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# SOIL SUITABILITY ASSESSMENT FOR SUSTAINABLE PRODUCTION OF CUCUMBER (*Cucumis sativus* L.) IN THE SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

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## ABSTRACT

The problem of selecting the correct land for the cultivation of a certain crop is a long-standing and mainly empirical issue and nowadays, sustainability is one of the important issues in land use system. A Typic Plinthustalfs soil developed on Pre-Cambrian basement complex rocks was evaluated for its suitability for cucumber (*Cucumis sativus* L.) in the southern guinea savanna zone of Nigeria. Three mapping units that were established along the topo-sequence and three profile pits that were dug in 2017 were used for the experiment. Linear parametric and square root models were used for assessing the suitability of the soils for sustainable cucumber production. Land qualities considered in the study were climate, topography, wetness, soil fertility and soil physical properties. Except for the fertility status of the land, other qualities were not a constraint to the production of cucumber at study site. None of the pedon is highly suitable for production of cucumber by both linear and square root models with index of current productivity (IPc) that ranged between 18.7 and 70. Linear model indicated pedon 2 as currently not suitable with IPc of 18.7. Potentially, the index of potential productivity (IPp) ranged between 25 and 70 which rated pedon 1 and 3 as moderately suitable and pedon 2 as marginally suitable for cucumber production by both linear and the square root model. The limiting factors were mainly low levels of available macro-nutrients (N, P, K, Mg), low organic carbon (<0.54%), and low cation exchange capacity (<5.61cmol/kg) in all three pedons studied. Field trial also confirms the claim as application of both organic and NPK fertilizers significantly affect the yield of cucumber in all the pedons. In conclusion, it is therefore recommended that organic fertilizer should be applied for sustainable cucumber production on soils of the studied site.

**Keywords:** Soil suitability; Typic Plinthustalfs; Linear Parametric and Square root Models; Limiting factors; organic fertilizers; Macro-nutrients.

## INTRODUCTION

The need for increase food production to feed the ever-increasing human population cannot be over emphasized. Hence it is of great importance to carry out land evaluation assessment in relation to crops that are planted in different regions of the Nation.

Land sustainability assessment is a method of land evaluation, which identifies the major limiting factor for planting a particular crop. Land suitability assessment includes qualitative and quantitative evaluation, it is important to step in the process of land use planning where resources are limited. The assessment is carried out separately for each categories of land use (Reshmideri *et.al,* 2009).

Land suitability assessment provides information on constraints and opportunities for land use and hence serves as guide for decisions on optimal utilizations of the land resources; whole knowledge is an essential prerequisite for land use planning and development. (Kappo *et. al*, 2004). These kinds of assessment identify the main limiting factors for the agricultural production and enable decision makers such as land users and agricultural support services to develop crop management that can overcome such constraints thereby increasing yield (Rabia, 2012). Soil assessment can tell farmers how suitable their land is in terms of soil limitations to specific land use and management practices.

Soil suitability classifications are therefore based on the knowledge of crop requirements, prevailing soil conditions and defined soil management. From the basic soil requirements of crop, a number of soil characteristics directly related to crop yield performance. (Jimoh, *et. al.* 2018). Soil suitability assessment for agriculture is a means to evaluate the ability of soil to provide optimal ecological requirements of a certain crop variety. This is a strategy for achieving food security as well as sustainable environment. Nutrients deficiencies and imbalance are the main constraints of crop production in Nigeria, and thus assessing the suitability of soil for agricultural production is very important in the production of crops to meet the ever increase in population.

The food sub-sector of Nigerian agriculture parades a large array of crops, amongst this crop is cucumber (*Cucumis sativus*).

It belongs to the cucurbitaceae family which comprised of 118 general and 825 species.

Information on soil-site suitability evaluation for cucumber production is not available for the study area. The present study was therefore undertaken to unfold this information. Therefore, the main objective of this study is to evaluate the soils of teaching and research farm, Malete, Kwara State, for sustainable production of Cucumber (*Cucumis sativus*)

## MATERIALS AND METHODS

### Description of Experimental Site

The study area was Kwara State University Teaching and Research farm, Malete. It is located in Southern Guinea Savanna ecological region of Nigeria. It lies between Latitude $08^0 71'$N; longitude $04^0 44'$E in Moro Local Government Areas of Kwara State at 360 m above sea-level and the relief is very gentle. The climate is characterized by distinctive wet and dry seasons with a mean annual rainfall of about 1150mm, with a double maximal pattern between April and October. The wet season begins in April and ends around October while the dry season begins in November and ends in March. In addition, the annual mean temperature ranges from 25 to $28.9^{0C}$

The soil at the site is Sandy loam and slightly acidic (Alabi *et al*. 2017), Its land area forms part of the South-Western sector of Nigerian basement complex, a zone of basement reactivation. The natural vegetation has been destroyed due to farming activities and procedures such as ploughing, harrowing and ridging by man making it anthropogenic. Presently, the type of vegetation in the area is savannah woodland. The area is predominantly used for the cultivation of arable crops such as maize, groundnut and cowpea, perennial trees such as cashew and mango. The site also contains woody species such as baobab (Adansonia digitata), Neem tree (Azadractha indica) and acacia (*Acacia species*), grasses such as spear grass (*Cylindrica imperata*), Elephant grass (*Pennisetum purpreum*) and guinea gamba grass (*Andropogon gayanus*).

### Field Survey and Sampling

Detailed soil survey was conducted in the area using rigid-grid method. Three mapping units and soil profiles that was already dug in the study area for its classification in 2017 was scraped, redressed and used and Surface samples were collected at 0-20 cm for laboratory analysis.

### Laboratory analysis and procedure

Surface samples collected together with samples from pedogenetic horizons were air-dried. The samples were passed through a 2mm sieve to separate the large particles, stones and debris. Sample collected were analyzed for physical and chemical properties. Particle size analysis was determined using the hydrometer method modified by Gee and Or, 2002. Soil pH was determined electrometrically in 1:1 soil:water suspension. Organic carbon is determined by Walkey-Black method (1945) while Total Nitrogen was determined by the Micro-Kjeldahl method (Bremner and Mulvaney, 1982) and extractable P was determined by Bray and Kurtz, 1945). Exchangeable Ca, Mg, Na and K were extracted with 1M ammonium acetate (1M NH4OAc) solution buffered at pH 7.0, as described by Anderson and Ingram (1998). The exchangeable sodium ($Na^+$) and potassium ($K^+$) content of the filtrates were determined by Flame photometer while the exchangeable calcium ($Ca^+$ ) magnesium ($Mg^+$) were determined by EDTA titration method and were read with atomic absorption spectrophotometer (AAS). Micronutrients (Fe, Cu, Mn, Zn and B) of the soils was extracted by Mehlich-III multi-nutrient extraction method.

### Land Evaluation Procedure

The pedons were first placed in suitability classes by matching their characteristics with the requirements in Table 1 below. The suitability class of a pedon is that which is indicated by its most limiting characteristics. This affirms the well famous "Law of Minimum" in agriculture, which states that crop yield will be determined by the plant nutrient in lowest supply (FAO,1984). Secondly each limiting characteristic would be rated for the parametric method. The index of productivity (IPp) for each pedon was calculated using the equation below:

$$IPc = A \times \frac{B}{100} \times \frac{S}{100} \times \frac{C}{100} \times \frac{F}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$IP = A.\sqrt{\frac{B}{100} \cdot \frac{C}{100} \ldots \cdot \frac{F}{100} \ldots\ldots\ldots (ii)}$$

Where A is the overall lowest characteristic rating, B, C…F are the lowest characteristics rating for each land quality group.

The five land quality groups to be used in this study are climate, topography, soil physical properties, wetness and chemical fertility. Only one member in each group would be used because (IPP) and current (actual) index of productivity (IPC) would be calculated without putting the calcium (Ca) mole fraction and available phosphorous (Bray's P1) into the 'f' group, while the IPC would be calculated with the calcium mole fraction (exchangeable $Ca^{2+}$ as a fraction of cation exchange capacity) and available phosphorous (Bray's P1) forming part of the 'f' group.

**Agronomic Evaluation**

The performance of cucumber was evaluated experimentally using a 3 × 3 factorial experiment. The factors were topo-sequence and types of fertilizer or soil amendments. There are three levels of each factor; namely, upper slope, middle slope and lower slope, application of farmyard manure, N P K and control replicated three times making twenty-seven Experimental plots.

**Experimental Design and Land Management**

The experiment was carried out using a randomized complete block design (RCBD) with 3 replications. Experimental plots consisted of 17m by 11m in each mapping unit. Farmyard manure was applied at two weeks before planting to allow for proper decomposition and mineralization. Plant spacing of 0.60 m × 0.30 m was used. Marketmore variety of cucumber was planted and 2 seeds were planted per stand given a plant population of 111,111 plants per hectare.

**Data collection**

Growth and Yield parameters collected include: Number of leaves, Vine length, Leaf area at 4,6 and 8 weeks after planting**,** Days to 50% flowering**,** Days to 50% fruit setting**,** Fruit length (cm), Fruit yield per plant, Fruit weight (g)**,** Yield per ha (ton)**.**

**Statistical Analyses**

Data collected was subjected to analysis of variance (ANOVA). Using DSAASAT and treatment means where significant, were separated using Duncan Multiple Range Test, at 5% level of probability.

## RESULTS AND DISCUSSION

**Soil Physical and Morphological Properties**

**Land Evaluation for Cucumber production**

Suitability ratings of the land characteristics (Table-7) was constructed using the rating of limiting characteristics (Table-1) and land requirements for suitability classification for cucumber cultivation (Table-2) suitability ratings of the various land characteristics as well as their aggregate rating (potential and actual) were computed using the linear and square root parametric models presented in the write up

None of the pedons is highly suitable for Cucumber production by both linear parametric and square root model. Using linear model, the actual productivity (IPc) indicated pedon 2 as currently not suitable (18.7 (N) and pedon 1 and 3 as marginally suitable (37.5 -S3). The limiting factors were mainly low level of CEC, organic carbon and low micro nutrients. The evaluation of the potential suitability without considering fertility factors which are regarded as temporary limitation, using the linear model indicated that pedon 1and 3 are classified as moderately suitable and pedon 2 as marginally suitable for production of cucumber with the productivity index of IPp 70 and 50 respectively.

However, evaluation of the suitability using the square root model, both the actual productivity (IPc) and potential productivity (IPp) ranged from 50 to 70 which indicated pedon 1 and 3 as moderately suitable and pedon 2 as marginally suitable for cucumber production.

**Agronomic Evaluation of suitability Mapping Units**

The analysis of variance of the data collected on physiological growth and yield parameters for cucumber grown on different mapping units during 2021 planting seasons are presented in Table8. The result showed that the performance of cucumber differed significantly ($P<0.01$) in all measured parameters across the pedons.

NPK Fertilizer application had significant effect in terms of vine length and leaf area. However, in terms of fruit yield, application of manure, NPK and control are significantly different with manure ranking the highest followed by NPK. In terms of number of leaves both at 4 and 6 weeks, the control performing best followed by manure and NPK. The significant effect of NPK fertilizer over Organic manure in terms of Vine length and leaf area may be attributed to delay response in Organic manure in the release of nutrients for plant use. The significant effect of organic manure on the fruit weight and fruit yield over NPK may has resulted from the presence of micronutrients in the organic manure and this may have rectified the micro-nutrient deficiencies observed in the soils. Also, the slower rate of release of nutrients from the mineralization of the organic manure may have synchronized nutrient requirement by the cucumber with nutrient release, thereby minimizing nutrient loss by leaching. There is no significant difference at 50% days to flowering and 50% fruit setting with the application of organic manure, NPK and control.

With the application of NPK at 4weeks, leaf area is significantly different from control and manure while the upper, middle and lower elevations have significant difference. This is also similar to that of 6weeks where NPK is significantly different. Upper elevation is significantly different from middle and lower elevation. At 8weeks, application of organic manure and NPK, performed better than control with the upper elevation performing better than the lower and middle respectively.

In terms of fruit weight and fruit yield, the cucumbers in the upper slope pedon were significantly higher than plants in the middle and lower slope. Also, the upper slope pedon maintained a significantly higher average number of leaves per plant and in the average leaf area per plant. The yield at upper slope pedon was slightly higher than that of lower slope and middle slope had the lowest fruit yield.

Although there was no significant difference ($P<0.05$) in the 50% days to flowering and 50% fruit setting, with the application of either organic manure or NPK. But the middle slope pedon performed better than the upper and lower slope pedons (Table 8). There was interaction between soil amendment and slope positions.

## DISCUSSION

Land suitability evaluation enables more accurate and useful predictions to be made for specific purposes. Soil characterization helps us understand soils better and provides useful information for the assessment and monitoring of the behaviour of soils.

The analysis of research work showed the constraint of these soils to sustainable cucumber production. The constraints include low level of macro nutrients (N, P, K) which are needed in large quantities by the plants especially for cucumber production, low organic carbon and low exchange capacity.

Constraints of soils identified can be managed through some of these management systems; The low levels of micro-nutrients, organic carbon and CEC could be managed through the application of both organic and inorganic manure. Among the different sources of organic manure which have been used in crop production poultry manure was found to be the most concentrated in terms of nutrients content (Yagock and Awoniyi; 1974, Lombin et al., 1992).

Lia and Mathur (1998) stated that inclusion of organic manure improves soil fertility and crop yield. Sarkar et al. (2003) reported that the combination of farmyard manure along the recommended inorganic fertilizer dose increased yield significantly. Incorporation of crop residues could also be suggested as this would control soil erosion, crusting and improve physical conditions of crop root zones (Tarawali et al., 2001, Odunze, 2006). Minimum tillage is also suggested as heavy mechanized land preparation will increase structural destruction.

## CONCLUSION AND RECOMMENDATION

Three Pedons (upper, middle and lower slope) were established and classified as USDA soil order Alfisol and was classified further as sub-group Typic Plinthiustalfs (Plinthosol, cutanic, Hypereutic) still remain. None of the pedon is highly suitable for the production of cucumber by both linear and square root models. Pedon 2 was classified as currently not suitable but potentially marginally suitable for cucumber production by both models. The limiting factors were mainly low levels of available macro and micro-nutrients (low total Nitrogen, Available Phosphorus, CEC, Organic Carbon and organic Matter). Potentially (without considering soil fertility which is regarded as temporal limitation) by both Models, Pedons 1 and 3 are moderately suitable (S2) for the Production of cucumber.

Field trial confirms the claim that low level of fertility is the major factor limiting the Productive Potentials of the soils for cucumber production in the area. Application of manure and NPK had significant improvement on the growth and yield of cucumber. However, application of manure had the higher effect in terms of Fruit weight, fruit yield per ha and the other parameter taken in the upper slope segment than the middle and lower slope. In conclusion, the productive capacity of the soils for cucumber production can be achieved through the use organic fertilizers.

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**Table 1 Soil–site suitability criteria (crop requirement) for Tomato/ Cucumber/Cabbage**

| Land quality | Soil-site characteristics | Unit | S1 | S2 | S3 | N |
|---|---|---|---|---|---|---|
| Climate | Total Rainfall | mm | 600-750 | 500-600<br>750-1000 | 450-500<br>>1000 | |
| | Mean Temperature in growing season | °C | 25-28 | 29-32<br>20-24 | 33-36<br>15-19 | <15<br>>36 |
| | Rainfall in growing season | mm | >150 | 120-150 | 90-120 | |
| | Length of growing season | Days | >150 | 120-150 | 90-120 | |
| Topography (t) | Slope | % | 1-3 | 3-5 | 5-10 | >10 |
| Wetness (w) | Soil drainage | Class | Well drained | Moderate | Imperfect | Poor |
| Soil physical properties (s) | Texture | Class | Sl,l,cl,scl | Sicl,sic,sc,c(m/k) | c (ss) | Ls,s |
| | Coarse fragment | Vol (%) | <15 | 15-35 | >35 | |
| | Effective soil depth | cm | >75 | 50-75 | 25-50 | <25 |
| Fertility (f) | pH | 1-2.5 | 6.0-7.0 | 5.0-5.9<br>7.1-8.5 | <5 | |
| | CEC | cmol(p+)/kg | >15 | 10-15 | <10 | |
| | $CaCO_3$ in root zone | % | Non-calcareous | Slightly calcareous | Strongly calcareous | |
| Soil toxicity (n) | Salinity (EC) | dSm-1 | Non-saline | Slightly saline | Strongly saline | |
| | Sodicity (ESP) | % | Non-sodic | Slightly sodic | Strongly sodic | |

S1=Highly suitable (IP = 100-75%), S2=Moderately suitable (IP = 74-50%); S3=Marginally suitable (IP = 49-25); N=Not suitable (24-0%).
Source: Modified from NBSS&LUP, 1994

## Table 2: Land requirement for suitability classes for cucumber cultivation

| **Land quality** | **Unit** | **S1** | **S2** | **S3** | **N** |
|---|---|---|---|---|---|
| Climate (c): | | | | | |
| Mean temperature | $^{0}C$ | 25 – 28 | 29 – 32 | 33 – 36 | >16 |
| Total rainfall | mm | 600 – 750 | 500 – 600 | 450 - 500 | |
| Rainfall in growing season | mm | > 150 | 120 – 150 | 90 – 120 | |
| Length of growing season | days | > 150 | 120 – 150 | 90 – 120 | |
| Topography (t) | | | | | |
| Slope | % | 1 – 3 | 3 – 5 | 5 – 10 | >10 |
| Wetness (w) | | | | | |
| Soil drainage | class | well drained | moderate | imperfect | poor |
| Soil physical properties (s) | | | | | |
| Texture | class | sl, l, cl, sclsicl, sic, sc, c (m/k) | | c(ss) | ls, s |
| Coarse fragments | vol% | <15 | 15 – 35 | >35 | |
| Effective soil depth | cm | >75 50 – 75 | 25 – 50 | <25 | |
| Fertility (f) | | | | | |
| pH | 1 – 2.5 | 6.0 – 7.0 | 5.0 – 5.9 | <5 | |
| CEC | cmol[p+]/kg | >75 | 10 – 15 | <10 | |
| $CaCO_3$ in root zone | % | non-calcareous | slightly calcareous | strongly calcareous | |
| Soil toxicity (n) | | | | | |
| Salinity [EC saturation extract] | dS $m^{-1}$ | non-saline | slightly saline | strongly saline | |
| Sodicity [ESP] | % | non-sodic | slightly sodic | strongly sodic | |

S1=Highly suitable (IP = 100-75%), S2=Moderately suitable (IP = 74-50%); S3= Marginally suitable (IP = 49-25); N=Not suitable (24-0%). Source: Modified from NBSS&LUP, 1994

## Table 3: Soil chemical Characteristics of surface sample 2021

| Sample No | pH 1:1 ($H_2O$) | Nitrogen % | Organic carbon % | Organic matter % | Sand % | Silt % | Clay % | Texture | Ca++ | Mg++ cmo/kg | Na++ cmol/kg | K++ cmol/kg | Acidity | Available. P mg/kg | EC. E.C. cmol/kg | Base saturation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2A | 8.4 | 1.75 | 0.39 | 0.67 | 80.64 | 6 | 16.34 | S/L | 2.47 | 1.08 | 0.49 | 0.65 | 0.8 | 9.31 | 5.49 | 85.43 |
| 2B | 7 | 1.47 | 0.54 | 0.93 | 82.64 | 6 | 13.34 | S/L | 2.68 | 0.96 | 0.36 | 0.84 | 0.76 | 3.36 | 5.61 | 86.45 |
| 3A | 6.5 | 1.05 | 0.19 | 0.33 | 82.64 | 6 | 11.36 | S/L | 2.11 | 0.78 | 0.27 | 0.76 | 0.74 | 7.49 | 4.66 | 84.12 |
| 3B | 6.9 | 1.54 | 0.19 | 0.33 | 80.64 | 6 | 13.36 | S/L | 2.01 | 0.71 | 0.25 | 0.81 | 0.6 | 9.94 | 4.38 | 86.3 |
| 4A | 6.7 | 1.61 | 0.36 | 0.62 | 80.64 | 6 | 13.36 | S/L | 1.96 | 0.48 | 0.27 | 0.63 | 0.6 | 10.36 | 3.94 | 84.77 |
| Block 4 | 6.8 | 1.47 | 0.04 | 0.06 | 82.64 | 6 | 11.36 | S/L | 1.78 | 0.44 | 0.22 | 0.71 | 0.8 | 4.2 | 3.95 | 79.74 |
| Crop Museum | 7.4 | 1.54 | 0.04 | 0.06 | 80.64 | 6 | 13.36 | S/L | 2.01 | 0.38 | 0.24 | 0.62 | 0.84 | 5.81 | 4.09 | 79.46 |

## Table 8: The analysis of variance of the data collected on physiological growth and yield parameters for cucumber

| Soil Amendment | Fruit weight(g) | Fruit yield per hectare (tons) | Vine length at 6 weeks (m) | Vine length at 8 weeks (m) | Leaf area at 6 weeks (cm) | Leaf area at 8weeks (cm) | Number of leaf at 6 weeks | Number of leaf at 8 weeks | Day to 50% flowering | Day 50% fruit setting |
|---|---|---|---|---|---|---|---|---|---|---|
| Manure | 462.01a | 8816.9a | 0.48b | 0.73a | 147.8b | 213.52a | 24.7b | 28.2b | 35.70a | 43.08a |
| NPK | 348.49b | 7085.2b | 0.57ab | 0.68a | 172.1a | 213.7a | 28.05ab | 35.2a | 35.70a | 43.07a |
| Control | 278.23b | 5165.6c | 0.61a | 0.72a | 142.08b | 160.916b | 29.7a | 35.9a | 35.71a | 43.07a |
| LSD | 93.12 | 660.80 | 8.972 | 6.409 | 16.73 | 7.966 | 3.82 | 2.105 | 0.9158 | 1.323 |
| Elevation/Location | | | | | | | | | | |
| Upper | 690.02a | 11299.1a | 0.78a | 0.904a | 223.1a | 270.39a | 48.06a | 58.49a | 35.03b | 42.09b |
| Middle | 194.0b | 4237.1c | 0.40b | 0.631b | 116.22b | 135.809c | 15.51b | 18.13c | 37.03a | 44.05a |
| Lower | 204.73b | 5531.5b | 0.49b | 0.604b | 122.76b | 181.9b | 18.9b | 22.8b | 35.05b | 43.08ab |
| LSD | 93.12 | 660.80 | 8.972 | 6.409 | 16.73 | 7.966 | 3.82 | 2.105 | 0.9158 | 1.323 |
| SOA x Location | * | * | * | * | * | * | * | * | NS | NS |