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DEPLOYMENT OF GROUND PENETRATING RADAR (GPR)TECHNIQUE IN THE DETERMINATION OF SOIL MOISTURE CONTENT OF PARTS OF UNIVERSITY CROSS RIVER STATE SOIL FOR PRECISION AGRICULTURE IN SOUTHSOUTH NIGERIA

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Abstract

The soil moisture content in the studied areas has been successfully characterized using a single offset of GPR technique. At the University of Cross-River State in Calabar, the average water content ranges from $0.26m^3m^{-3}$ to $0.39m^3m^{-3}$. According to the study, the study area is largely made up of loamy soil, which contains tiny sand and silt particles. Sand, silt, and a little quantity of clay make up the majority of loamy soil, which when dry takes on the consistency of concrete and becomes a sticky mixture when wet. In comparison to other soils, loam soil can be preferred for growing the majority of plants and crops. The best type of soil is loam since it has almost equal levels of all three of these elements. In conclusion, parts of soils of the Cross River University of Technology (CRUTECH), Calabar would be a favorable place for farming.

Keywords: Moisture content, Ground penetrating radar

1. Introduction

The amount of water in the soil that is contained in the gaps between soil particles is known as the soil moisture. According to Jung et al. (2010) and Mittelbach et al. (2012), soil moisture modifies the interaction between the land's surface and the atmosphere, which affects the climate and weather. It also plays a key role in defining the crucial rainfall-runoff processes. An essential ecosystem function provided by natural ecosystems is the maintenance of increased soil moisture; poor management could result in desertification (MEA, 2005a).

For natural cycling to occur, which is a requirement for primary production, soil moisture availability is crucial. The water, energy, and carbon cycles are all intertwined with the land evapotranspiration process, which is influenced by soil moisture (Wan et al., 2007; Garten et al., 2009; Jung et al., 2010, Falloon et al., 2011). According to Pielke et al. (2002) and Rhymer et al. (2010), maintaining these associated ecosystem services increases the productivity of natural ecosystems and supports biodiversity. The chemical and physical characteristics of a soil, such as alkalinity, acidity, field capacity, wilting point, soil water potential, and soil matric potential, determine the quality and productivity of the soil (Burk and Dalgliesh, 2008). Soil moisture retention is also a significant factor in determining the availability of water in agroecosystems (Power, 2010).

Moisture in the soil acts as a binder, altering the stability and strength of the soil's structural integrity. In terms of both chemical and biological characteristics, soil moisture is involved in the processes of development and degradation, and the output of agricultural crops is primarily impacted by water availability. The chemical and physical characteristics of a soil, such as alkalinity, acidity, field capacity, wilting point, soil water potential, and soil matric potential, determine the quality and productivity of the soil (Burk and Dalgliesh, 2008). Soil moisture retention is also a significant factor in determining the availability of water in agroecosystems (Power, 2010). The soil's moisture serves as a binder, changing the stability and toughness of the structural integrity of the soil. Water availability primarily affects the yield of agricultural crops, and soil moisture plays a role in the processes of development and degradation in terms of both chemical and biological properties. Therefore, in order to create site-specific management techniques that fit human activities with regional environmental requirements, the classification and monitoring of the soil properties in the environment are necessary (Zhang et al., 2002). The inaccessibility of the subsurface and intrinsic variability makes it difficult to obtain soil data with the necessary spatiotemporal resolution. The dielectric constant of the host material plays an important role in GPR technology, so determining the velocity and depth of the target dielectric constant is important in this study. Ground Penetrating Radar (GPR) is a geophysical technique that uses an electromagnetic (EM) technique method to probe the sub-surface. Its purpose is to characterize the behavior of the (GPR) wave under various hosting dielectric constants (Seyfried D et al., 2015). This non-destructive method makes use of electromagnetic waves and the signals that are reflected off of subsurface structures. A wide variety of media, including rocks, dirt, ice, snow, water, and buildings, can be analyzed using GPR. It can identify subterranean objects, material variations, fissures, and voids. Safety, likelihood, low cost, and non-destructivity are advantages of the GPR approach. In (Liang et al., 2007), the history of GPR is covered in great detail.

In the past, geophysics has been used in a variety of sectors, including engineering, hydrology, and archaeology. When geophysics is used in agriculture, there have been many advancements, but little attention has been placed on it.The term "sustainable agriculture" accurately describes the interrelationship between agriculture and the environment, with a focus on food, fiber, and raw materials, as well as the need to manage a challenging environment while preserving and improving the quantity and quality of environmental resources. One of the intricate systems in which the lithosphere, hydrosphere, and biosphere interact is the area where agriculture is practiced on this upper part of the earth's crust (sometimes known as the "skin" of the planet"). According to Alfred et al. (2000), the thickness of the zone below the earth's surface that is relevant to agriculture research is around 0.2 meters. The purpose of this study is to deploy Ground Penetrating Radar (GPR) as a geophysical approach to identify the kind of soils and their moisture content. It also aims to validate the GPR method as an alternative tool for determining soil moisture content in CRUTECH. Additionally, the survey results will be utilized to determine how soil qualities behave for agricultural and engineering reasons.

1.2 Statements of Problems

The geophysical examination of the subsurface previously required a number of intricate procedures, but with the development of GPR, a direct procedure was established, reducing the time needed for geophysical interpretation of the subsurface. One issue that the GPR has been successful in resolving is this one.For uses like the identification of underground objects, ground penetrating radar (GPR) has proven to be a useful technology. It is appropriate for both wooden and plastic goods in addition to metallic ones. Despite its many benefits, detection is challenging because of the GPR's significant shortcomings. Low resolution, the antenna gain effect, clutter, and potential remedies, including the use of windowed average subtraction, are

GPR-related issues that are examined. Another problem of the Ground Penetrating Radar (GPR) is its high cost of renting the equipment.

1.3 Location and Geology of the Study Area

The University of Cross River (UNICROSS), formerly known as Cross-River University of Technology (CRUTECH), Calabar, is the site of the study. It is located at Ekpo-Abasi, Calabar South-Region. The university covers and occupies 178.8 hectares on the South Eastern end of the city of Calabar. According to the NAA weather report from 2006 and Eni and Effiong (2011), Calabar South experiences 3000mm of annualized rainfall on average, with a relative humidity of more than 85%. According to the climatic data, the monthly temperature ranges between 23.10C and 28.70C, while the monthly precipitation ranges from a low of 26.7 mm in February to a high of 459.1 mm in July (Edet and Okereke, 2002). According to Ileoje (1991), the research area is a lowland and marsh region of southern Nigeria. In this region, elevations are typically less than 100 meters above mean sea level. The study area's geography is dominated by three major rivers. These rivers are the Cross River, Great Kwa, and Akpayafe, which pour into it from the south.

The Tertiary to Recent, continental fluviatile sands and clays known as the Coastal Plain Sands make up the research area's geology. According to Short and Stauble (1967), this formation is characterized by an alternating succession of loose gravel, sand, silt, clay, lignite, and alluvium. Most of the rocks that form its foundation are from the Cretaceous Calabar Flank and pre-Cambrian Oban Massif (Figure 1). All of the water boreholes in the region are found in the Coastal Plain Sands (Benin Formation), which is by far the most abundant aquiferous hydrogeologic setting in the region (Esu and Amah, 1999). In the southern portions of the study region, the Benin Formation is underlain by alluvial sediments. Within the local Coastal Plain Sand, two water bearing units were found by Edet and Okereke (2002) and Amah and Esu (2008). These are the lower fine sand aquifer (LFSA) and the upper gravelly sand aquifer (UGSA).

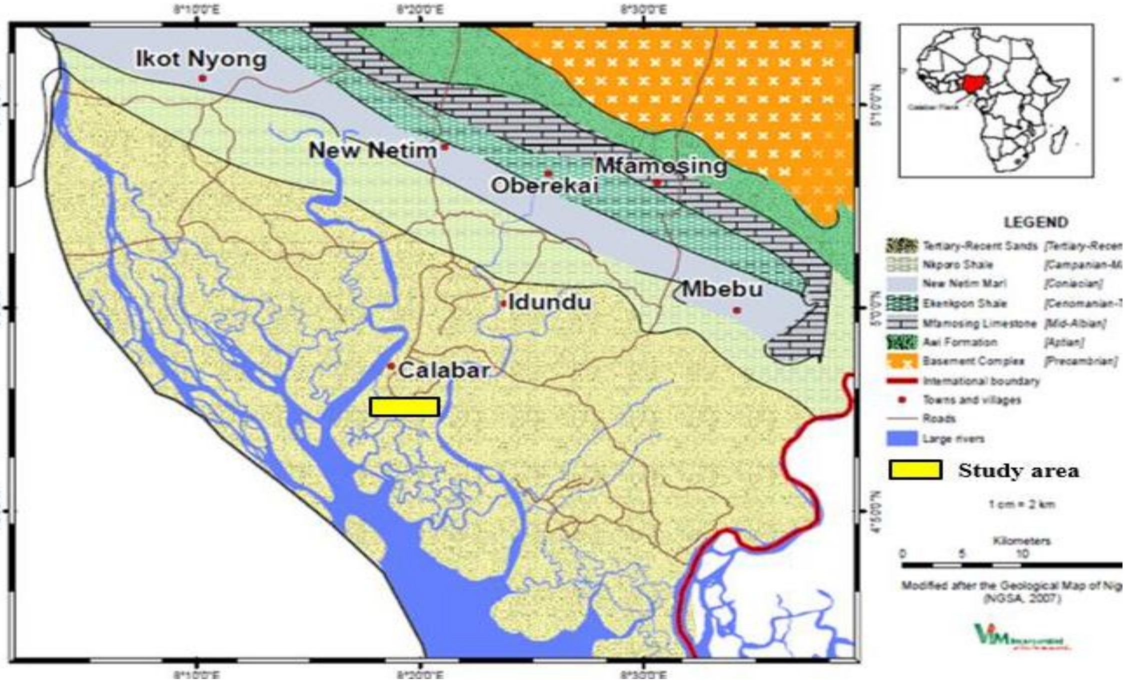

Fig.1: Geologic map of the study area (Modified from Amah et al., 2012)

South Eastern Nigeria's Calabar flank sedimentary basin is where Calabar is situated. Geologically, it is bordered to the north by the Oban Massif, which is influenced by igneous and metamorphic activity, and to the south by cretaceous sedimentary that includes sandstones, limestones, marlstones, and shales.

The island south of Ikot Ekpo, between the alluvial deposits of the Calabar River and the large Kwa River, has geology made up of coastal plain sand from tertiary deposits. For Calabar's development, this sand from the coastal plain is ideal. Typically, low-lying, swampy places appropriate for construction operations are where alluvial deposits are found. Asuquo (1998) notes that the predominant soils are light brown, grey, and white sand with clay, grey shales, carboniferous shales, feldspar pieces, and pest bands that alternate from 80' downwards. According to Short and Stauble (1967), the loose gravel, sand, silt clay, lignite, and sand are alternated with one other to form the coastal plain sand. Cretaceous Calabar flank and Precambrian Oban Massif serve as evidence for this.

The Calabar flank is a sedimentary basin in southern Nigeria that is bounded to the west by the enormous Oban Massif crystalline foundation group. According to Reijers (1998), the subsurface is defined by the NW-SE trending Ikang Trough and Ituk High, which link the Calabar flank to the South Atlantic Cretaceous marginal basin and its horst-and-graben-like formations in Angola and Gabon, respectively. The Niger Delta, the most recent of a series of basins to emerge in the Benue Trough, which cuts Nigeria diagonally from the southwest to the northwest, borders the features on the western arm (Petters, 1982).

Table 1: Attenuation, Conductivity and Velocity of various materials

Material	K	Velocity v (m/ns)	Attenuation ∝ (dB/m)	Conductivity σ (mS/m)
Air	1	0.30	0	0
Distilled water	80	0.033	0.002	0.01
Fresh Water	80	0.033	0.1	0.5
Sea water	80	0.01	1000	300000
Granite	4 – 6	0.13	0.01 – 1	0.01 – 1
Ice	3 – 4	0.16	0.01	0.01
Limestone	4 – 8	0.12	0.4 – 1	0.5 – 2
Shale	5 – 15	0.09	1 – 100	1 – 100
Dry Salt	5 – 6	0.13	0.01 – 1	0.01 – 1
Silt	5 – 30	0.07	1 – 100	1 – 100

Clays	5 – 40	0.06	1 – 300	2 – 1000
Dry Sand	3 – 5	0.15	0.01	0.01
Saturated(wet) Sand	20 – 30	0.06	0.03 – 0.3	0.1 – 1

(Source: David and Annan, 1998)

Table 2: Electrical conductivity of different soil type

Soils and Clays	**Electrical Resistivity**	**Electrical Conductivity**
Clay (general term)	1-100	10-1000
Loamy soil	4-40	25-250
Sandy soil	400-4000	0.25-2.5
Loose sands	1000-10^5	0.01-1
Clay-rich soil	100-400	2.5-10

2. Review of related literature

In order to assess the soil moisture, water content, and porosity in the farmlands of the settlements of Ekenkpon and Odukpani, George et al. (2017) used ground penetrating radar (GPR). Since the longest root of the crop can reach a depth of 1.8mm, the mean depth of 2.075mm was chosen for the calculation of the wave velocity in the soil. According to the study's findings, the soil at Ekenkpon measured 0.12245 mm3 and 0.4606 mm3 while at Odukpani it measured 0.1393 mm3 and 0.4556 mm3 respectively. These findings demonstrated that loamy soil and sandy soil make up the majority of the local soil types. So, for the purpose of precision agriculture, GPR has proven to be the most effective technology for hydro-geophysical soil characterizationThe soil water content of a 3 acre California vineyard's top 10 cm is estimated using the Ground Penetrating Radar (GPR) ground wave technology. In order to assess the water content, closely spaced GPR travel time measurements utilizing 900 and 450MHz antenna were conducted over a year. The gravimetric, time-domain reflectometry, and soil texture measurements are contrasted with the GPR estimate of water content. The findings of this study suggest that GPR ground wave can be used to quickly and non-invasively assess the shallow water volume of wide areas. With the largest inaccuracies occurring in extremely dry soils, volumetric water contents of 0.11 for the 900MHz data and 0.017 for the 450MHz data were found (Grote et al., 2003).

The spatial correlation of water content in a three-acre field was characterized by Grote et al.

(2010) using the GPR as a function of sampling depth, season, vegetation, and soil moisture/texture. With the aid of 450MHz and 900MHz antennas, the GPR data was collected. At four distinct intervals, the soil water content was estimated using measurements of the GPR groundwave. Using measurements of soil texture and time domain reflectometry, further water content estimates were discovered.

These results showed that shallow-rooted vegetation reduces regional variability whereas precipitation and irrigation enhance the spatial variability of water content. The study demonstrated that water content and soil texture generally have different small-scale spatial correlations, with deeper soil layers having a closer association between water content fluctuation and soil texture than shallower soil layers.It is challenging to quantify soil moisture consistently and geographically comprehensively (Bindlish et al., 2006). To improve our comprehension of water movement in soil and to determine the water content in it, non-destructive methods that can be used to directly estimate moisture content and give precise results with higher accuracy and resolution are needed (Nissen et al., 1998; International Atomic Energy Agency, 2008).The available methods are classified into two categories:

I. Direct methods and
II. Indirect methods.

When employing direct methods, measurements are made through calibrations against other measurable variables that fluctuate with soil moisture content (Evett and Parkin, 2005; Munoz-Carpena, 2012). The soil moisture is estimated by comparing the weights of a soil sample before and after it has been dried. All other methods fall under the category of indirect approaches; the only direct method is the gravimetric method or the thermostat weight technique. All of the techniques used to estimate soil moisture are based on the ground, with the exception of remote sensing.

2.1 Theory of Ground Penetrating Radar (GPR)

GPR is a geophysical method that employs electromagnetic radiation to find things or interfaces that are buried below the surface of the earth (Daniels, 2002). According to Conyers (2013), a GPR system typically consists of three parts: transmitting and receiving antennas, a control unit with a computer and related software, and a display device. Radar pulses are created by the transmitting antenna and are sent into the earth. The energy is absorbed, reflected, or scattered by the items buried in the ground. A fraction of the emitted radiations travel for a while before returning to the receiving antenna, where they are routinely evaluated to improve the signal-to-noise ratio and record the subsurface conditions with accuracy (Cassidy, 2009). The electromagnetic spectrum's VHS-UF area is where GPRs often operate. One wants to select the lowest frequency possible since low frequencies provide reasonably good earth penetration depths. However, a high enough frequency must be chosen to make the radar wavelength short, enabling the detection and resolution of tiny objects like pipes. The average center frequency for cart-mounted radars is 250MHz. However, frequencies as low as 20MHz are utilized to find deep caves or mine tunnels, and 500MHz and 1000MHz are occasionally employed for high resolution probing (Daniels, 2004).

A source antenna (Tx) is used to transmit radio wave pulses (between 100 MHz and 2.6 GHz) into the ground during GPR investigations. The earth's electromagnetic qualities cause the radio wave signal to be distorted as it travels through the planet. The reception antennas (Rx) then measure radio wave signals at limits where the subsurface electromagnetic characteristics abruptly change. Receiver antennas serve as transducers by transforming receiving GPR signals into electrical current since they are sensitive to the electric fields conveyed by radio waves. The voltage that results from the induced current is then digitally recorded. Finally, as a function of time, GPR receivers measure the amplitude and polarization of incoming radio wave signals. Since the raw data are eventually normalized, the amplitude and polarization of radio wave signals alter as they are distorted by earthly propagation. GPR uses radio waves to transmit information over relatively small distances and at speeds close to the speed of light (C=3.0 x 108 m/s) into the earth. GPR signals pass from the transmitter antenna to the receiver antenna, and as a result, their overall travel periods are quite brief. A single GPR short's time series can be recorded for up to a few hundred nanoseconds after the signal is created.

Data is acquired for a shorter amount of time after the transmitter emits the GPR signals, but, for GPR surveys intended to scan very close to the surface (resulting in a shorter journey time). GPR measurements for a single short can be repeated numerous times for the same transmitter-receiver pair at the same place (sounding) because they last for such a brief period of time. To replicate the various geological circumstances, a variety of models have been developed. The first model is a single profile to give a sense of how electromagnetic waves propagate through various materials and how electromagnetic characteristics (such as and) affect the wave. The second model is used to investigate how electromagnetic waves (reflected waves) from radar-grams travel through the geologic backdrop. Maxwell's formula. IEE, T. Anten 1966.

2.2 Velocity determination

The velocity of the wave is related to antenna spacing (a) reflector's depth d, and two-way travel time by:

$$V=\frac{2\sqrt{d^2+(0.5a)2}}{TWTT}(1)$$

The dielectric permittivity**(k)** is related to electromagnetic wave c by;

$$K = \binom{c}{v}(2)$$

Where: K = dielectric permittivity,

C = Velocity of EM wave in m/n,

V = Velocity of the wave GPR analysis.

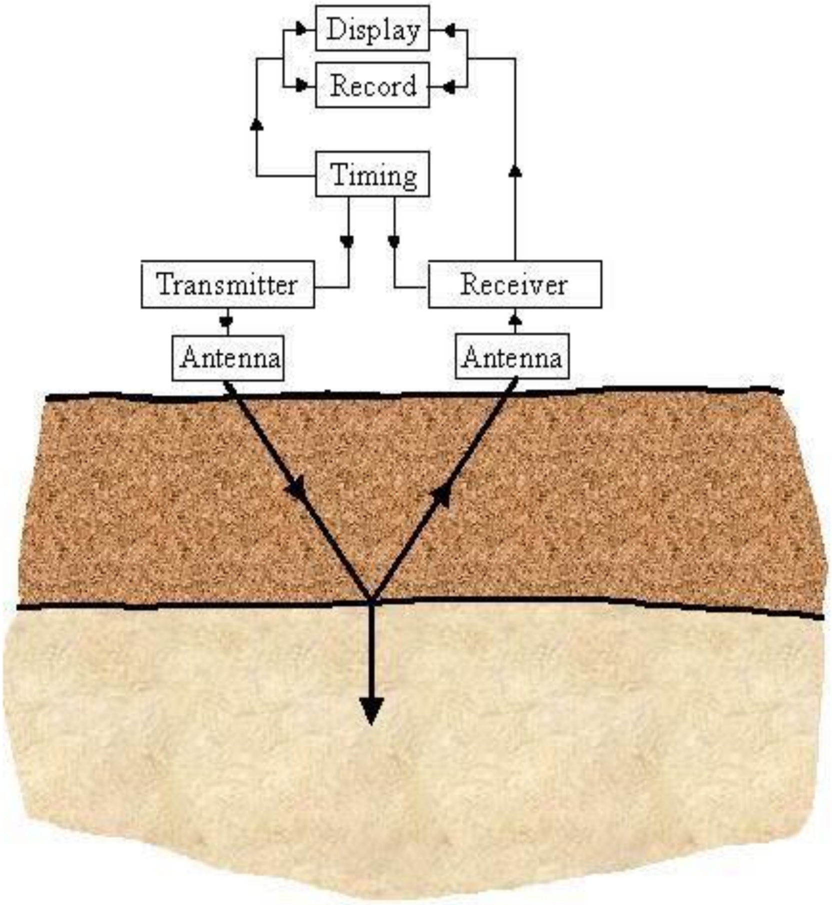

Fig 3: Diagram showing working principle of a GPR Apparatus

3. Materials and method

The materials used in this research work are;

1. MALA ProEx control unit
2. 200MHz pairs of unshielded antenna pairs (Transmitter and Receiver)
3. Ethernet cable
4. 0.6m antenna separator
5. Measuring tape
6. GPS (Global Positioning System)
7. Interfacing cable
8. PC with windows 7 or XP
9. Battery

The MALA ProEx control unit is a fast acquisition, processing and storage device.The MALA ProEx controller has parallel processors and uses a separate processor to handle each data stream.GPS (Global Positioning System): Irrespective of time, location, weather, GPS provides unparalleled range of services to commercial, military and consumer applications. Majority of these services enables airborne, land, and sea users to know their exact velocity, location, and time whenever and wherever on Earth.

Ethernet Cable:

- Ethernet cable lets you physically connect your PC to the internet.
- Ethernet connections are almost always faster than Wi-Fi connections, and are usually more stable.

3.1 Field Data Collection Procedure

The traverse and data collection were taken inside the Cross-River University of Technology, (CRUTECH) at various points. The antennas of frequency 200MHz were adopted as it has suitability for shallow depth of penetration. The antenna used is the unshielded antenna with the Transmitter and Receiver separated by a fixed distance of 1.0m and the whole system is moved at once with the transmitter and receiver at fixed distance of 0.6m. There is a connection between the GPR system unit and the antennas via three (3) cables, the Data cable (D), the Receiver cable (R) and the Transmitter cable (T). at this point, another cable is connected to a personal computer (PC) through the Universal Series Board (USB) port. There is an insertion of two batteries into the battery section on the antenna which powers them; one of the batteries is inserted on the optical module system, Thereafter, the system unit is turned on to enable some instrument parameters. At the point where the antenna switches are turned on, a ping sound with flash light is given out, which signifies that the equipment is ready to be used.

The GPR reflection data were gotten by the movement of both antennas across the ground surface at a constant or fixed interval of 1m by pressing the ENTER key on the PC at a point where the antenna was well positioned. In other to make survey easier and fast, a member of the field crews assisted in carrying the antennas while another held the cables to avoid cut. During the field work, five (5) profiles were taken across the entire location, with two at the first location, two at the second location and one at the CRUTECH farm.

Fig 5: Field work on GPR Survey(Aurthors Fieldwork 2023)

4. Results and Discussion

1. The raw GPR data was processed using RadExplorer 1.4 software by employing the following routines:
2. DC removal: In the event that there are any constant components in the signal, this routine removes them by setting the mean mode's start time to 0 ns and end time to 100 ns.
3. Time adjustment routine: This sets time zero, or the instant the wave actually departed the antenna, as the zero point of the vertical time scale. Should the instrument fail to recognize the field's zero time, this was done.Correct depths in the profile were ensured by this repacking (Awak et al., 2017). To choose the number of traces and samples, use 2D spatial filtering. To average the data inside the filter application window's

boundaries, a 2-D mean filter of this type was used. The number of traces was chosen based on the length of the profile.

Antenna properties for acquisition of GPR data

Antenna frequency	200MHz
Centre frequency	200MHz
Resolution	1.0m
Depth	7-12m
Number of samples	516
Trace number	According to profile length
Start time/end time	0/100ns
Antenna separation	0.6m
Background velocity	0.1m/ns
Air wave velocity	0.3m/ns

Farm land behind Department of Mass Communication building

DIST: 50 m

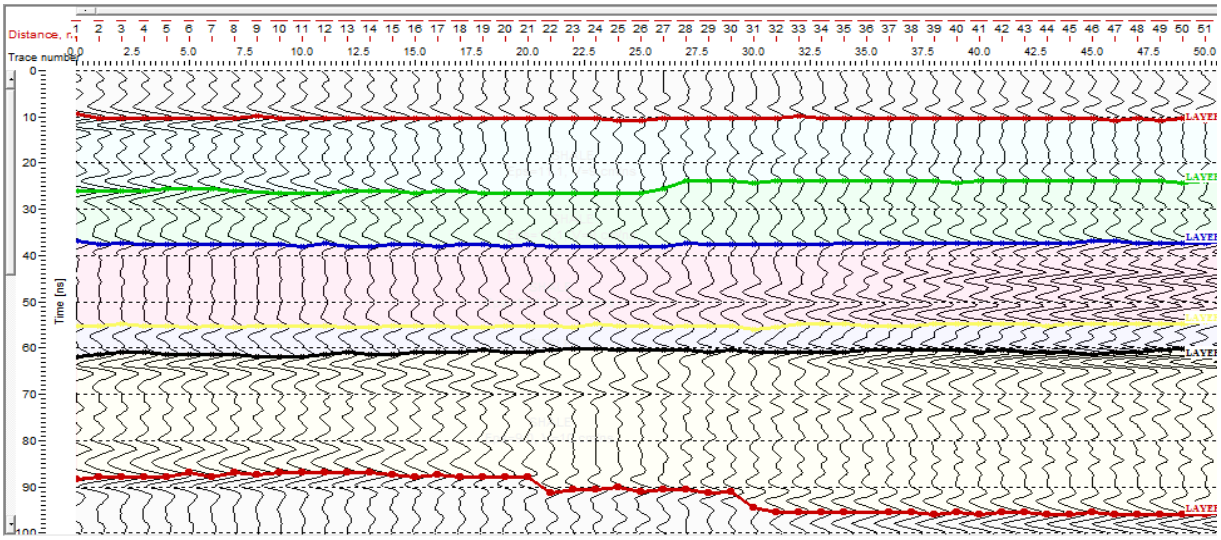

Fig. 1a: Raw data
Location: Farm land behind Mass Comm. building
Profile length: 50m
Av. depth: 2.075m, av. twtt: 40.012 ns, V = 10.4 cm/ns, K = 8.3
TW
TT = Two Way Travel Time

In Fig. 1a above, a profile length of 50m was carried out at the Farm land behind the Mass Communication building, and from the Raw data above, it is observed that there are several wiggles in each layer which entails water content.

Wiggles are due to the changes in dielectric constant that has caused deflection in the electromagnetic wave. So, the wiggles in the Raw data above are as a result of a deflection caused by water content present in the layer of the ground.

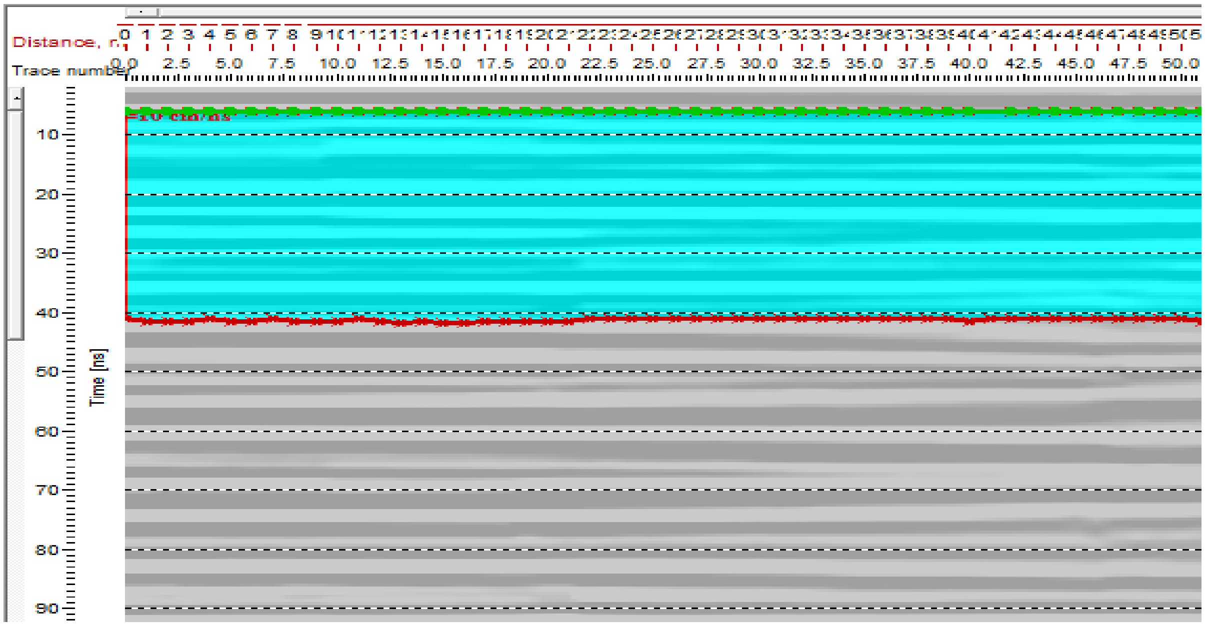

Fig. 1b: Model

Open field in front of PHYSICS DEPT.

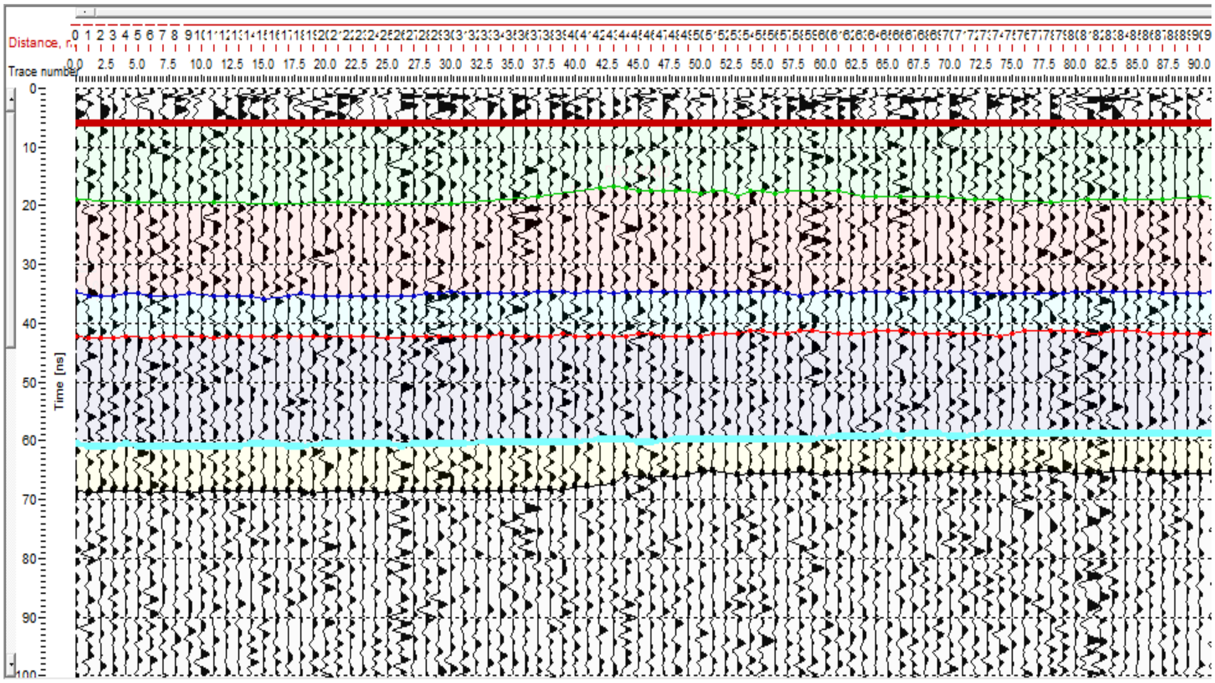

Fig. 2a: Raw data

PROFILE DISTANCE: 100m DIRECTION E-W: OPEN FIELD

AVE. DEPTH: 2.075m AVE. TRAVEL TIME: 37.727 ns (43.687 – 5.960)

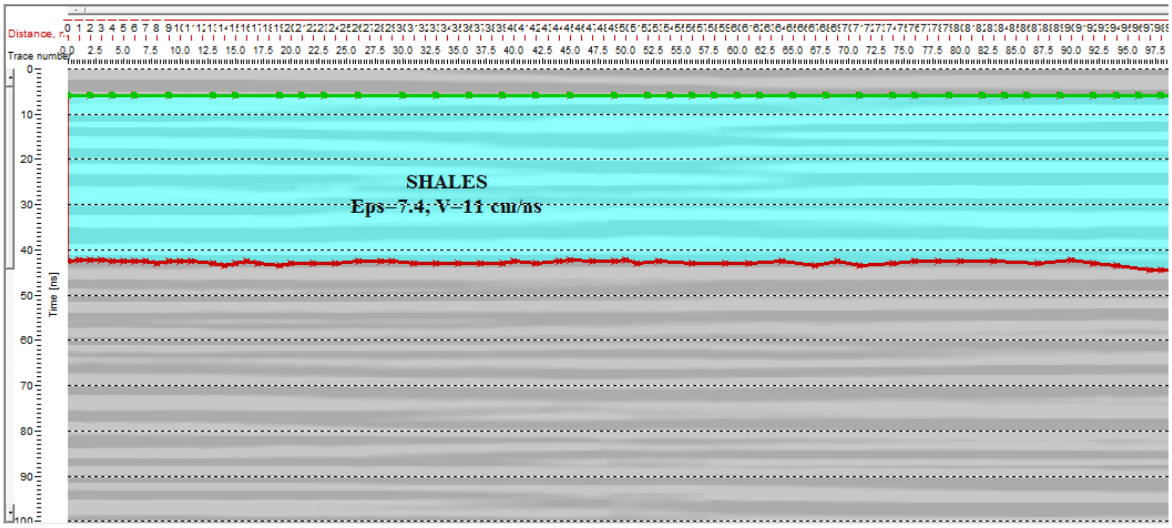

Fig. 2b. Model data

DISTANCE 100m DIRECTION: E-W: BEHIND MASS COM. BUILDING

MEAN. DEPTH: 2.075m MEAN. TRAVEL TIME: 33.417s

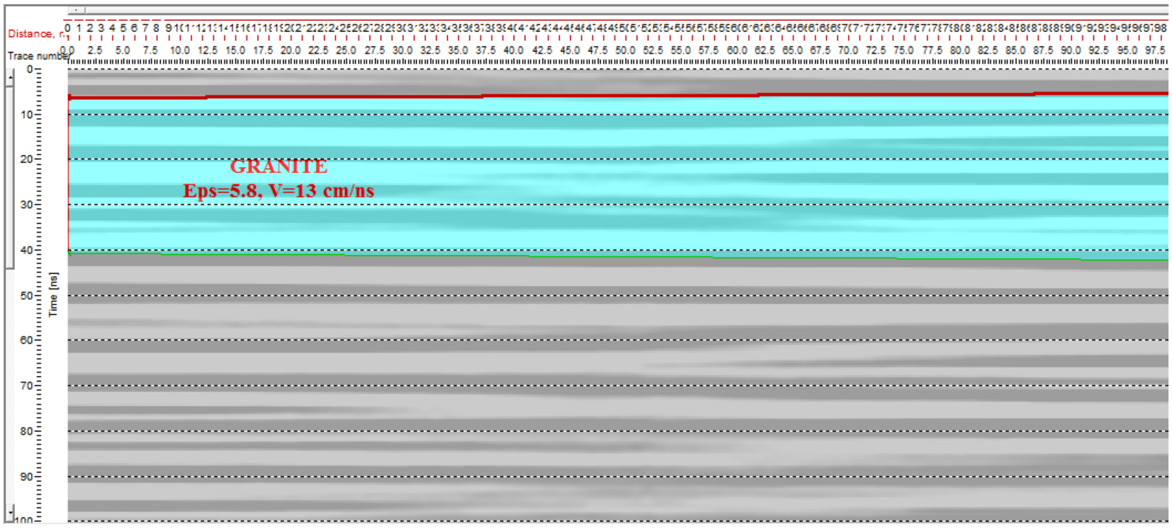

Fig. 2c. Model Data

DISTANCE 100m DIRECTION: N-S: CRUTECH Farm

Table 4, showing the results of the Average depth (m), Average Two-Way Travel Time (ns), Velocity V(cm/s), Dielectric constant (K), and the Soil moisture content **θ**(m^{3}m^{-3})

LOCATION	**Profile Length**	**Av. Depth (m)**	**Av. TWTT (ns)**	**V (cm/ns)**	**K**	**ϴ (m^{3}m^{-3})**
Farm land	50	2.075	40.012	10.4	8.3	0.1539
Open field	100	2.075	37.727	11.0	7.4	0.1347
Back of Phy.	100	2.075	33.417	12.5	5.8	0.0987

Dept.

According to George, Awak and Abong (2017[3]), soil water content θ is related to apparent permittivity K by Topp's equation.

From the table above, it is seen that the Average depth for all the profiles is 2.075m, but it is worthy to note the fact that the maximum length of every root is about 1.5m. So, for the fact that we are working based on the soil moisture content, we tend to increase the distance to be able to sort for better water content within that location.

From the values of the soil moisture contents gotten from three (3) different locations, it is observed that the soil moisture content at the Farmland is higher compared to others, which happens to be a suitable ground for vegetation and agricultural works; while that of the other locations at the back of Physics department consists of mostly shales. The range of values from my results shows that the study area is characterized by Loamy soil which was delineated from the general dielectric constant and the amount of soil moisture content in each layer which is dependent on the soil type. Loamy soil has a high level of water holding capacity and ability to drain away excess water. The particles allow free drainage after the rain or irrigation and water which is left moves downward. Loamy soil is not subjected to formation of cracks when it gets dry, which is of no harm to the root of plants.

Table 5: Shows the list of soil water contents expressed in different units for different soil.

Soil type	**Available water content (AWC)**		
	$(\mathrm{mm/m})$	$(\mathrm{m^2m^{-2}})$	(%)
Sand	25 – 100	0.025 – 0.1	2.5 – 10
Loamy	100 – 175	0.1 – 0.175	10 – 17.5
Clay	175 – 250	0.175 – 0.25	17.5 – 25

(Adapted from FAO Cooperate Document Repository, 1985)

Table 6: The ranges of water content that can support crop yield cultivated in the area

Crop	Available water content (mm/m)	
	Sandy soil	Loamy soil
Cassava (1st year)	40 – 64	70 – 112
Cassava (2nd year)	56 – 80	98 – 140
Pumpkin	80 – 120	140 – 210
Maize (field corn)	80 – 136	140 – 238

Maize (sweet corn)	64 – 96	112 – 168
Cucumber	56 – 96	98 – 168
Sweet melon	64 – 120	112 – 210
Water melon	64 – 120	112 – 210
Tomato	56 – 120	98 – 210
Sweet pepper	40 – 80	70 – 140
Groundnut	40 – 80	70 – 140

5. Conclusion

A single offset method of GPR has proven to be suitable to characterize the soil moisture content in the study area. The mean value of soil water content at the University of Cross-River State, Calabar, ranges from $0.26m^3m^{-3}$ to $0.39m^3m^{-3.}$ The study revealed that the study area is mostly composed of Loamy soil, which comprises of small particles of sand and silt. Loamy soil is composed mostly of sand, silt and a smaller amount of clay that form concrete-like consistency when dry and a sticky mixture when wet. Growing most plants and crops in Loam soil can be a preferable compared to other soils. Loam soil is the best type of soil because it contains all three of these components in almost equal amounts. One of the major contributions of this work is in contributing to the growing discuss sustainable food security, specifically, the result from this study indicated that planning precision agricultural programs and measuring the effectiveness of water use which depended on the monitoring of soil moisture content leads to crop yield maximization and minimization of damages by maximizing the use of the water and land resources by adapting the soil moisture content (SMC) to the particular agricultural crop. With increased field productivity and lower irrigation costs, optimization benefits the economy and the environment.

In conclusion, some parts of the Cross River University of Technology (CRUTECH), Calabar might be good location for farming since it is mostly composed of loam soil which describes the ideal soil composition for most garden plants. Furthermore, in consideration of the level of soil moisture content which makes the soil bearing capacity not to be compromised, the soil is also considered suitable for civil engineering construction and infrastructure.

References

Alfred D., Daniel, J., & Reza E. M. (2000). Handbook of Agricultural geophysics. Taylor and Francis, Boca Roton, FL, USA.

Amah, E. A., Ugbaja, A.N and Esu, E.O (2012). Evaluation of Groundwater Potentials of the Calabar Aquifers. Journal of Geography and Geology, 4(3), 130-140.

Amah, E. A and Esu, E. O. (2008). Geophysical and hydrological studies of shallow aquifers of Calabar area, South-Eastern Nigeria. International Journal of Environmental Sciences, 4(2), 78-90

Asuquo, F.E. (1998). Physiochemical characteristics and anthropogenic pollution of the surface waters of Cross-River, Nigeria. Global J. Pure Applied sciences 5: 595-600.

Awak, E. A., George, A.M., Urang, J.G. & Udoh J.T. (2017). Determination of soil Electrical Conductivity using Groundenetrating Radar (GPR) for precision Agriculture. International Journal of Specific and Engineering Research, 8(1): 1972-1975.

Bindlish, R., Jackson, T.J., Gasiewski, A., Klein, M., Njoku, E.G., 2006. Soil Moisture mapping and AMSR-E validation using the PSR in SMEX02. Remote Sens. Environ. 103, 127-139.

Bitteli, K., Flury, M., 2009. Errors in water retention curves determined with pressure plates. *Soil Sci. Soc. Am. J. 72, 1453-1460.*

Burk, L., Dalgliesh, N., 2008. Estimating Plant Availabile Water Capacity – a Methodology. CSIRO Sustainable Ecosystems, Canberra, 40p.

Cassidy N.J (2009). Ground Penetrating Radar data processing modelling and analysis: in ground penetrating modelling and application.

Conyers, L.B. (2003). Ground Penetrating Radar for archaeological, Rowman and Littlefield publishers Alta, Mira Press Lathon, MD, USA.

Daniels, D.J. (2004). Ground Penetrating Radar (GPR). The institution of engineering and Technology, London, UK: 1-4.

Davis JL, Annan AP. 1989. Ground-Penetrating Radar for High-Resolution Mapping of Soil and Rock Stratigraphy. Geophysical Prospecting, 37:531-551.

Edet, A. E. and Okereke, C. S. (2002). Delineation of shallow groundwater aquifers in the coastal plain sandy area (Southern Nigeria) using surface resistivity and hydrogeological data. Journal of African Earth Sciences, 35, 433-443.

Eni, D. I. and Effiong, J. (2011). Seasonal Variations in Hydrochemical Parameters of Groundwater in Calabar South, Cross-River State, Nigeria. British Journal of Arts and Social Sciences, 3(1), 85-97.

Esu, E. O., and Amah, E. A. (1999). Physiochemical and bacteriological quality of nature water in parts of Akwa-Ibom and Cross-River state, Southern Nigeria. Global Journal of Pure and Applied Sciences, 5(4), 525-534.

Evett, S.R., Parkin, G.W., 2005. Advances in soil water content sensing: the continuing maturation of technology and theory. Vadose Zone J. 4, 986-991.

Falloon, P., Jones, C.D., Ades, M., Paul, K., 2011. Direct soil moisture controls of feature global soil carbon changes: an important source of uncertainty. Glob. Biogeochemist. Cycles 25, GB3010.

Garten Jr., C.T., Classen, A.T., Norby, R.J 2009. Soil moisture surpasses elevated CO_2 and temperature as a control on soil moisture dynamics in a multi-factor climate change experiment. Plant. Soil 319, 85-94.

George, A.M., Awak, E. A. & Abong A.A (2017). Precision Agriculture using Ground Penetrating Radar (GPR): A case study of part of Odukpani Local Government area, Cross-River state, Nigeria.

Grote. K, Anger. C, Kelly. B, Hubbard. S & Rubin. Y. 2010. Characterization of Soil Water Content Variability and Soil Texture using GPR Groundwave Techniques. J. Environ. Eng. Geophys., 15:93-110.

Grote K, Habbard S. & Rubin Y. (2003). Field-scale estimation of volumetric water content using Ground-Penetrating Radar wave techniques. Water Resources Research: 39(11): 1-3

Ileoje, N. P. (1991). A New geography of Nigeria Longman, Nigeria. International Atomic Energy Agency, 2008. Field Estimation of Soil Water Content a practical guide to Methods, instrumentation and Sensor Technology. International atomic energy agency, Vienna, 141p. International Journal of Scientific and Engineering Research, 8(1): 1978-1980.

Israelson O.W., & West, F. L. (1992). Water holding capacity of integrated soils. Utah state Agricultural Experiment station Bulletins No. 183; 1- 24.

Jung, M., Reichstein, M., Ciais, P., Sheffield, J., Goulden, M.L., Bonan, B., et al., 2010. Recent decline in the global land evapotranspiration trend due to limited moisture supply. Nature 467, 951-954.

Madsen, H.B., Jenson, C.R., Boyson, T., 1985. A comparison of the thermocouple psychrometer and the pressure plate methods for determination of soil water characteristic curves. J. Soil Sci. 37 (3), 57-362,

MEA (Millennium Assessment), 2005a. Ecosystems and Human Well-Being. Current State and Trends Working Group. Island Press.

Mittelbach, H., Lehner, I., Seneviratne, S.I., Comparison of four soil moisture sensor types under field conditions in Switzerland. J. Hydrol. 430-431, 39-49.

Munoz-Carpena, R., 2012. Field devices for monitoring soil water content. Agricultural and Biological Engineering Department, University of Florida. BUL343. <http://edis.ifas.ufl.edu>.

Nissen, H.H., Moldrup, P., Henriksen, K., 1998. High-resolution time domain reflectometry soil probe for measuring soil water content. Soil Sci. Soc. Am. J. 62,1203-1211.

Pielke, R.A., Sr., Marland, G., Betts, R. A. Chase, T. N., Eastman, J. L., Niles, J. O., Niyogi, D., and Running, S.: 2002, “The influence of land use change and landscape dynamics on the climate system relevance to climate change policy beyond the radiative effect of greenhouse gases”. Phil. Trans. A 360, 1705-1719.

Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Phil. Trans. Roy. Soc. B. 365, 2959-2971.

Rao, B.H., and Singh, D. N. (2010). “Establishing soil-water characteristic curve of a fine-grained soil from electrical measurements.” *J. Geotech. Geoenviron. Eng., 136(5), 751-754.*

Rhymer, C.M., Robinson, R.A., Smart, J., Whittingham, M.J., 2010. Can ecosystem services be integrated with conservation? A case study of breeding waders on grassland. Ibis 152, 698-712.

Reijers, T. J. A. & Petters, S. W. (1987). Depositional Environment and Digenesis of Albian Carbonate in Calabar flank S. E. Nigeria. Journal of Petroleum Geology, (10), 283-294.

Seneviratne, S.I., Koster, R.D., Guo, Z., Dirmeyer, P.A., Kowalczyk, E., Lawrence, D.m Liu, C.-H., Mocko, D., Oleson, K.W., Verseghy, D., 2006b. Soil moisture memory in AGCM simulations: Analysis of Global Land-Atmosphere

Coupling Experiment (GLACE) data. J. Hydrometerol., 7, 1090-1112.

Seyfried, D. et al; (2015). Proceedings of SPIE, volume 4158, iii0 April to 2 May 2002. University of California, Santa Barbara, California.

Short, K. C. and Stauble, A. J. (1967). Outline Geology of Niger Delta. America Association of Petroleum Geologist, 51, 761-779.

Veihmeyer F. J. & Hendrickson A.H (1928). Soil moisture at permanent wilting of plants. Plant physiol, 3(3): 355-357

Veihmeyer F.J. & Hendrickson A.H. (1931). The moisture equivalent as a measure of the field capacity of soil: 33(3)

Wan, S., Norby, R.J., Ledford, J.F., 2007. Responses of soil respiration to elevated CO_2, air warning, and changing soil water availability in a model Oldfield grassland. Glob. Change Bio. 13,1-14.

Western, W.A., Grayson, R.B., Blöschl, G., 2002. Scaling of soil moisture: a hydrologic perspective. Annu. Rev. Earth Planet. Sci. 30, 149-180.

Zhang, R., Wienhold, B.J. The effect of soil moisture on mineral nitrogen, soil electrical conductivity, and pH. *Nut. Cycl. A.*

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