ZEAL SCIENTIFIC PUBLICATION

World Journal of
Advanced Science and Tehnology

Journal homepage: https://zealjournals.com/wjast/

(Research Article)

Suitability of soil in Ukpiovwin community in Udu LGA of Delta state for oil palm plantation based on its physicochemical properties

Blessing Ojochenemi Emiovwoo * and Duke Okoro

Department of Chemistry, College of Science, Federal University of Petroleum Resources, Effurum, Delta State, Nigeria.

World Journal of Advanced Science and Technology, 2024, 05(02), 068–073

Publication history: Received on 17 May 2024; revised on 26 June 2024; accepted on 28 June 2024

Article DOI: https://doi.org/10.53346/wjast.2024.5.2.0036

Abstract

Soils of Ukpiovwin community in Udu LGA of Delta State were evaluated for suitability for oil palm cultivation based on its physicochemical properties. Suitability of soils for oil palm was assessed using FAO's land and soil requirement and suitability ratings. Soil texture classes identified were dominated by clay. The soils were slightly acidic, with pH ranged from 4.49 to 6.40. The results showed that certain land characteristics such as, mean annual temperature, rainfall, soil depth and drainage were rated highly suitable (S1) to marginal suitable (S2), organic matter, total nitrogen, and potassium were rated highly suitable (S1) Available phosphorus and ECEC were generally low and rated as marginally suitable (S3) for oil palm cultivation in the study area. The main limiting factors that lower the suitability of these soils for oil palm establishment in the area were the soil texture which is clay and the low level of phosphorus available the soil. In order to enhance the soil condition and raise the productivity of the land to an ideal level, focus should be put on soil management practices that will improve the soil's ability to effectively drain water in order to prevent water logging and keep water at ≥20cm below soil surface. The amount of phosphorus available in the soil can be increased through the application of phosphate fertilizer and through installation of erosion control measures such as bunds, platforms, and terraces to lessen losses of native and applied phosphate in surface run-off water and eroded soil.

Keywords: Ukpiovwin; Soils; Oil palm; Physicochemical; Production

1. Introduction

Oil palm is generally believed to have originated from the tropical rain forest of West Africa. (FAO 2002). Oil palm tree is one of the largest oils producing perennial crops (Murphy et al., 2021). As of 1965, Nigeria was the world's top producer and exporter of oil palm (Bassey 2016). Nigeria was surpassed by Malaysia and Indonesia in terms of global palm oil production in 1966. One of the most significant impediments to oil palm cultivation in Nigeria is a lack of knowledge about soil fertility and effective management techniques. Suitability is a measure of how well the features of a land unit matches the requirements of a specific form of land use (FAO 1993). For agricultural purposes, soil suitability depends on the crop requirements and the characteristics of the land (Oviasogie *et al.,* 2020). The suitability of the soil for crop growth is influenced by a number of variables, including soil pH, water availability, air, space for root growth, and structure of the soil (Parikh *et al.,* 2012). The levels of suitability are usually classified into three categories: highly suitable land (S1), moderately suitable land (S2) and marginally or poorly suitable land (S3). Identification of the main production barriers and solutions can be achieved by conducting a suitability evaluation of the area that supports oil palm (Ogunkunle 1993). The physicochemical characteristics of the soil greatly affect the soil quality (Raju *et al.*, 2017). The physical and chemical characteristics of soil are classified into those that directly influence crop growth, such as water, oxygen, temperature, and soil resistance, and others that indirectly influence crop growth, such as bulk density, texture, aggregation, and pore size distribution (Ingole 2015). The physical characteristics of the soil, such as its depth, texture, and structure, are crucial in assessing whether it is suitable for large-scale oil palm planting (Mutert 1999). The

* Corresponding author: Blessing Ojochenemi Emiovwoo

ability of the soil to give water to the crop is controlled by its physical features, which are more significant than its chemical ones because they cannot be easily changed by management (Rhebergen *et al*., 2016). According to Popkin *et al*., (2022). The best types of soil for growing oil palm are loamy or alluvial, well-drained soils: rich in organic matter, pH 4.0 to 6.8, at least one meter deep for root development, and with enough soil moisture. Oil palm is well adapted to a variety of soil types and tolerates low pH levels but does not perform well at very high pH levels (higher than 7.5) (Mutert 1999). The oil palm production cycle, which lasts for around 25 years, is made up of various stages, each with its own unique nutrient demand requirements (Prabowo *et al.,* 2023). A sufficient supply of macro- and micronutrients is necessary for efficient plant cultivation. Lack of nutrients prevents plants from growing properly (Popkin *et al.,* 2022). The nutrients required by oil palm in large quantity (macro nutrients) are nitrogen, potassium, phosphorus and magnesium. Oil palm is one of the most important economic cash crop which through the advancement of science, is now been cultivated in different parts of the world. Thus, this study was therefore designed to assess the potentials and limitations of soil properties and their suitability for oil palm cultivation in the study area.

2. Material and methods

2.1. Study Area

The study area is located within Ukpiovwin community in Udu local government area of Delta State. It is situated at latitude 5° 26' 41" N and longitude 5° 50' 43" E. The entire study area is approximately 8 hectares. And it is 5.3 km away from the train station which is located in the neighbouring town of Ujevwu also in Udu local government area of Delta state (Figure 1). It is a tropical environment with a climate that is hot and humid with seasonal rainfall, high temperatures and high relative humidity. Dry and Rainy season are the two distinct seasons experienced throughout the year. Typical rainy season is from March and November while the dry season is between December and February

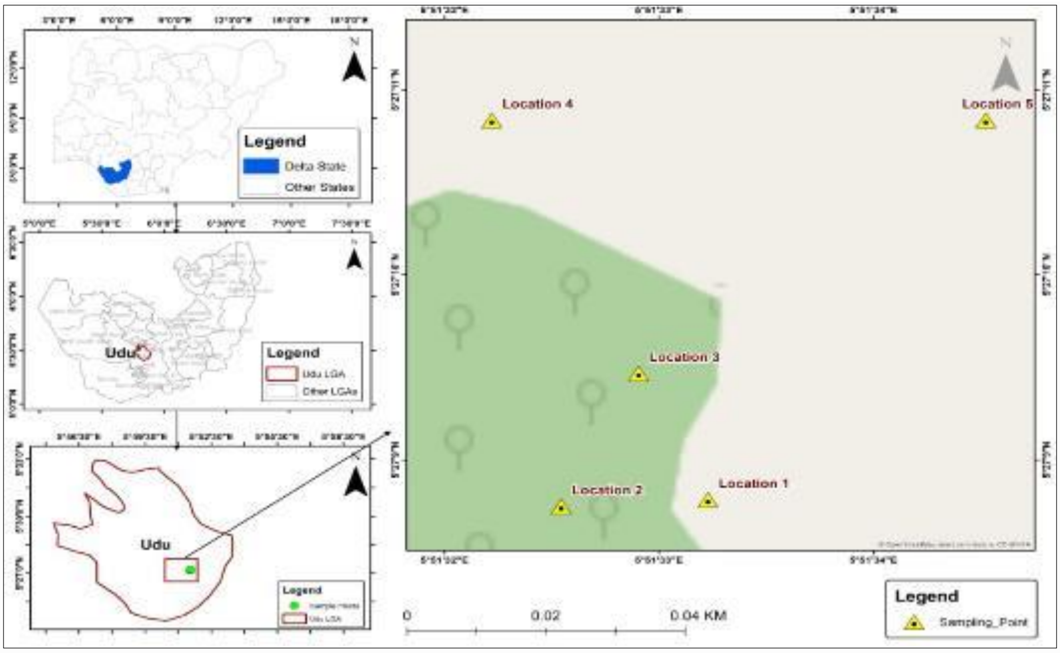

Figure 1 Map of the study area showing the sampling points

The average amount of rain fall per annum is ≥2000 mm with a mean monthly relative humidity between 50-95 %. And a mean temperature of 26 °C. The soil is mostly clay loam making it very rich and fertile with good water retention ability which is favorable for agricultural activities. The area is plain open field with grasses, shrubs and sporadic trees, mostly of commercial value, such oil palm, exhibiting signs of ongoing forest degradation.

2.2. Field Investigation

Sampling of the soil was carried out solely to ascertain the suitability of the site for oil palm plantation based on its physicochemical properties. The fundamental strategy was to define the area with relatively homogenous units based on other observable characteristics that could affect soil variance include terrain, drainage, vegetation, and land use. Sampling was carried out using the soil auger for each sample collection. At each point of collection, the soil auger was screwed into the soil and samples collected at depth 0-15 and 15-30 cm respectively using a meter rule to measure the depth. The auger was then carefully pulled up and the grabbed soil sample transferred into the labelled polythene bag and put into the chest for preservation and onward transportation to the laboratory for analysis. The geographic positioning system (GPS) was used to geo-reference every sampling point by means of a GPS application from an android phone.

2.3. Soil Laboratory analysis

Surface and subsurface soil samples (0–15 and 15–30 cm) were collected, air-dried at room temperature, crushed, and passed through a 2 mm sieve before being subjected to standard methods of analysis. The following parameters' physical and chemical characteristics of the samples were examined: The 1:1 soil to water ratio method was adopted in analysing for soil pH according to ASTM D1293B. Moisture content of the soil samples were determined in line with the standard method BS 1377-3. PSD (particle size distribution) was obtained using the hydrometer method and sieving, which is recommended for soil samples containing more than 35 % fine particles, such as clays and slits (Gavlak *et al.,* 2005). Available Phosphorous (P) was determined by Bray P-I method. The amount of organic carbon in the soil was calculated using the Walkey-Black method. Total Nitrogen content was determined in line with APHA 4500. Exchangeable cations were determined using the Schimadzu AA7000 spectrophotometer

3. Results and discussion

3.1. Soil and climatic requirements for oil palm

The terrain and soil quality determines whether a plot of land will be chosen for oil palm cultivation. The land must be level or slightly sloping, well-drained, and fertile. The average amount of rain fall per annum is ≥2000 mm and this falls within the range of the 2000 mm to 2500 mm as recommended by Hartley, (1998 as cited in Oviasogie & Duke, 2020) and is therefore considered highly suitable (S1) for oil palm cultivation in terms of quantity and distribution.

The average duration of sunshine is less than five hours, which is below the criteria for the oil palm, according to Popkin *et al.,* (2022), oil palm in plantations needs at least 5–6 hours of strong sunshine each day and humidity levels between 75–100 % to develop properly the average temperature is greater than 26 ^{o}C and is regarded to be moderately suitable (S2) for oil palm cultivation. As oil palm grows best at temperatures between 30 and 32 degrees Celsius (86- and 89.6-degrees Fahrenheit) for at least 80 days. About 60 % of the entire land has poor drainage, which could result in serious flooding; and this is considered not suitable (N). Because it implies that the general water table in the surrounding area is high and saturated most of the year with high rainfall. Oviasogie *et al.,* (2020) in similar research carried out in north central part of Nigeria, observed that this condition is damaging because palms' roots are tolerant of anaerobic soil layer only to a moderate extent.

3.2. Soil physical and chemical properties

Table 2 shows the physical and chemical properties of soils in the study area. The soil is clayey in texture and this is marginally suitable S3 for oil palm plantation. According to Goh (2000 as cited in Oviasogie *et al.,* 2020), the best soil types for oil palm are clay loam or sandy loam. Likewise, a similar report recently carried out, specified that the best types of soil for growing the crop (oil palm) are loamy or alluvial, well-drained soils containing appropriate soil moisture, being at least one meter deep for root development (Popkin *et al.,* 2022). The analysis of the particle size reveals that mineral particles (clay) predominate over sand with no significant difference down the profile. The percentage of silt in the soil was the lowest with no specific pattern.

The pH of the soil when measured in water was slightly acidic with a range between 4.49 to 6.02 (table 2). This is considered highly suitable (S1) for oil palm cultivation. From table 3 it is clear that the pH range obtained is within the expected range for optimum performance of oil palm. According to Popkin *et al*., (2022) the best soil pH for oil palm cultivation is between 4.0 to 6.8. The consistent decrease in acidity with increasing depth may be as a result of cultivation of the land and leaching of basic cations down the soil profile. These findings is in line with Oviasogie *et al.,* (2020) who reported a general decrease in pH values in the lower profile of the soil with increasing depth.

The analysis shows that the concentration of organic carbon present in the site range from 0.45 to 1.23 mg/kg (table 2). This result shows that organic carbon at the top soil was higher and decreased steadily in concentration down the profile at all locations across the site. This is highly suitable S1 for oil palm cultivation. Soil for oil palm cultivation must be rich in organic matter (Popkin et al., 2022). Oviasogie and Duke (2020) in similar research carried out in Edo State observed a steady decrease in the concentration of organic carbon down the profile. The higher concentration of organic carbon at the top soil might be attributed to the presence of decaying plant matter, microbes and soil organisms (Jared et al., 2013).

Total nitrogen available across the entire site as seen in table 2 is within the expected range for oil palm cultivation. The value ranged from 0.21 to 0.94 mg/kg. Based on the soil fertility evaluation for oil palm (table 3), the values obtained for total nitrogen is highly suitable (S1) for oil palm cultivation. There was a steady decrease down the soil profile in the total nitrogen available.

Table 1 The descriptive statistics of the physicochemical properties of the soil

Soil properties	Mean ± SD	Minimum	Maximum
pH	5.49 ± 0.256	4.49	6.02
Organic carbon	0.861 ± 0.236	0.45	1.23
Total nitrogen	0.575 ± 0.191	0.21	0.94
P mg/kg	0.963 ± 0.296	0.38	1.57
Ca cmol/kg	6.014 ± 2.512	2.09	9.85
Mg cmol/kg	2.342 ± 1.161	0.32	3.80
Na cmol/kg	0.178 ± 0.157	0.02	0.45
K cmol/kg	0.222 ± 0.069	0.11	0.32
ECEC cmol/kg	8.667 ± 3.339	2.74	13.43
Clay %	88.28 ± 1.320	88.60	90.20
Silt %	9.028 ± 3.337	7.40	11.90
Sand %	2.492 ± 0.660	1.50	3.40

Table 2 Some selected physical and chemical properties of soil in the study area

Point	Depth (cm)	Ph	O.C %	N %	P	Ca mg/kg	Mg	Na	K	ECEC cmol/kg	Clay %	Silt %	Sand %
T. S1	0-15	5.43	1.23	0.63	1.06	9.85	3.07	0.22	0.29	13.43	88.20	8.50	3.30
S. S1	15-30	5.61	0.72	0.44	1.08	8.03	3.67	0.45	0.20	12.35	87.30	9.30	3.40
T. S2	0-15	5.51	1.04	0.54	0.38	2.28	0.32	ND	0.18	2.78	86.80	10.60	2.60
S. S2	15-30	5.66	0.83	0.21	1.57	2.09	0.51	ND	0.14	2.74	88.60	8.78	2.62
T. S3	0-15	4.94	0.99	0.94	1.04	5.75	1.62	ND	0.32	7.69	89.20	7.40	3.40
S. S3	15-30	5.35	0.45	0.62	0.94	4.01	2.03	0.02	0.21	6.27	90.00	7.80	2.20
T. S4	0-15	5.44	0.86	0.77	1.04	9.14	2.75	0.03	0.19	12.11	88.60	9.70	1.70
S. S4	15-30	5.49	0.52	0.51	0.63	6.09	3.80	0.17	0.11	10.17	86.60	11.90	1.50
T. S5	0-15	5.45	1.12	0.67	0.84	7.05	2.40	ND	0.31	9.76	90.20	7.60	2.20
S. S5	15-30	6.02	0.85	0.42	1.05	5.85	3.25	ND	0.27	9.37	89.30	8.70	2.00

Available phosphorus was very low between 0.38 to 1.57 mg/kg. There was no particular pattern of variation with increasing soil depth. These values are marginally suitable (S3) for oil palm cultivation because they are far below the expected range (table 3) of available phosphorus for oil palm cultivation giving the fact that phosphorus is an essential nutrient required for proper growth of oil palm.

The result of the effective cation exchange capacity (ECEC) obtained (table 1 - 3) was between 2.74 to 13.43 cmol/kg. The effective cation exchange capacity was obtained by summation. It is the total amount of exchangeable cations, mostly bases calcium, magnesium, sodium, and potassium in non-acidic soils. It decreases gradually down the soil profile at all points across the site. Due to the low values observed ECEC is rated suitable (S2) based on suitability classes and soil fertility requirements for oil palm cultivation (table 3). The low value observed in ECEC can be improved through effective soil management such as increasing soil organic matter by using empty fruit bunch (EFB).

Table 3 Soil fertility evaluation for oil palm

Property	V. low	Low	Moderate	High	Very high
pH	<3.5	4.0	4.2	5.5	>5.5
Organic C %	<0.8	1.2	1.5	2.5	>2.5
Total N %	<0.08	0.12	0.15	0.25	>0.25
Total P mg/kg	<120	200	250	400	>400
Avail. P mg/kg	<8	15	s	25	>25
Ex. K cmol(+)/kg	<0.08	0.20	0.25	0.30	>0.30
Ex Mg cmol(+)/kg	<0.08	0.20	0.25	0.30	>0.30
ECEC cmol(+)/kg	<6	12	15	18	>18
Fertilizer Response	Definite	Likely	Possible	-	Possible

Source: Goh Kah Joo, 1997 as cited in Mutert 1999. cmol(+)/kg = meq/100g; mg/kg = parts per million (ppm)

4. Conclusion

The results of the analysis carried out in the study area shows that the entire land is suitable (S2) for oil palm plantation. The main limiting factors are the soil texture which is clay and the low level of phosphorus available in the soil. In order to enhance the soil condition and raise the productivity of the land to an ideal level, focus should be put on management strategies that will improve the soil's ability to effectively drain water in order to prevent water logging and keep water at ≥20 cm below soil surface. The amount of phosphorus available in the soil can be increased through the application of phosphate fertilizer and through installation of erosion control measures such as bunds, platforms, and terraces to lessen losses of native and applied phosphate in surface run-off water and eroded soil. Also cover crop planting and the application of organic residue, such as empty fruit bunches (EFB), should be taken into consideration to make up for the soil nutrient deficit especially during the dry month when the production of fresh fruit bunches begins.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Bassey, O.I. Overview of Oil Palm Production in Nigeria; Comparative Social and Environmental Impacts: The Case of the Ekong Anaku Community in Cross River State, Nigeria. Institute of Social Science, Erasmus University of Rotterdam, The Hague, Netherlands, 2016.

[2] FAO Guidelines for Land-Use Planning. From: Step 5. Evaluate land suitability (fao.org), 1993

[3] FAO Oil Palm. From https://www.fao.org/3/y4355e/y4355e03.htm, 2002

[4] Gavlak, R., Donald H., D., Miller R.O. Soil, plant and water reference methods for the western region. (3rd ed.), 2005

[5] Ingole, S. A Review on Role of Physico-Chemical Properties in Soil Quality. Chemical Science Review and Letters, 2015, 4, 57-66.

[6] Jared, P., David, L., Burt, L., Chaminda, G. Residual Soil Properties of South East Queensland. Australian Geomechanics Journal, 2013, 48(1), 67-76. http://eprints.qut.edu.au/59538/c

[7] Murphy, D.J., Goggin, K., Paterson, R.R.M. Oil palm in the 2020s and beyond: challenges and solutions. CABI Agric Biosci 2021, 2, 39.

[8] Mutert, E. Suitability of Soils for Oil Palm in Southeast Asia. Better Crops International, 1999, 13(1), 36-38

[9] Raju, M. N., Golla, N. Vengatampalli, R. Soil physicochemical properties. Soil Enzymes, 2017, 26 (1), 1-9

[10] Ogunkunle, A.O. Soil in land suitability evaluation: an example with oil palm in Nigeria. Soil Use Manag. 1993, 9, 35–39. https://doi.org/10.1111/j.1475-2743.1993. tb00925.x

[11] Oviasogie, P. O., Okoro, D., Ikyaahemba, P. T. Suitability Assessment of Soils of Egbili Obebe in Ibaji Local Government Area of Kogi State for Oil Palm Establishment. FUPRE Journal of Scientific and Industrial Research, 2020, 4(3). 22-34

[12] Oviasogie, P. O., Okoro, D. Suitability Assessment of Soils for Oil Palm Cultivation in Ofunwengbe, Ovia North East Local Government Area of Edo State, Nigeria. FUPRE Journal of Scientific and Industrial Research, 2020, 4(3), 13-23

[13] Prabowo, N. E., Foster, H. I., Nelson, N, P. Potassium and magnesium uptake and fertiliser use efficiency by oil palm at contrasting sites in Sumatra,Indonesia Nutrient Cycling Agroecosystems, 2023, 126:263–278

[14] Parikh, S. J., James, B. R. Soil: The Foundation of Agriculture. Nature Education Knowledge, 2012, 3(10):1-9

[15] Popkin, M., Reiss-Woolever, V.J., Turner, E.C., Luke, S.H., A systematic map of within-plantation oil palm management practices reveals a rapidly growing but patchy evidence base. PLOS Sustain Transform, 2022, 1(7): e0000023. https://doi.org/10.1371/journal.pstr.0000023

[16] Rhebergen, T., Fairhurst, T., Zingore, S., Fisher, M., Oberthur, T., Whitbread, A. Climate, soil and land-use based land suitability evaluation for oil palm production in Ghana. Eur. J. Agron., 2016, 81.1-14

[17] USEPA Regional screening levels (RSL) for chemical contaminants at superfunds site (RSL soil Table May 2013) Regionalscreening Table user's guide; 2013.

[18] Van den Berg M. Birnbaum L S. Dennison M. Devito M. Farland W. Feeley M. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency fators for dioxin like compounds. Toxicological Sciences. 2006, 93, 223-241.

[19] Van Den Berg M. Birnbaum L S. Bosveld A T C. Brunstrom B. Cook P. Feeley M. Toxic equivalency factors for PCBs, PCDFs for human and wildlife. Environmental Health Perspectives. 1998, 106, 775-792.

[20] Idowu A A. Godwin N I. Horsfall M. Carcinogenicity of dioxin-like poly chlorinated biphenyls in transformer soil in vicinity of university of Porthartcourt Choba, Nigeria. Chemistry International. 2020, 6, 144-150.

[21] Ibrahim E G. Salami S J. Gushit J S. Gube-Ibrahim M A. Distribution and Carcinogenicity of PCBs in Soil Contaminated with Transformer Oil in Selected Locations in Jos, Plateau State Nigeria. International Research Journal of Pure & Applied Chemistry, 2021, 22, 1-7.

[22] Jun L. Yang H. Rong Y. Guo LY. Han ZW. Peng, H. Source identification and health risk assessment of persistent organic pollutants (POPs) in the topsoils of typical petrochemical industrial area in Beijing China. Journal of Geochemical Exploration. 2015, 158, 177-185.

[23] Guanghui X. Yong Y. Yang W. Jihong W. Rui Y. Xiaorong C. Polychlorinated biphenyls in vegetable soil from Changchun, North East China: Concentrations, distribution soures and human health risk. 2017, 12, 1-14