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Soil Mapping of Physical Properties Using GIS on A Toposequence In Faculty of Agriculture Farm, Shabu-Lafia Campus, Nasarawa State University Keffi, Nigeria.

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Abstract
Field studies were conducted in the University/Faculty of Agriculture farm, Shabu community – Lafia, Nasarawa State, Nigeria with the objectives of investigating the spatial variability of some physical parameters. A total of seventy soil samples were collected at 0-30 cm depth (root zone) through regular grid sampling of 120m x 105m grid size interval. The soil samples were analyzed for some physical properties using standard laboratory procedures. Results obtained showed that the soils were mostly sandy in texture, low in cone index(0.20-7.00kg/cm) and high in bulk density (1.52-1.82g/kg), low in clay content and water holding capacity. Results of the physical soil parameters were interpolated using Inverse Distance Weighted (IDW).

Keywords: *Interpolation, Mapping, Physical properties and Toposequence*.

Introduction

Topography is an essential factor in determining the variability of soil properties and nutrient distribution especially in a non-uniform agricultural landscape. Therefore, good knowledge of variability on soil physical properties of croplands with different topography is necessary for sustainable agricultural production of such land (Amuyou and Kotingo, 2015)

According to Wild, (1993), soil is the combination of loose weathered minerals (rock materials) and decayed organic matter, found on the earth's surface. This ecosystem (source of life) is considered the most vital and valuable natural resource. In essence, the soil plays an important role in an ecosystem by providing a medium for plant roots growth and development by tapping available nutrients and water in form of soil solution critical to the entire plant life cycle (Brady and Weil, 1999; Tandon and Muralidharudu 2010).

Soil properties are classified into two (physical and chemical properties) as highlighted in Brady and Weil, (2002) and McClauley and Jacobson, (2005) but With respect to this study, we are focusing on physical parameters. These soil properties viz infiltration rate, water holding capacity, permeability, aeration, plasticity, texture, structure, bulk density among others which are influenced by size, proposition, arrangement and mineral composition of the soil. They are dynamic in natural (changes) due to the impact of both natural and human derived factors under which the soils are located (Aweto and Dikinya, 2003; Ayoubi*et al*., 2011; Agarwal, 2012).

The use of geo-statistical tools in recent time/years and the introduction of the digital soil mapping by spatial prediction in combination with Global Positioning Systems (GPS) data, and Geographic Information Systems (GIS) have all accelerated modeling, remote sensing and predictions of landscape study. This has resulted in the demarcation of potential areas of low or high nutrients distribution (Burrough and McDonnell, 1998; Webster and Oliver, 2001). In order words, geo-statistical mapping has been used to produce maps for soil physical properties status, through which the levels of nutrient availability and threshold values that can be used to measure such lands, and such values could be useful in designing trials with the objective of formulating fertilizer recommendations and management practice considered most appropriate in such locations, at regional or country scale (Goovaerts, 1997) with a view to ensuring efficiency in the management of soil (McCauley *et al.,*1997). Hence, it is essential to adapt new technologies for the purpose of improving soil management and quality as well as cost control/benefit results in agricultural production like Geospatial Technology (Iftikar *et al.,* 2010; Markoski *et al.,* 2015). Advance technologies used by specialists in the field of soil science have estimated and mapped the soil fertility distribution of un-sampled locations, using interpolation techniques like Inverse Distance Weight method (IDW). The objective of this study is to analyze the spatial variability of physical parameters using GIS and geo-statistical tools to support soil management practices for optimal utilization of land for crop production.

Materials and Method

Details of the Study Location

The study site is between latitude 8° 34'02.18" N and 8° 33'55.06" N and longitude 8° 33' 02.96" E and 8° 33' 17.38" E, with two (2) main seasons (wet and dry seasons) according to NIMET weather data for Lafia (2017), annual average temperature ranges between 31.8 ^{O}C to 21.6 ^{O}C, with an average of 26.8 ^{O}C. The months of May and January are the hottest and coolest respectively (NIMET weather data for Lafia 2017) *Climate-Data.org*. The studied area falls within the Guinea Savannah vegetation/belt, it is covered by open savannah woodland consisting of trees and grasses of varying heights. The topography of the land is slightly undulating (high to low), Shabu community, a suburb and a gateway to the city of Lafia, Nasarawa State capital is located in the North Central Region of Nigeria.

Sampling Materials and Details of Field Studies

The following materials were used in the soil sample collection:- Global Positioning System (GPS), marker, auger, core samplers, bowl/tray, sampling bags, recording book, biro/pencil, spade, masking tape, eraser among others. A total of seventy (70) sampling points were generated using regular grid sampling with 120m x 105m grid size interval as shown in figure 5. Soil sampling was carried out using soil auger from 0- 30cm depth (root zone) into a bowl. Soil samples were kept in labeled plastic containers and transferred to the Laboratory for routine analysis of physical characteristics as depicted in the figures below.

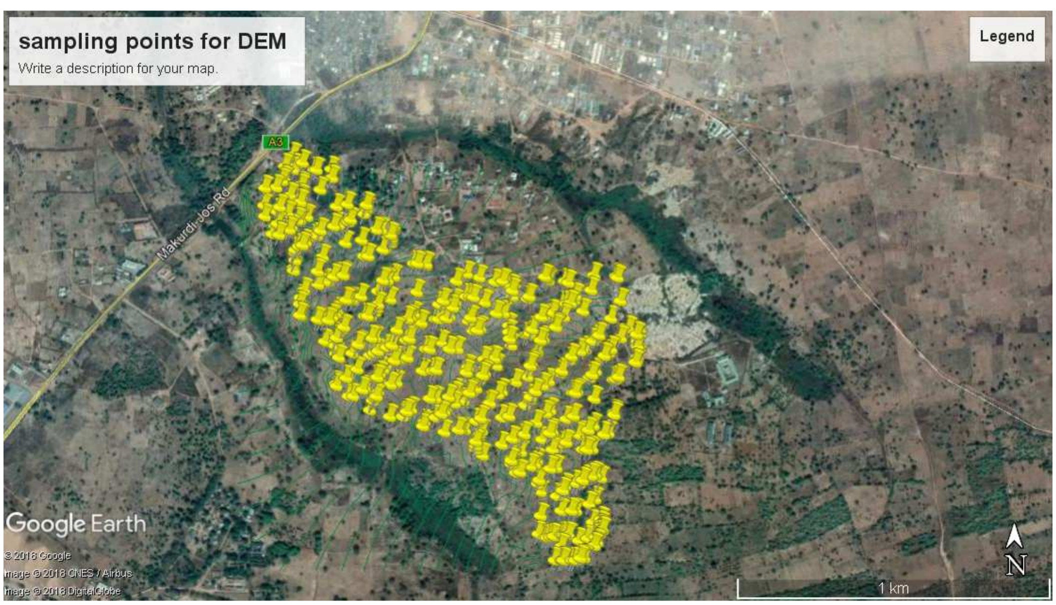

Figure 1: Sampling points for generation of Digital Elevation Model (DEM).

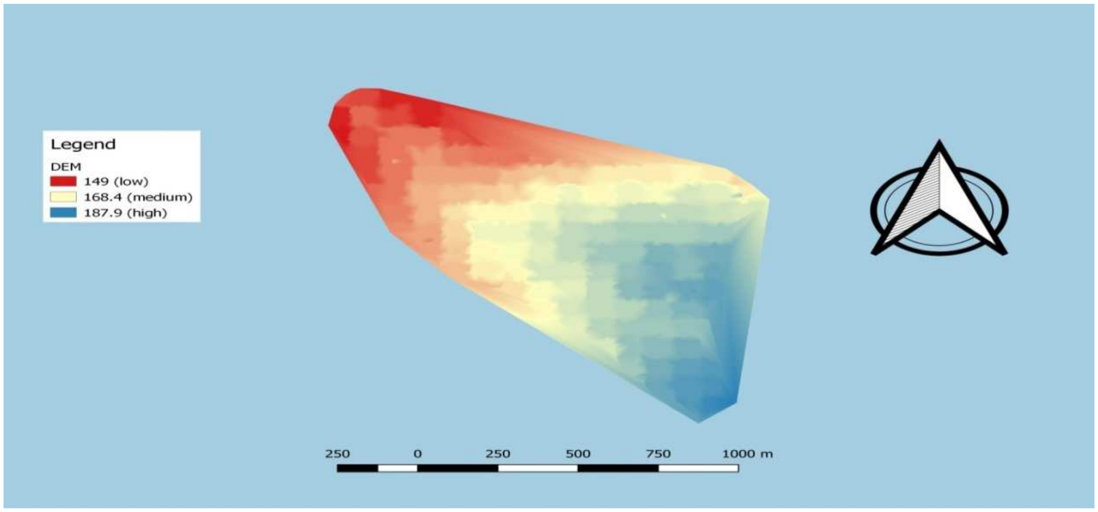

Figure 2: Digital Elevation Model (DEM) of the Study Area

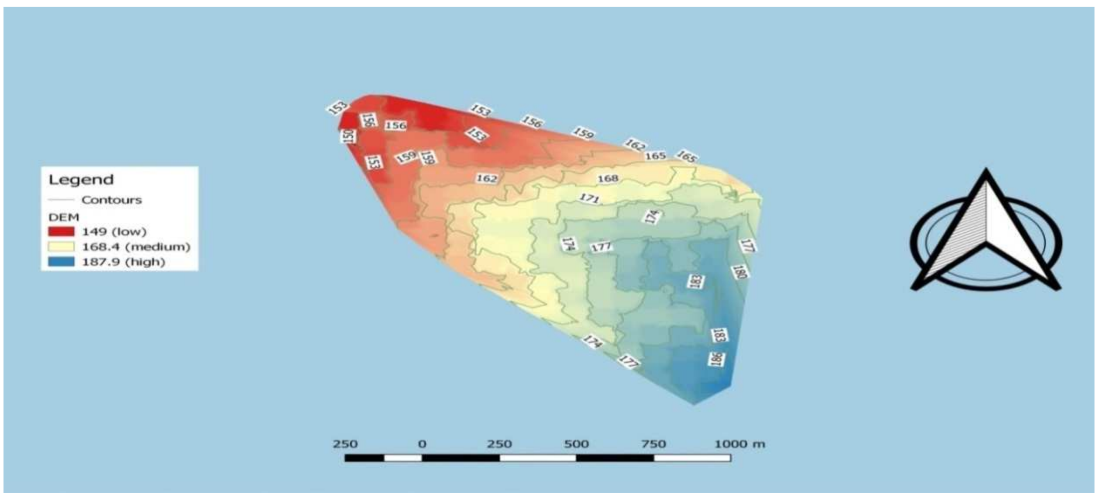

Figure 3: Contours showing variation in Elevation

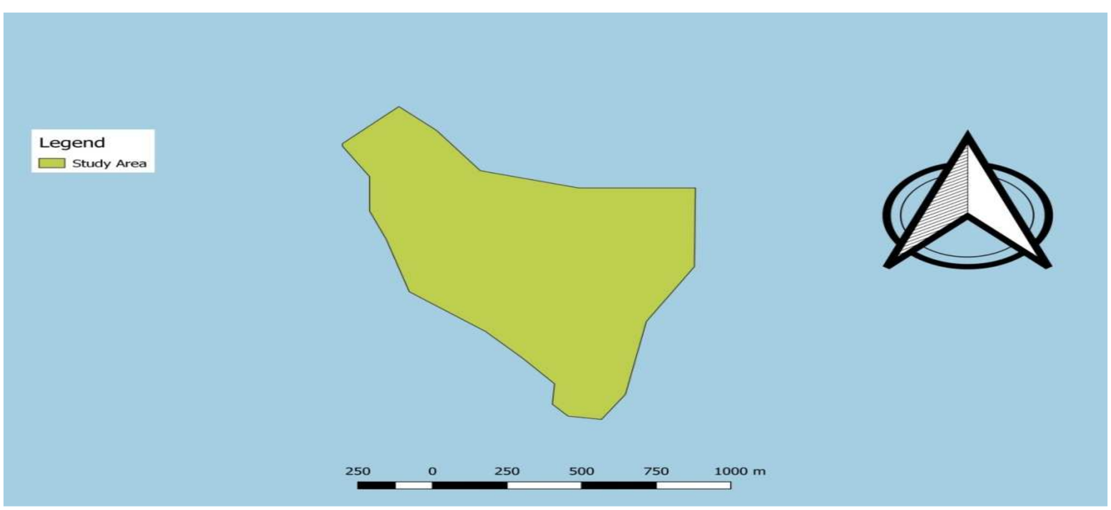

Figure 4: Shapefile of the study location on QGIS

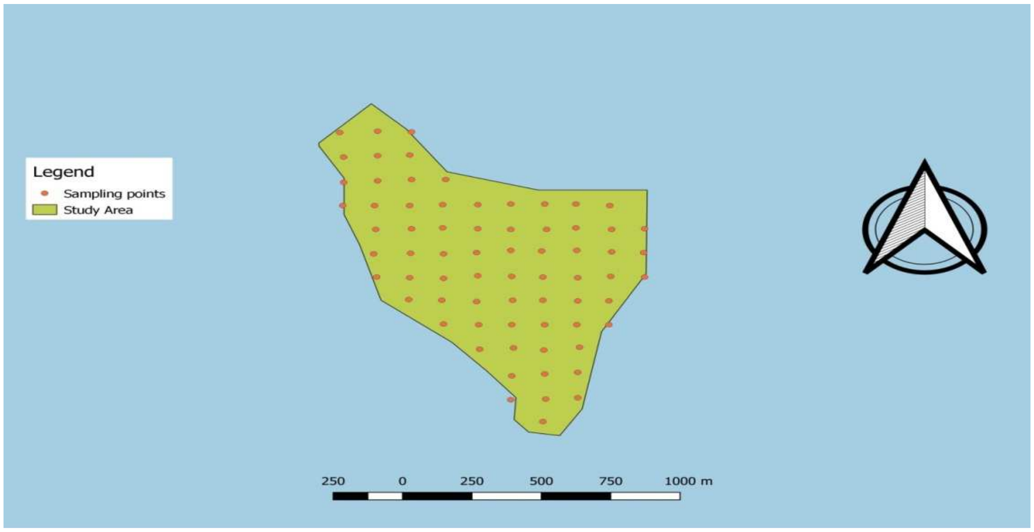

Figure 5: Seventy (70) sampling points for physical analysis.

Laboratory Analysis

The soil samples were air-dried, crushed/grinded and sieved through a 2 mm sieve (10 mesh). Particle Size was done using sedimentation - Bouyoucos hydrometer method (Gee and Or, 2002) as explained by Agbenin, (1985). Bulk density was determined using procedures described by Agbenin (1985), Bulk densities were determined by taking wet soil samples with known weighed metallic cans/core samplers. The wet soils collected from the field with known weight of metallic cans were weighed on the field. Then, the samples were oven dried to a constant weight/mass at 105°C as described by (Klute 1987). The determination of particle densities were done when the entrapped air in soil sample was removed using the pycnometer method as described by Blake and Hartge (1986) as described by Agbenin (1985), Dhyan*et al.,* (2005). That is a clean, dry pycnometer was weighed, filled to half of soil and weighed again.

Soil moisture was determined using metallic can/core sampler without and with its content was weighed in the field and the sample oven dried at 105ºC to a constant mass in the laboratory. The moisture content was determined at field capacity for the 70 samples as described by Klute (1987) method as described by Agbenin (1985), Dhyan*et al.,* (2005). Total porosity was determined when the sum of pore spaces tagged total porosity of soil was determined mathematically or calculated from the data generated from particle density and bulk density determinations as described by Anderson and Ingram (1998), and by Tandon (2009).

Results and Discussion

Particle Size Analysis of Soils

The sand particle values obtained from 70 soil samples varied/ ranged from 55.00 to 96.00 (mean = 90.06) % as shown in Table 1 above. It was observed that the proportion of sand in most sample points were high and dominant as delineated in blue colour, while some low values also observed in some locations of the studied area figure 6 below**.** Silt values/content on the other hand varied from 3.00 to 24.00 (mean = 6.31) % - Table 1 above. The silt content was observed to be low as represented in red colour, except for some few sample points that showed higher silt content as represented in blue colour in figure 7 below. The clay values/content equally varied from 2.00 to 21.00 (mean = 3.69) % Table 1 above. It was observed that the study area was dominantly low in clay content as delineated with red colour. While some few sampled points showed high clay content as represented in blue colour figure 8 below. These few sampled points that displayed high content of clay, silt and low sand gave *sandy clay loam* textural class of soil taxonomy. This may be attributed to the undisturbed portions (*cashew stands and fallowed portions*) of the study area maps 6, 7 and 8

Table 1: Soil Physical Properties

	Particle size distribution			**Penetrometer Readings**		**%**		**Bulk density(gcm^{-3})**
	Corrected to 20°C					Moisture content (%)	Total porosity	
	Clay (%)	Silt (%)	Sand (%)	(mm)	(kg/cm^3)			
Min	2.00	3.00	55.00	0.80	0.20	6.06	31.40	1.52
Max	21.00	24.00	96.00	20.00	7.00	14.28	45.00	1.82
Mean	3.69	6.31	90.06	10.17	2.46	9.19	35.93	1.70

In other words, The laboratory analysis (particle size analysis) revealed that the most dominant soil type of the study area was sand while sandy clay loam was the least soil type (Table 1) .ie sand fraction dominates the particle size distribution, while silt fractions was followed by clay fractions. This corroborates earlier reports by Malgwi, *et al.,* (2000) and Shobayo (2010) in their works within the Zaria region of guinea savannah vegetation and Jimoh *et al.,*(2016). Weathering process of granitic origin parent materials may have produced a class of soil high in sand fractions (Wilson, 2010).

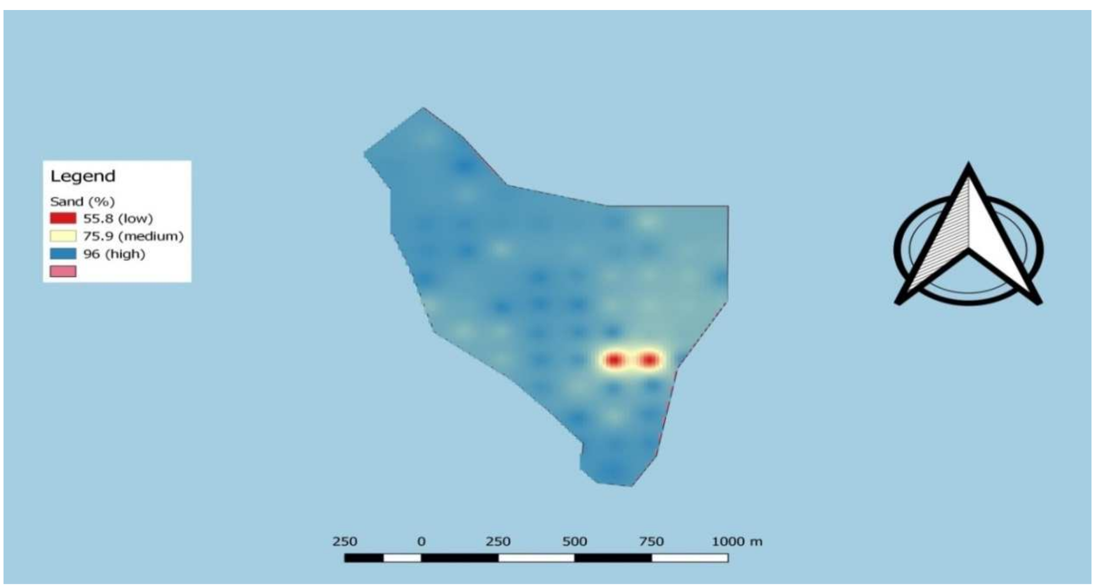

Figure 6: Map of the study area showing spatial distributions of sand particle.

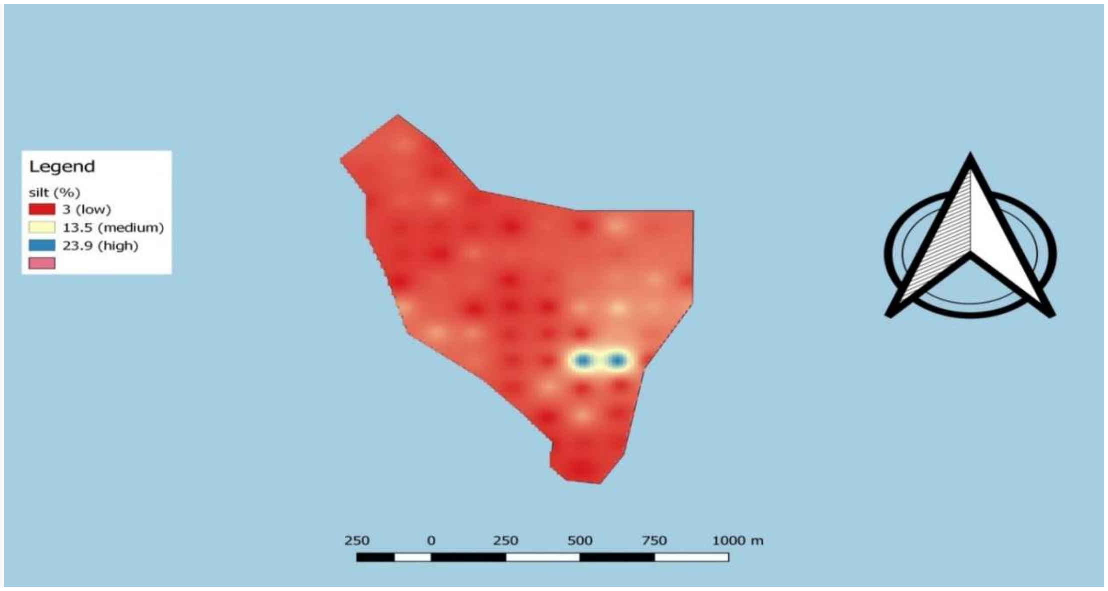

Figure 7: Map of the study area showing spatial distributions of silt.

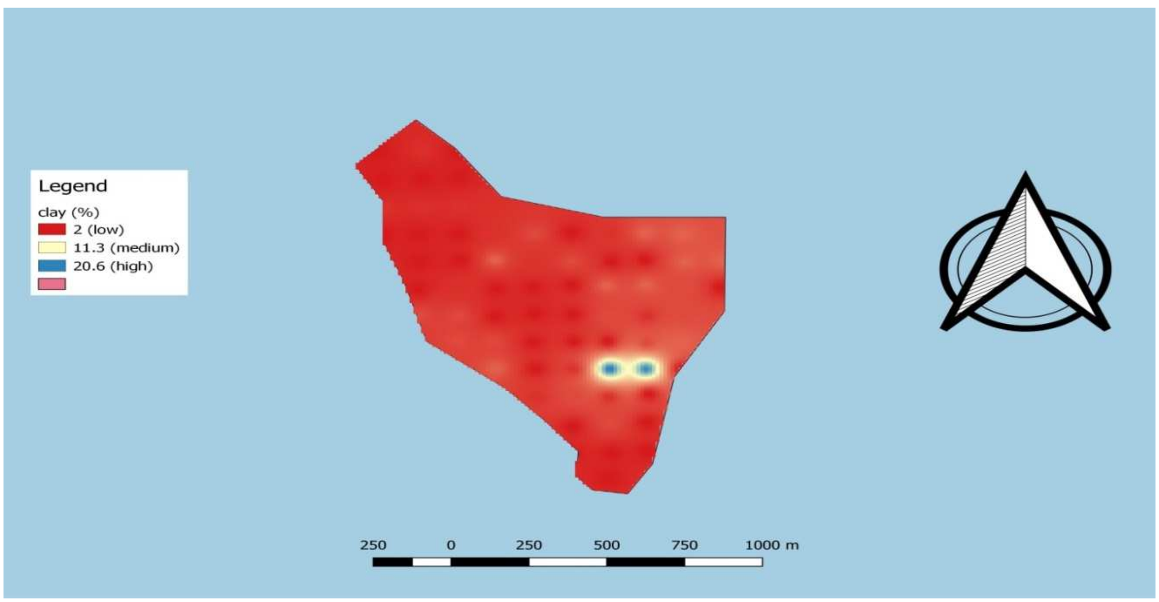

Figure 8: Map of the studied area showing spatial distributions of clay distribution.

Bulk Density (BD) and Total Porosity (TP)

The bulk density values obtained from 70 soil samples of the studied location/area varied from 1.52 to 1.82 (mean = 1.70) g/cm^3 - *Table 1* above, an indication of a sandy soil or textured class. This work corroborates earlier reports by Aminu and Jaiyeoba, (2015) on sandy soil with 1.80g/cm^{3}BD, Landon (1991) concluded that BD values greater than 1.75 g/cm^3 have no negative effect on root penetration and development, this concord with (Donahue *et al.,* 1990). The 1.82g/cm^3 bulk density is influenced by the predominate high fractions of sand particles, an indication that movement of water and air in the soils are optimum for growth and development of plants (Esu, 2010). Hence, such bulk density may not be a threat for workability and crop

production/cultivation on this soil, though there may be high rates of evaporation. The study area is dominated by high bulk density represented in blue colour followed by the medium/moderate bulk density (yellow colour) and low bulk density (red colour) - figure 9 below.
Equally, total porosity (pore spaces) values of the studied location/area varied from 31.40 to 45.00 (mean = 35.93) % Table 1 above. It indicates that the studied area is predominately sandy soil which agreed with (Obi, 2000; Agarwai 2009) that pore spaces for sandy soil are about 35- 60%; 30% respectively while pore spaces for clay soil ranges between 30 -70%; 50 - 60% respectively. ie clay soils tend to possess greater number of pore space than sandy soils and for peat as high as from 80 – 85% (Obi, 2000). Hence, sandy soils have more macro pore spaces compared to other textural classes of soils and do not pose drainage threat due to the porous nature of the soil

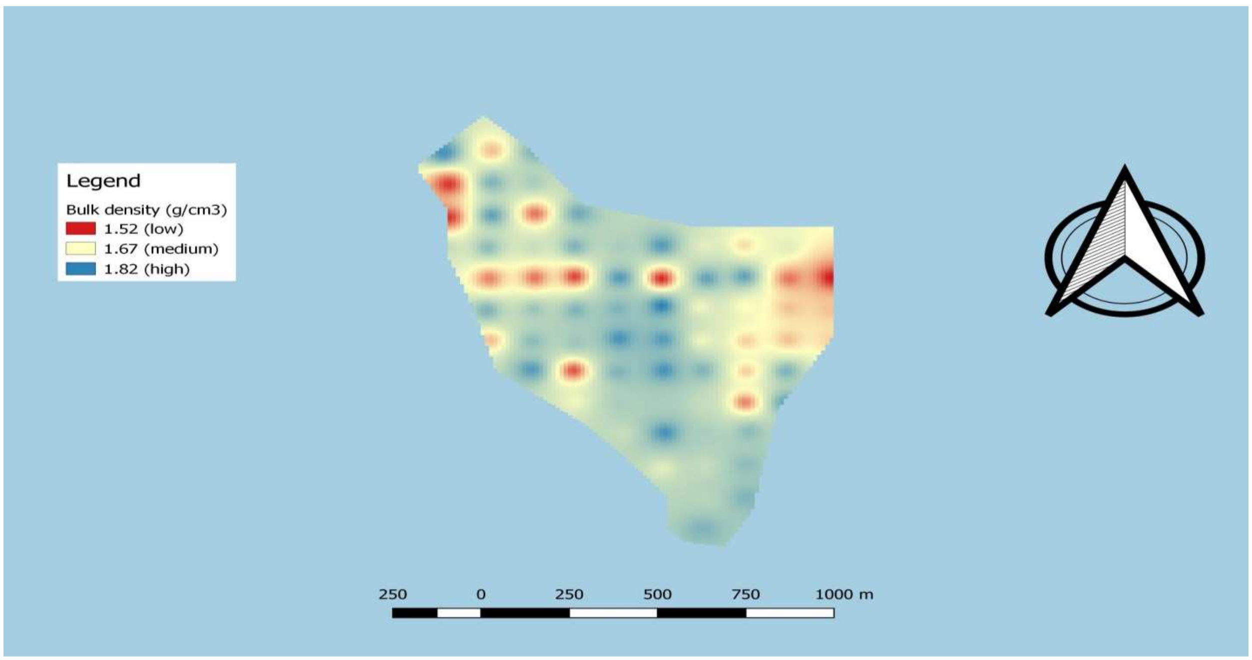

Figure 9: showing bulk density of the studied area across.

Soil Moisture.
Soil moisture values obtained from 70 soil samples of the studied area varied from 6.06 to 14.28 (mean = 9.19) % Table 1 above. The dominant textural class of the studied area was observed to be sandy soil and the mean value (9.19) percent is rated low. Therefore, water holding capacity of a sandy soil is low due to large numbers of macro pore spaces that dominates; this creates room for high rate of evaporation of water from the soil surface. Crop cultivation in sandy soils requires frequent water application (irrigation) especially at dry season to enable crops/ plants complete their life cycles. This low water holding capacity of the studied area is represented in red colour. Medium to high values are represented in yellow and blue colours respectively as reflected on figure 10 below.

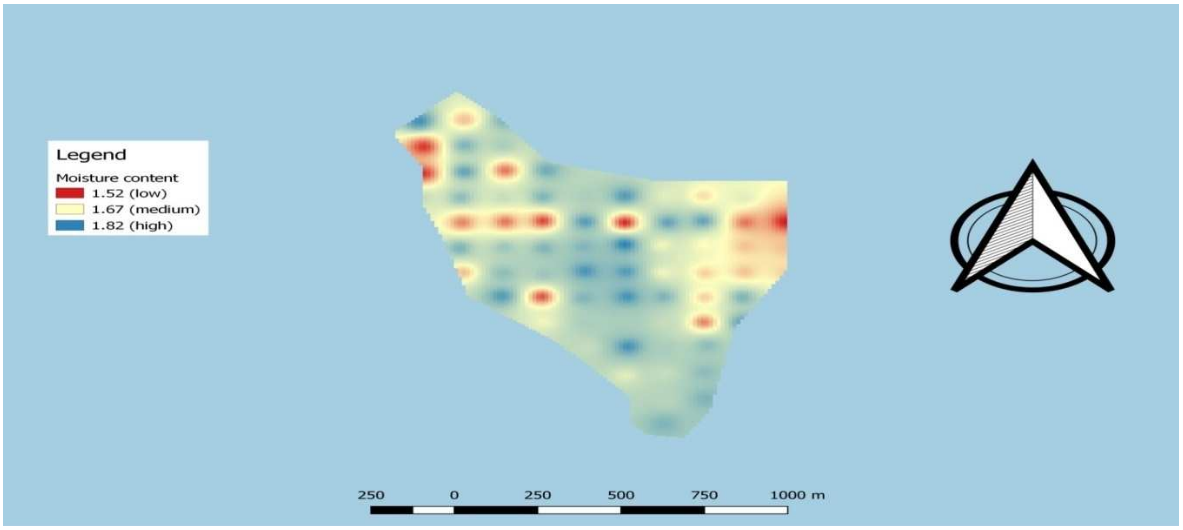

Figure 10: showing the soil moisture of the study area.

Soil Surface Resistance.

Soil surface resistance values obtained from 70 sample points of the studied area using penetrometer varied from 0.80 to 20.0 (mean = 10.17) mm and 0.20 to 7.00 (mean = 2.46)kg/cm^2 - Table 1 above. The resistance posed by the soil surface to the penetrometer penetration was observed low, this indicates no hard pan development, less or no resistance to seed germination and root penetration, less nutrient loss through runoff, enhance gaseous exchange between the soil surface and the atmosphere and workability as well .

From the map 12 below, the low cone index of penetrometer is represented in red colour, medium cone index represented in yellow colour, while high cone index is represented in bluish colour.

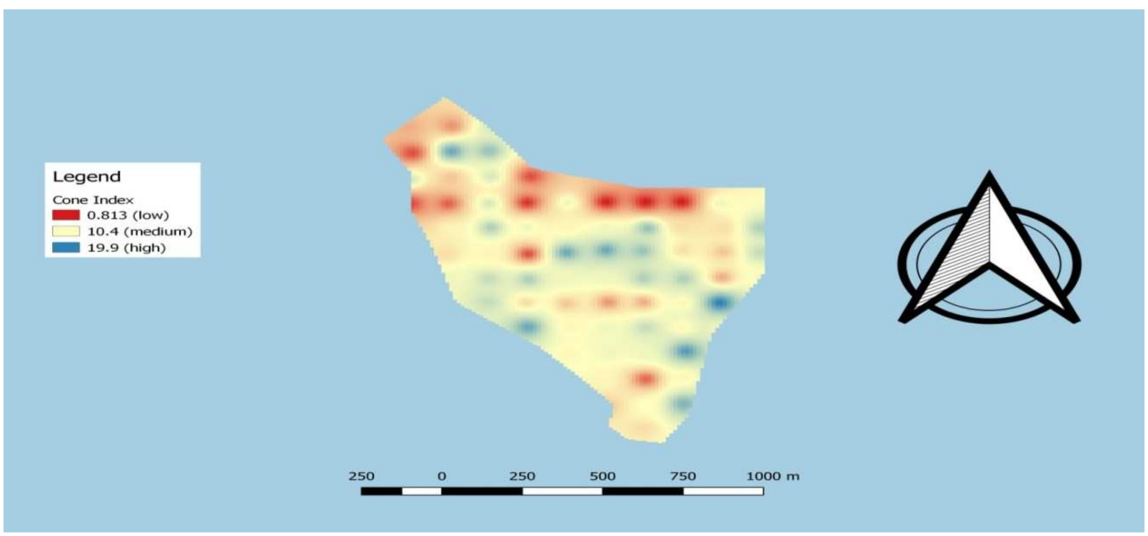

Figure 11: Show the soil surface resistance of the study area**.**

Conclusion

It can be concluded from the results obtained in the studied soils that, the soils are dominantly sandy, bulk density were high, moisture content were low and low in clay content as well. Based on the above observations, for successful crop production in the area studied, it is recommended that concerted efforts should be geared towards improving the soil texture, water holding capacity, bulk density and soil structure in all locations.

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