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**AGRICULTURAL GEOPHYSICAL INVESTIGATION IN RESOLVING LAND
AND OPTIMUM EXPLOITATION CHALLENGES AT IBBU LAPAI FARM SITE,
NIGERIA**

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ABSTRACT

Geophysical techniques have become very valuable and indispensable tool in addressing the agricultural activities challenges ranging from; soil quality determination, monitoring and appropriate usage challenges, etc. Agricultural geophysical investigations are therefore, generally focused on delineating geologic features within the soil profile at depth range within the crop root zone (0 to 2 m depth) over very large farm size. Consequently, Geophysical characterization using high resolution Vertical Electrical Sounding (VES) with Schumberger electrode array was conducted at a portion of the IBBUL farm site to delineate the subterranean geologic features of interest to agricultural output yields. The results revealed the lithological units in the study area. The analysis of VES points 1 and 3 revealed lithological units of highest moisture contents with resistivity variation of (19.00 to 79.80) Ωm . Three distinct geo-electric layers were delineated in the study area; (first layer) shallow subsurface with the highest moisture contents, (second layer) a good aquifer unit and (third layer) weathered Basement complex. The weathered layer (second layer) has the highest resistivity range of between (22.87 and 304.00) Ωm . It exhibited some observed presence of fractured parts acting as high yield point for the good groundwater resource within the farm site. From the delineated subsurface properties, this farm land may have high agricultural yields at VES points 1 and 3, while VES points 4 with higher resistive (31.31 and 156.00) Ωm geologic features may be best for locating heavy agricultural infrastructures. Venturing into Precision and dry season farming are recommended for the IBBUL University at the investigated portion of the farm site considering the soil quality and the viable groundwater potentials.

Keywords: Agricultural output yields; Lithological unit; Moisture content; Vertical electrical sounding; Geo-electric layers; Dry season farming



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INTRODUCTION

Geophysical methods for Farm site investigation or soil profile evaluation according to Bitella *et al.* (2015) involves the most commonly used geophysical methods; Electrical Resistivity (ER), Electromagnetic Induction (EMI) and Ground-Penetrating Radar (GPR). However, researches in the present days faces challenges stemming from the most urgent needs of the society, Government or other non-governmental organizations from a growing population to the reduced availability of important resources and problems in cycling of renewable ones (Osumejeh *et al.*, 2023). Ensuring agricultural output sustainability plays a major role and requires the accurate and precise knowledge of the agricultural mechanisms and the ability to monitor the impact of quality soil nutrients and strategy implementation for high crop yields. The concept of “sustainable agriculture” well identifies the relationship between agriculture and environment, with the specific challenge to produce sufficient food and fiber, as well as raw materials for national growth and economic buoyancy with acceptable environmental costs and to manage agricultural lands noninvasively while preserving and enhancing the amount and quality of environmental resources. The integration of the use of the geophysical techniques in assessing and monitoring the soil quality into agricultural policy is the key strategy for enhancing the sustainability of agro-ecosystems (EIR Report, 2013).

This relationship is more evident if we consider the increasing frequency of the incidences of poor agricultural output/yields and the role of the agriculture in the nation economy and the citizenry health sustainability. The arena where agricultural land use and environmental processes meet is the soil: the thin upper part of Earth Crust (Earth Skin) represents one of the more complex systems in which lithosphere, hydrosphere, and biosphere interact and are strongly linked (Alejandro *et al.*, 2018). The thickness of the zone beneath the Earth surface that is of interest for the agriculture scientists is within the range 0–2 m for most crops (Osumejeh *et al.*, 2023). This have prompted a growing demand for high resolution near-



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surface investigation technologies for identifying and monitoring of the soil quality and farm site characterizations having implications on agriculture and environment.

High resolution Geophysical Techniques addressed these challenging issues with novel technologies based on completely innovative sensors (i.e., optical fibers, electromagnetic devices), advanced algorithms for 2D and 3D tomographic imaging, and new technologies for field surveying (i.e., drones and Land Unmanned Vehicles). Today, geophysics provides a set of robust, cost-effective, and completely noninvasive or minimally invasive technologies for near-surface investigations able to estimate the physical properties of the shallow layers of soil and subsoil required for profitable and sustainable agricultural practices. Such geophysical techniques are used in a range of near-surface investigations, from archaeology to hydrology or precision agriculture, and allow information acquisition that can either be used directly for the description and monitoring of soil quality or can serve as proxy/guide for strategies for sampling for further soil analysis.

In response to the growing interest in the maintenance of favorable soil structure largely motivated by its central role in plant growth, soil ecological functioning, and impacts on surface water and energy fluxes, various Scientists have applied geophysical techniques with several reviews. Such reviews like that of (Alejandro *et al.*, 2018), covered basic aspects of soil structure and challenges of characterization across spatial and temporal scales and the offer of the geophysical methods on the task. The use of geophysical models, inversion techniques, and combination of geophysical methods for extracting soil structure information at previously unexplored spatial and temporal scales were among the challenges put forward by the reviewer's.

Consequently, Geophysical methods have become increasingly valuable tools for agricultural applications. Agricultural geophysical investigations are thus therefore focused on delineating



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small- and/or large-scale objects/features of interest to the farm product yield within the soil profile in the range of (0 to 2 m depth) over very large agricultural areas. Along that line, Osumejeh *et al.* (2023) also carried out geophysical investigation at Ahmadu Bello University farm site, to delineate the subsurface structures along with depth. The investigation revealed various lithological units with properties indicating the possibility of low agricultural yield. This revelation is capable of limiting the cultivation potential of the investigated region; however, the region investigated was still identified as a good underground water potential which is also a vital ingredient in agricultural activities.

Gregory *et al.* (2018) also used integrated geophysical approach in their study on Near-surface Geophysical Characterization of Cole Farms in the Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, USA. The result of their findings demonstrated the ability to quickly and efficiently develop critical zone structure models that can reveal the linkage between potential surface and subsurface controls on landscape evolution.

This study was therefore designed to characterize the portion of the IBBUL Farm site with a view to model the site so as to facilitate partitioning for possible precision agricultural activities by the University. This is to aid the IBBUL Agricultural Engineers and Agronomists. A Farm site without accurate and comprehensive geophysical database may lead to very expensive agricultural input and poor agricultural output yields in the long run which may ultimately lead to the farm failure and collapse of the farm site. Subsurface geological features such as soil water/humus contents/retention capability, conductivity, fractures, voids, and nearness of water resources/table to the surface are among the inconveniences that pose considerable constraints to some farm sites especially at shallow subsurface (Andrews *et al.*, 2014). Geophysical methods, particularly geo-electrical resistivity techniques, have been extensively used for a wide variety of agricultural engineering, farm cultivation and crop yield related problems with convincing successes (Gregory *et al.*, 2018).



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The use of electrical resistivity technique has been the most convenient and economical tool for the geophysicists in monitoring and determination of soil quality because of the wide range of natural resistivity values exhibited by the geologic features. The use of electrical resistivity survey thus become the optimum choice, as a result of its economic conveniences; time saving, non-invasiveness and easy to carry out (Andrews *et al.*, 2014). In addition to the agricultural engineering applications, the method can also be of great importance in the search for groundwater resources which is key ingredient to any sustainable agricultural practices (Dogara *et al.*, 2016). Therefore, the non-invasive geophysical technique involving Vertical Electrical Sounding using Schlumberger array was adopted to investigate the subsurface conditions of the portion of the IBBUL Farm with the sole aim of determining the soil quality and groundwater resources within the IBBUL Farm site.

Site Location and Geology

The IBBUL Farm Site is geographically located between Latitude co-ordinates $9^{\circ} 02' 60.00''$ N and $9^{\circ} 03' 00''$ N; and longitude $6^{\circ} 34' 00''$ E and $6^{\circ} 34' 12''$ E within the Bida basin Complex of Nigeria. It is indicated on the IBBUL map by the circled point with an arrow pointing to it (Figure 1). The surface terrain is fairly uniform permitting easy stretch of the Schlumberger array. The Lapai town where the IBBUL Farm site is located serves as a market center for varieties of agricultural farm products such as; the sorghum, yams, rice, millet, shear nuts, peanuts (groundnuts), and cotton grown majorly by the Gbagyi and Nupe communities. Swamp rice is also cultivated in the floodplains of the Gurara and the Niger rivers surrounding the Lapai town. It is the capital town of Lapai local government with a total Population of 110,127 according to 2006 census data it covers total land area of $3,051 \text{ km}^2$.



Figure 1: Map of Ibrahim Badamasi Babangida University main campus showing the study area

MATERIALS AND METHODS

ABEM SAS 300C Terrameter, four electrodes (C1 and C2, P1 and P2), measuring tape, hammers and other materials such as GPS, Cutlass and water were some of the materials used during the field work at the IBBUL Farm site. The site was probed using the high resolution geophysical technique of Vertical Electrical Sounding (VES) conducted across 4 VES points using Schlumberger electrode configuration.

The technique of this methodology involves transmitting the electric current I (in amperes, A) into the subterranean through the two current electrodes (C1, C2) hammered down, while two other hammered down potential electrodes P1 and P2 connected between the current electrodes were used to measure the resulting potential difference in V (volt, V) (Figure 2). Schlumberger electrode configuration of maximum electrode separation, $AB/2$ of 60 m was used. The potential electrodes remained fixed and the current electrodes were expanded simultaneously about the center of the spread (Figure 2) until when the distance between the



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current electrodes became so large, the distance between the potential electrodes were then increased to have a measurable potential difference. The recorded apparent resistivity values at each of the sounding points were plotted against electrode spacing ($AB/2$). The VES data obtained were modeled using IPI2Win computer software. The resulted combined model (VES points 1 to 4) in form of Pseudo cross section, geo-electric sections, Log-Log Table; (layer resistivity, thicknesses and depth) and graphs along direction N-S were produced (Figure 3).

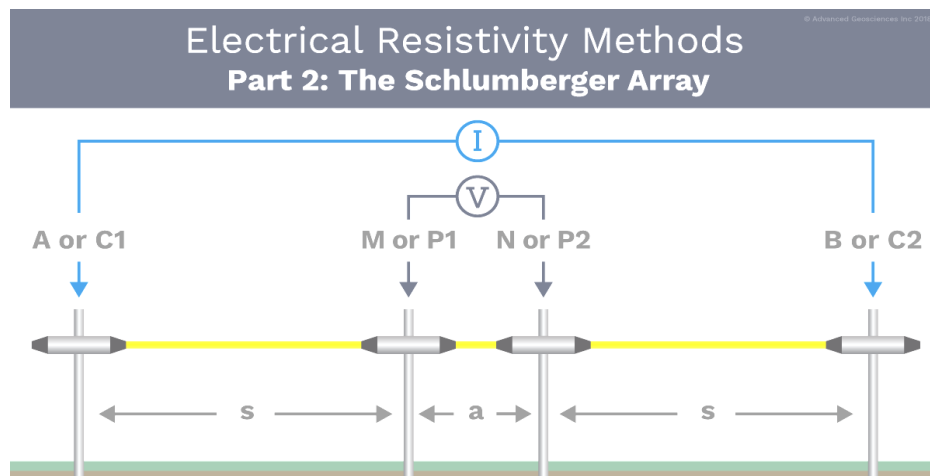


Figure 2: Schulumberger Electrode Configuration showing the arrangement of the two current (C1 and C2) and two potential (P1 and P2) electrodes

RESULTS AND DISCUSSION

The results from the investigated four VES points at the IBBUL Farm site were presented as Pseudo cross section, Geo-electric sections, thicknesses and depth (Figure 3 and Table 1). The summary of the Apparent Resistivity variations within the investigated portion of IBBUL Farm site was determined and given in Table 2. The Figure 3 is the modeled field data for VES points 1 to 4, three geo-electric layers were probed across all the VES points (Table 1 a - d). The variations in the resistivity zones were represented by the various colour codes as



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observed in the figure 3. The scale of the of colour codes by right side (Figure 3) indicated that the low resistive geologic features were represented by black to blue range, while along that ascending direction up to the red colour at the pick representing the geologic features with highest resistivity values.

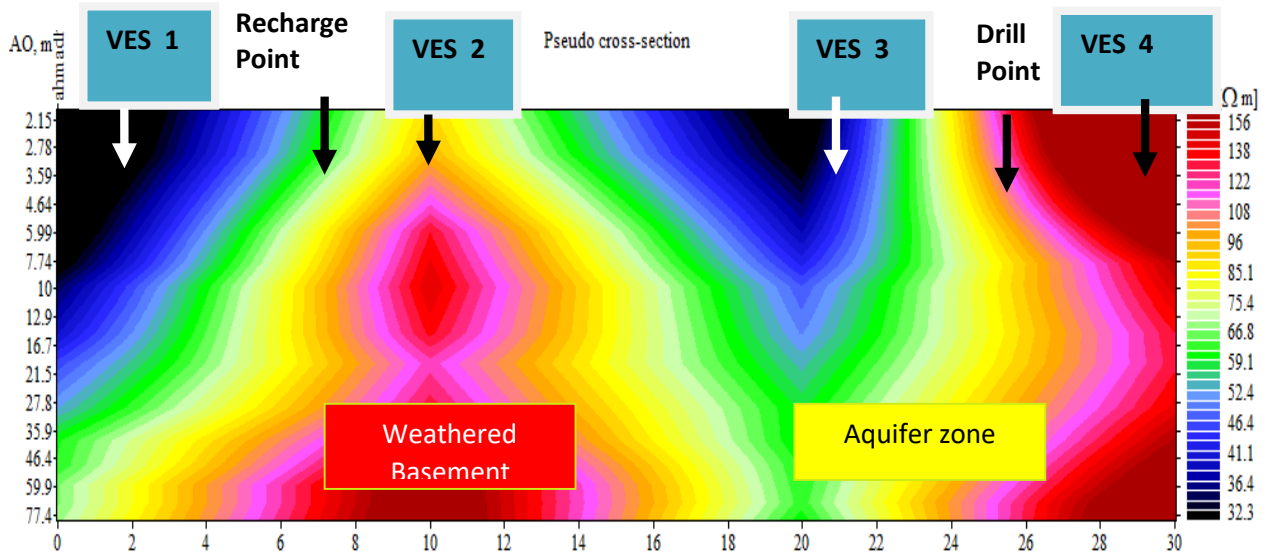


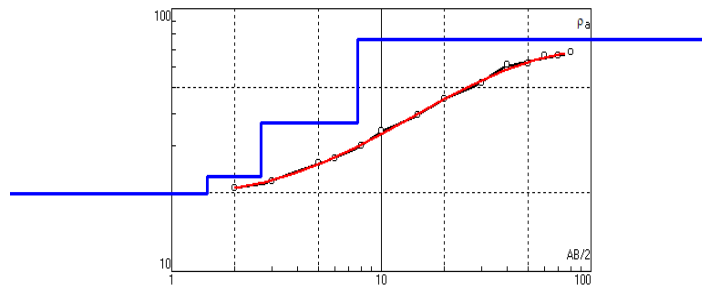
Figure 3: Pseudo cross section showing VES points 1 to 5.

Table 1(a-d): Log-Log Tables for VES points 1 to 4 within the investigated portion of IBBUL Farm site

VES POINT 1

N	p	h	d	Alt
1	19.83	1.478	1.478	-1.477
2	22.87	1.19	2.668	-2.668
3	36.89	5.04	7.708	-7.708
4	76.11			

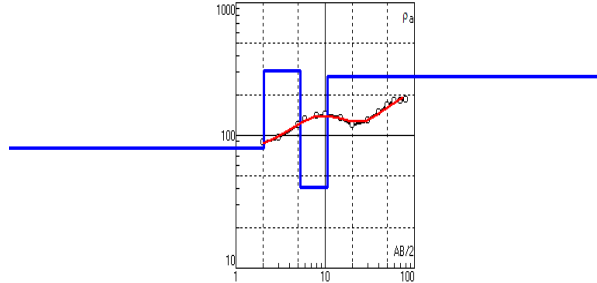
(a)





VES POINT 2

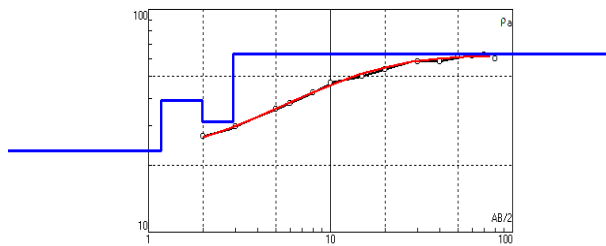
N	p	h	d	Alt
1	79.8	2.07	2.07	-2.065
2	304	3.19	5.26	-5.26
3	40.5	5.26	10.5	-10.52
4	278			



(b)

VES POINT 3

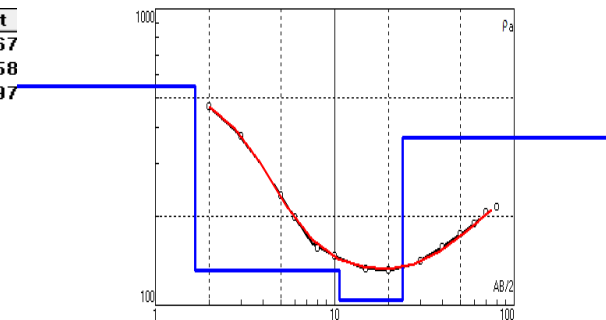
N	p	h	d	Alt
1	23.19	1.174	1.174	-1.173
2	38.86	0.8017	1.975	-1.975
3	31.31	0.9486	2.924	-2.924
4	63.1			



(c)

VES POINT 4

N	p	h	d	Alt
1	550	1.667	1.667	-1.667
2	131.5	8.918	10.59	-10.58
3	104.1	13.39	23.97	-23.97
4	366.6			



(d)



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Table 2: Apparent Resistivity variations within the investigated portion of IBBUL Farm site

PARAMETER	1 ST LAYER VARIATION (Ωm)	2 ND LAYER VARIATION (m)	3 RD LAYER VARIATION (m)
APPARENT RESISTIVITY	19.00 – 79.80	22.87 – 304.00	31.31 – 156.00
THICKNESS	1.17 – 2.07	0.80 – 8.92	0.95 – 13.39
DEPTH	1.17 – 2.07	1.98 – 10.59	2.92 – 23.97

VES Points 1 and 3

These two points exhibited the lowest resistive features which outcropped up to the surface from the depth of 10 m. This is interpreted as highest moisture content zones, indicative of a very weak and weathered layer zone due to its high moisture content. The resistivity of the first geo-electric layer of this zone varies from 19.00 to 79.80 Ωm , while the thickness varied between 1.17 and 2.07 m with a depth variation of between 2.15 and 10 m (Figure 3). This delineated low resistive zones (VES points 1 and 3) implied highest conductive and moisture contents zones which favours high potential for crop yields and ease in agricultural cultivations (Said, 2006). These two zones can therefore be partitioned for precision agricultural cultivation area. The second geo-electric layer exhibited highest resistive zone where the resistivity variation was between 22.87 and 304.00 Ωm . The thickness of the layer varied from 0.80 – 8.92 m at a depth variation of between 1.98 – 10.59 m. this is interpreted as the aquifer zone (Oladunjoye *et al.*, 2014). The possible viable point for exploiting this aquifer zone is observed midway between VES points 3 and 4 (Figure 3). The third geo-electric layer exhibited moderately higher resistivity zone that varied between 31.31 and 156.00 Ωm . The thickness of the layer varied from 0.95 – 13.39 m at a depth range of between 2.92 – 23.97 m. this is interpreted as the weathered basement giving some protective support



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to the aquifer reservoir (Yusuf, 2020). The possible viable point for exploiting this aquifer zone is located midway between VES points 3 and 4 (Figure 3).

VES Points 2 and 4

In VES point 2, the resistivity ranged from 40.50 to 304.00 Ω m with the thickness varied from 2.07 to 5.26 m at depth range of between 2.07 and 10.50 m. this zone was characterized by a very serious weathering activity which have even outcropped to the surface thereby creating recharge points at the surface. At VES point 4 the highest resistive features were delineated and interpreted as basement complex. This portion of the IBBUL Farm is a good point for locating any civil engineering structures such as Farm House, Silos Roads etc. considering its consolidated and high resistivity/less moisture contents nature.

CONCLUSION

The investigation of the portion of the IBBUL Farm site using Geophysical method involving Electrical resistivity technique has been successfully conducted to delineate the various spatial subterraneous parameters which influence agricultural output yields. Four VES measurements were taken and the results obtained from the interpretation of the modeled field data through IPI2Win computer software were used to produce the Pseudo cross section, geo-electric sections along four cross sections so as to reveal the subsurface lithologic successions and features of concern to agricultural activities. Three major layers were delineated from the study area which comprises the topsoil, aquifer layer and weathered basement. Geo-electric section at VES point 1 and 3 revealed that the two areas has the richest sequence of moisture contents even at the shallowest topsoil down to depth of up to 10 m from the topsoil as required by the crop root zone. These two areas possibly can be very favourable and capable of producing high crop yields based on the delineated very low resistive geologic features and so are recommended for reservation for agricultural practices. VES point 4 can as well be earmarked for locating any high/heavy buildings or other civil engineering infrastructures



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related to farming activities. The site was also characterized to possess viable groundwater resource which could as well sustain and guaranteed IBBUL venturing into dry season farming. This noninvasive, successful and economical delineation of the geologic features of interest to the agricultural activities therefore confirmed the efficacy of the method used in characterizing the investigated portion of the IBBUL Farm site with the view of determining the soil quality, suitability, groundwater potential and partitioning for possible precision farming at Farm site.

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