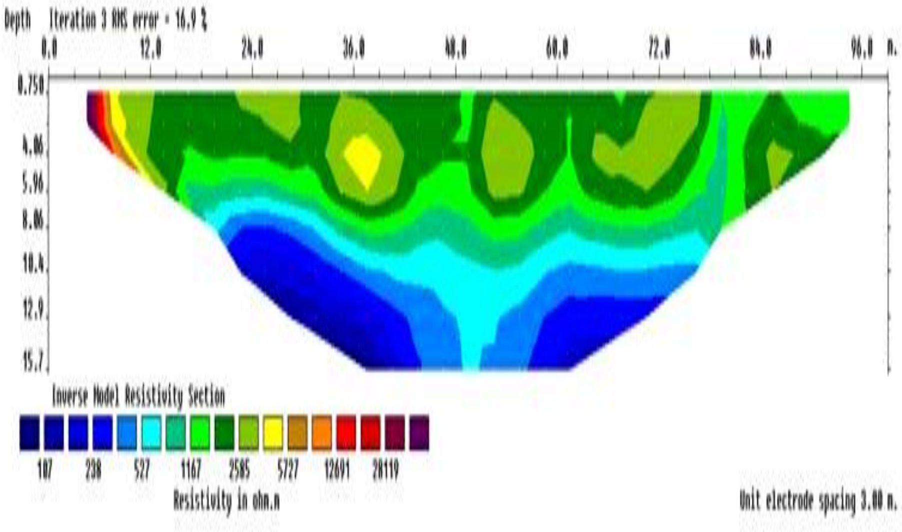
The resistivity variation within the second layer in all the locations indication moderately low values which could be inferred to be composed of clay, water, shales and clayey sand. The thickness of the first and second layer lies between 0.7-4.2m and 4.0-21m, Roots from the rice plant are mostly growing within the first layer but mineral elements from the parent rocks which are domiciled in the layers at deeper depth surges upward

Table 4: Electrical Resistivity and Grain Yield variation in the study area

Longitude (°E)	Latitude (°N)	Profile Code	ρ1	ρ2	ρ3	ρ4	D1	D2	D3	Location
8.2442336	5.9263929	OBP_1	5	16	132		0.9	15		OYADAMA
8.2554402	5.9511865	OBP_2	14	56	102	420	4.2	13	23	OFAT
8.2564444	5.9466236	OBP_3	3	68	438	1231	3.1	16	30	ODERIGA
8.2594334	5.9765854	OBP_4	4	84	160		1.1	21		OFODUA
8.2965245	6.0009532	OBP_5	13	48	26	90	0,7	7,5	19	APIAPUM
8.3064431	6.0865153	OBP_6	20	13	89	150	3.2	11	14	OBUBRA
8.3133433	6.1123423	OBP_7	59	24	67		1.8	13		OHIKE
8.293744	6.0475463	OBP_8	42	9	87		3.4	9		OYINA
8.3344654	6.0878436	OBP_9	200	70	91		0.9	19		OWAKWANDE
8.2993422	6.0580042	OBP_{10}	68	45	79		2.8	8.9		OGADA
8.3534222	6.0872334	OBP_{11}	17	30	75	678	4	17	24	OFUMBONGHA_1

Fig. 7: Electrical Resistivity Tomography (ERT) 2

Source: Author’s field computation, (2017)



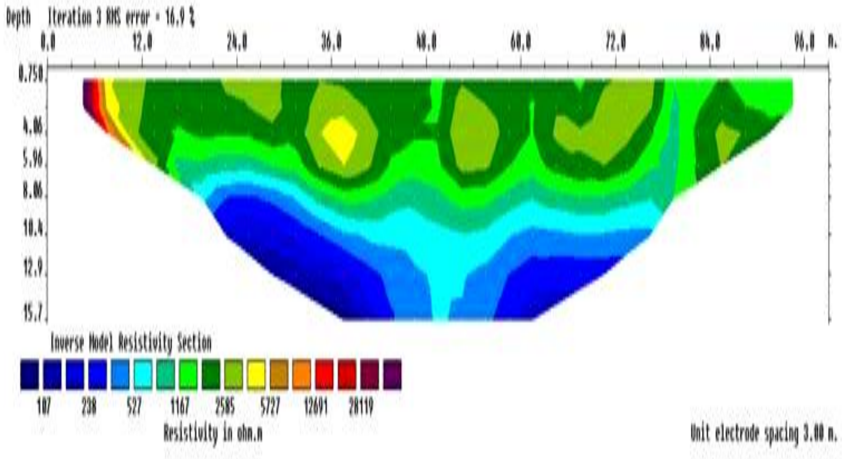
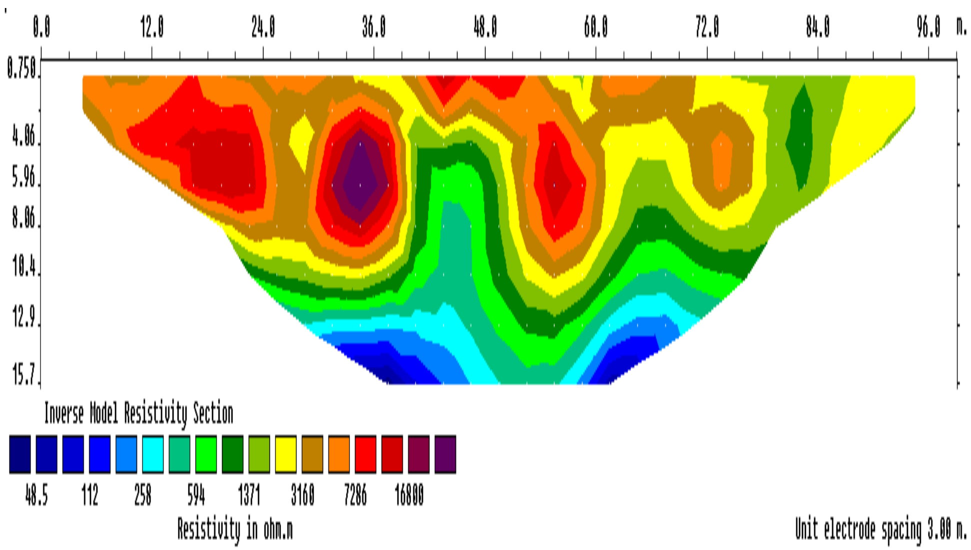


Fig.8: Electrical Resistivity Tomography (ERT) 3
Source: Author's field computation, (2017)



Conclusion

Electrical geophysical method was successfully used in the site and in the laboratory to monitoring and assessing soil quality for lowland rice production. Soil electrical properties reflect the transport of substances in landscapes, geochemical connection and reveled significant correlation if electrical resistivity, with soil quality properties.

The investigation into the relationship amongst soil quality (physicochemical) properties (organic matter, Al, P etc), lead to the conclusion that, electrical resistivity is a function of the soil quality properties. Electrical resistivity show a good correlation with soil quality properties with a correlation coefficient of R^2 = 0.776. ECEC, Ca, Mg, Clay Zn, BS, H and Organic matter (OM) greatly impact on electrical resistivity. However, there was little relationship between Electrical resistivity and TN, AP, Na, K, Al, Mn, Cu, Silt and BD while a negative correlation existed between electrical resistivity and pH EC, Fe and sand. Thus the reported variations in electrical resistivity values amongst locations resulted from a cascade of changes in soil quality properties premised on the availability and the release of nutrients, level of farm management alongside agrochrmatic factors, all having a differential impact on soil quality.

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