International Journal of Plant & Soil Science
15(3): 1-8, 2017; Article no.IJPSS.32009
ISSN: 2320-7035

SCIENCEDOMAIN *international*
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Evaluation of Soils for Cowpea (*Vigna unguiculata* L.) Production: A Case Study of Siwes Farms of University of Agriculture Makurdi

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Authors' contributions

This work was carried out in collaboration between both authors. Author EAI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SI managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2017/32009
Editor(s):
(1) Peter A. Roussos, Agricultural University of Athens, Lab. Pomology, Greece.
Reviewers:
(1) Levent Son, University of Mersin, Turkey.
(2) G. O. Awe, Ekiti State University, Nigeria.
(3) Leyla Idikut, Kahramanmaras Sutcu Imam University, Turkiye.
Complete Peer review History: http://www.sciencedomain.org/review-history/18512

Original Research Article

Received 2nd February 2017
Accepted 28th March 2017
Published 5th April 2017

ABSTRACT

The soils of the University of Agriculture Makurdi Teaching and Research Farm were surveyed, with the view to evaluating their morphological, physical and chemical properties for cowpea production. Makurdi is in a strategic position in the agricultural map of Nigeria, producing a wide range of both annual and perennial crops such as yam, maize, rice, sorghum, groundnut, soybean, cowpea, citrus, mangoes, and a variety of vegetables. One of the factors responsible for this wide range of crops is the favourable climate. The study showed that the soils of the area had formed under climatic environment presently characterized by an annual rainfall of about 1330.20 mm and a mean annual temperature of about 27.80℃. The soi ls of the upper slope were classified as Typic Paleustalfs, while those of the middle and lower slopes were classified as Typic Haplustalfs and Typic Kandiaqualfs respectively, using soil taxonomy. The soils were well drained to poorly drained. The clay content ranged from 7.20 to 29.30%, increasing with depth. Organic carbon was low (0.47%) in the upland and relatively high (0.86%) in the low land. The soils had an irregular base saturation in all the Units. These soils are capable of moderately supporting cowpea production. The soils were moderately suitable for cowpea production.

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Keywords: Cowpea; classification; taxonomy.

1. INTRODUCTION

One of the serious problems affecting agricultural productivity in developing countries (Nigeria inclusive) is the ineffective and unplanned use of agricultural land. It is necessary that every hectare of land be used according to its productive capacity, as the world looks up to well-planned agriculture with best management practices to improve soil productivity.

The evaluation of land resources can be traced to the 1980s when considerable efforts were made to perform land resources surveys. These were aimed at giving insight into the atmosphere, soil, underlying geology, hydrology, plant and animal population. Past and present human activities influence land potential and land use [1] for sustainable agriculture.

Legumes are important food crops in the world in the tropical and subtropicalregions Gowda [2]. The most prominent in the leguminosaea family especially is cowpea. Cowpea is rich in protein, iron, starch, calcium, phosphorus and vitamins B, which make them excellent food even when eaten in small amount Ebong [3]. In West and Central Africa, cowpea is second in importance after groundnuts with Nigeria accounting for over 70% of total world production Sing [4]. The most important beneficial attribute of this legume is its contribution to the soil nitrogen status through symbiotic nitrogen fixation, thereby enhancing soil fertility and reducing the need for N-fertilizer application Martins [5]. It is a naturally N_2 – fixing legume but it needs artificial inoculation to land not previously cultivated to the crop Ngakou [6]. The poor growth and yield of cowpea crops could be ascribed to a low effectiveness of indigenous bradyrhizobial populations and low nutrients content in the soils.

The primary and most effective land conservation method is appropriate allocation of lands to uses for which they are most suitable. Land suitability evaluation can tell the farmer the suitability of his land for specific crops. A land resource use should be economically viable, ecologically sound, evenly distributed and adopted to the area in which it is located. There exist thus, tragic paradox of severe food shortage in the midst of global abundance. For this problem to be solved there is need for estimation of food production along with information on the growing requirement of particular crops.

The present study was undertaken to evaluate the soils of the study area for suitability for cowpea production and also make recommendations on how to manage the soils for sustainable production.

2. MATERIALS AND METHODS

2.1 Study Areas

The study was conducted within the Teaching and Research Farm of the University of Agriculture, Makurdi. The University lies north east of Makurdi town which is between latitudes 7.45°N and 7.50°N and longitudes 8.00°E and 9.00°E.

Makurdi is in a strategic position in the agricultural map of Nigeria, producing a wide range of both annual and perennial crops such as yam, maize, rice, sorghum, groundnut, soyabean, cowpea, citrus, mangoes, and a variety of vegetables. One of the factors responsible for this wide range of crops is the favourable climate.

Makurdi has tropical climate conditions with distinct wet and dry seasons. The dry season starts from November to March while the rainy season starts from April to October. In the past, Benue state experienced a bimodal rainfall distribution pattern with one peak in July and another in September. Recent meteorological data point to unimodal pattern with the single peak in August. The mean annual rainfall for Benue state varies between 1000 and 1600 mm.

The mean minimum air temperature of Makurdi is 16.20 to 17.20°C during the period of harmattan, which is December to February. The mean maximum air temperature is 37.7°C in March prior to the onset of rains. The slope of the area is 0 to 5% and the elevation above mean sea level is about 93 m Ojanga [7].

2.2 Field Analysis

Field studies involved sinking of three (3) profile pits and morphological description of the profiles as well as the collection of bulk soil samples for laboratory analysis. The profile pits were sunk based on the nature of the slope of the study areas. One pit was located at the crest, the second at the mid slope and the third at the foot slope to enhance proper study of the soils of the areas. The profile pits were described using guidelines from SSS [8].

2.3 Laboratory Studies

Standard laboratory procedures were employed in the investigation of the physical and chemical characteristics of the soil samples collected from the field. The bulk soil samples collected from the field were air dried for three (3) weeks. The air dried samples were gently crushed using mortar and pestle. The samples were sieved through 2mm and 0.5 mm sieves and used for laboratory analyses. For laboratory analyses like particle size distribution, Boyoucos hygrometer method was used. Electrometric method as described by Hesse [9] was used for pH analysis. Walkley-Black method as described by Hesse [9] was used for organic carbon determination. Total nitrogen was determined by the use of macro Kjelidahl [10] method. Sodium bicarbonate $NaHCO_3$ extracting solution [11] was used for available phosphorus determination, and exchangeable cations (Ca, Mg, K and Na). Cation exchange capacity was also determined using neutral solution of ammonium acetate method.

3. RESULTS AND DISCUSSION

3.1 Soil Morphology

Three soils mapping units were identified in the study area based on their morphological characteristics mainly: texture, depth, colour, drainage, nature of underlying materials and surface characteristics. Topography was a prominent feature demarcating the soil boundaries. The spatial distribution of the three soil mapping units and their descriptions are shown in Table 2.

3.2 Soil Physical Characteristics

3.2.1 Soil particle size distribution

The particle size distribution values for the soil mapping units are shown in Table 3. The values revealed the sandy nature of the all the soil units. Soils of Units I and III generally have loamy sand surface texture while, soil unit II had sandy loam surface texture. The sand fraction of the three soil units ranged from 51.6 to 78.1%. This high fraction of sand could be attributed to the nature of the parent material (sandstone). Sand fraction decreased with depth in all Soil Units. The clay content of the soils was moderate to fairly high ranging from 7.2 to 29.3%, while silt fraction ranged from 13.5 to 20.4%. As a result of illuviation, the clay content of the soils was higher in the subsurface horizons than at the surface.

3.2.2 Soil structure

The weak fine to medium crumbs of “A” horizon of all Soil Units could be attributed to their low level of organic matter and sandy nature of the soils. In the surface horizons the three units had moderate to strong, medium to coarse sub-angular blocky structures. This may be attributed to the corresponding increase in clay content in the sub surface soils.

3.3 Soil Chemical Characteristics

3.3.1 Soil reaction

The pH (in water) of the soils ranged between 5.28 and 6.35 indicating strong to slightly acid [13]. However, most of the sub surface horizons were strongly acid in reaction. There was a general tendency among these soils to have higher pH values at surface, which decreased with depth. Ojanuga [14] attributed the slightly higher pH in the upper most soil horizon to the accumulation of exchangeable calcium (Ca) and magnesium (Mg) derived from plant roots and litter decomposition, as well as biogenetic cycling of bases. The pH values of the Soil Units I and III were higher than those of Unit II. As the cations are leached, hydrogen ion (H^+) from water (H_2O) replaces the leached cations in the exchange complex to balance the charge. Soil acidity is known to affect most soil nutrients especially P, N, S and micronutrients [15].

3.3.2 Organic carbon

The percentage organic carbon was low to fairly moderate with values ranging from 0.47% to 1.47%. These values decreased with depth in all the three Soil Units due to the concentration of plant roots and residue on the top soils. The low organic carbon content of these soil units could be attributed to annual bush burning in the area as well as the native vegetation cover and climate. Drainage appeared to have strong influence on the organic matter content of the soil.

Earthworms and other organic fauna increase organic carbon content of the soil by breaking and biochemically altering fresh organic matter through mixing with inorganic materials and later excreting them to form a moist homogenous blend of the organic and mineral matters which prevents rapid loss of humic compounds [16].

More earthworm casts were seen on the surface of soil unit III than units I and II which are on the crest and midslope respectively.

3.3.3 Total nitrogen

Total nitrogen values ranged from 0.101 to 0.54% for all the horizons of the profiles studied. The distribution of total nitrogen follows the same pattern as organic carbon both in profile distribution as well as on the top sequence. Jones [17] revealed that savannah soils are generally low in total nitrogen. This is due to the low percentage organic carbon content because the two are closely related. It is`` high where organic matter is high from the established relationship between soil organic carbon and nitrogen. It is obvious that climate, vegetation and human activities contribute to the low level of nitrogen.

3.3.4 Available phosphorus (P)

The soils generally had low levels of available phosphorus (2.20-4.26 mg/kg). The surface horizons of the soils have the highest amount of available phosphorus, which decreased with soil depth. This shows that much of the available P is in organic forms associated with organic matter.

3.3.5 Exchangeable cations

The values of exchangeable cations (Ca, Mg, K and Na) were low in all the soil units. The low values of exchangeable bases of these soils may be due to intensity of weathering and lateral translocation of bases. The amount of exchangeable calcium (Ca) ranged between 2.71 and 7.8 cmol/kg of soil. Magnesuim (Mg) ranged between 0.90 and 4.40 cmol/kg of soil. Potassium (K) ranged between 0.11 and 0.90 cmol/kg of soil while Sodium (Na) ranged between 0.06 and 0.12 cmol/kg of soil. The predominance of Ca over the other cations in these soils may be due to the fact that of all the exchangeable cations, Ca is least easily lost from the soil environment [18].

3.3.6 Cation exchange capacity

The CEC of the soil ranged from 4.8 to 15.7 cmol/kg of soil. The lowest CEC values were recorded in "A" horizon of unit III owing to their low organic matter content and perhaps low clay content. Donahue [19] reported that some sandy soils of the tropics with dominant sesquioxide clay may have low CEC hence, low fertility.

Table 1. Land requirement for suitability for cowpea cultivation

Land qualities	Suitability classes					
	$S1_1$	$S1_2$	S2	S3	N1	N2
	(85-95%)	(60-85%)	(40-60%)	(25-40%)	(25-40%)	(0-25%)
Climate (C)						
Annual rainfall (mm)	>1200	1000-1200	800-1000	600-800	-	>600
Length of rainy season (mouths)	>5	4-5	3-4	2-3	-	>2
Mean annual maxi. T (℃)	29	27-29	24-27	22-24	-	>22
Average daily min. T (℃)	>25	18-20	16-18	14-16	-	> 14
Mean annual temp. (℃)	>25	22-25	20-22	18-20	-	>18
Relative humidity (%)	>75	70-75	65-70	60-65	-	>60
Topography (t)						
Slope (%)	0-4	4-8	8-12	12-16	>16	-
Wetness (w)						
Flooding	F_0	F_0	F_1	F_2	-	F_2
Drainage	WD	WD	WD	IWD	PD	VPD
Soil physical properties						
Texture	LS	SL	SC	SCL	Any	C, CL
Soil structure	Crumb	Crumb	S. A. Blocky	S. A. Blocky	Columnar	Columnar
Coarse fragment (Vol. %) 0-30 cm	3-10	10-15	15-35	35-55	-	>55
Depth (cm)	>100	90-100	50-90	25-50	-	>25
Fertility (f)						
CEC (Cmol/kg)	>10	8-10	6-8	4-6	2-4	<2
Base saturation	>70	60-70	40-60	20-40	-	0
pH	>6.0-6.5	6.0-7.0	5.5-6.0	5.0-5.5	4.5-5.0	<4.5-7.5
Organic carbon (%)	>1.5-2.0	1.5-2.0	1.25-1.5	1.0-1.25	<1.0	<1.00
Ca (mole fraction)	0.8-0.9	0.7-0.8	0.6-0.7	0.4-0.6	0.2-0.4	<0.2
Avail. P (mg/kg) 0-30 cm	>20	16-20	12-16	8-12	4-8	<4.0
Salinity and Alkalinity (ds/m) (n)	<1	1-2	2-3	3-4	4-8	>8

Source: USDA [12]

Table 2. Soil morphological characteristics

Profile pit	Horizon	Depth (cm)	Colour	Mottles	Texture	Structure	Boundary
I	A	0 – 30	10 YR5/3	-	LS	1 Fcr	Gs
	B	30 – 59	7.5 YR6/2	-	SL	2 Mcr	ds
	BC	59 – 93	5 YR5/8	-	SL	2 MSbk	ds
	C1	93 – 117	10 YR6/6	-	SL	2 Msbk	gs
	C2	117 – 151	7.5 YR8/0	-	SCL	2 csbk	-
II	A	0 – 49	10 YR5/6	-	SL	1 Fcr	Ds
	B1	49 – 74	7.5 YR6/4	-	SL	2 Mcr	gs
	B2	74 – 103	10 YR6/4	-	SL	3 Csbk	dw
	C	103 – 130	10 YR8/4	5YR 5/3	CL	3 Csbk	-
III	A	0 – 37	10 YR5/6	-	LS	1 Fcr	Ds
	B1	37 – 78	10 YR8/4	-	LS	2 Mcr	gs
	B2	78 – 106	10 YR7/4	-	SCL	2 Msbk	gs
	C1	106 – 130	7.5 YR5/6	10YR8/5	SCL	3 Csbk	ds
	C2	130 – 145	7.5 YR8/10	10YR 5/6	SCL	3 Csbk	-

3.3.7 Base saturation

Base saturation by sum of cations ranged between 71.57 and 95.54% which is rated very high [20]. The high base status showed that the soils had high native fertility, which is confirmed by the luxuriant growth of the vegetation of the soil.

3.4 Soil Classification According to USDA Soil Taxonomy

Soils of Units I and III qualify as Alfisols because of the presence of argillic horizon and the high base saturation. The Ustic soil moisture regime places them under the suborder Ustalf. They are further classified as Gleysols because of the absence of diagnostic horizon other than ochric epipedon and presence of sandy particle sizes in their entire subsurface layer.

Soils of Unit II had well developed argillic horizons with slicken sides. They had strong coarse sub angular blocky structure. These coupled with the high base saturation qualify these soils as Afisol. The aquic soil moisture regime further places them into sub order Aqualfs. The low CEC of the argillic horizons qualify the soils as Kandiaqualfs. In the sub group category they are classified as Typic Kandiaqualfs.

3.5 Soil Correlation

The soils of the study area can be likened with other soils studied in the Benue Valley especially those of Fagbami [21] and Idoga [22]. The soils of unit II do not correlated with any of the soil studies by [21].

The soils of Units I and III correlated with soils of Benue valley and also with those of [21,22]. They also correlate positively with soils of the vihi series which have slow water infiltration capacity and sandy clay loam to clay with loam surface texture [21].

3.6 Agricultural Productivity Potential

Cowpeas are grown on a wide range of soils but the crop shows a preference for sandy soils, which tend to be less restrictive on root growth. It is more tolerant to infertile and acid soils than many other crops.

Cowpea is a heat-loving and drought-tolerant crop. The optimum temperature for growth and development is around 30℃. Varieties differ in their response to day length, some being insensitive and flowering within 30 days after sowing when grown at a temperature around 30℃. The time of flowering of photosensitive varieties is dependent on time and location of sowing and may be more than 100 days. Even in early flowering varieties, the flowering period can be extended by warm and moist conditions, leading to asynchronous maturity. The optimum sowing times are December to January. Early-sown crops tend to have elongated internodes, are less erect, more vegetative and have a lower yield than those sown at the optimum time.

The presence of nodular bacteria specific to cowpea, make it suitable for cultivation in the hot, marginal cropping areas of Benue State, as well as in the cooler, higher rainfall areas. However, cowpeas are much less tolerant to cold soils.

Table 3. Physical and chemical characteristics of the soils

Pit	Horizon	Depth (cm)	Mechanical analysis			Soil pH		O.C	O.M	Total N	Avail. P	Exchangeable cations (cmol/kg)				CEC	B. S
			Sand /------	Silt ---%-	Clay ----/	H_2O 1:1	KCl 1:1	/-----	-------	(%) -	--------/	Ca	Mg	K	Na		(%)
I	A	0 – 30	78.1	13.5	8.4	6.35	5.37	1.47	2.53	0.094	4.21	3.15	1.60	0.30	0.12	5.30	97.54
	B	30 – 59	62.8	19.0	15.2	5.83	5.16	0.63	1.09	0.080	4.11	3.60	1.90	0.25	0.11	6.20	94.51
	BC	59 – 93	61.4	18.5	19.1	5.58	4.90	0.59	1.02	0.080	3.70	4.50	2.80	0.19	0.09	8.50	89.17
	C1	93 – 117	58.6	15.1	26.3	5.46	4.70	0.51	0.88	0.070	3.38	5.40	3.07	0.23	0.09	9.40	93.51
	C2	117 – 151	55.3	16.0	28.7	5.37	4.55	0.47	0.81	0.065	2.80	5.70	3.39	0.26	0.10	10.3	91.74
II	A	0 – 49	68.2	17.3	14.5	5.61	4.80	0.74	1.28	0.077	3.97	3.66	1.78	0.34	0.07	6.72	87.05
	B1	49 – 74	67.7	18.1	16.2	5.39	4.40	0.68	1.18	0.071	3.42	3.09	1.98	0.30	0.07	7.60	71.57
	B2	74 – 103	62.2	20.2	17.6	5.32	4.33	0.60	1.03	0.066	2.70	4.70	2.50	0.25	0.07	8.50	88.47
	C	103 – 130	61.5	20.4	19.1	5.28	4.29	0.51	0.88	0.060	2.20	4.95	2.90	0.19	0.06	9.30	87.09
III	A	0 – 37	77.3	15.4	7.2	6.24	5.70	0.86	1.48	0.101	4.26	2.75	0.90	0.16	0.08	4.80	80.20
	B1	37 – 78	75.4	16.1	8.5	6.20	5.56	0.77	1.33	0.096	3.66	2.90	1.10	0.14	0.08	5.60	75.35
	B2	78 – 106	57.5	17.3	24.2	6.16	5.43	0.70	1.21	0.062	3.38	6.60	3.57	0.11	0.07	12.8	80.85
	C1	106 – 130	54.0	18.2	27.8	6.10	5.05	0.62	1.07	0.059	2.60	6.90	3.80	0.12	0.07	13.5	80.66
	C2	130 – 145	51.6	19.1	29.3	5.35	4.66	0.56	0.97	0.054	2.40	7.80	4.40	0.90	0.06	15.7	83.82

Cowpea can grow under rainfall ranging from 400 to 700 mm per annum. Well-distributed rainfall is important for normal growth and development of cowpeas. Cowpeas utilize soil moisture efficiently and are more drought-tolerant than soya-beans and groundnuts. Cowpeas can be produced satisfactorily with an annual rainfall between 400 and 750 mm. Adequate rainfall is important during the flowering/podding stage. Cowpeas react to serious moisture stress by limiting leaf growth and reducing leaf area by changing leaf orientation and closing the stomata.

Going by the production requirement of cowpea in Table 1, and the characteristics of the soils of the area, the major limitation of the soils are poor drainage among the Unit III soils, the high clay content and the presence of plinthite within 120 cm of the soil surface. The high clay content and plinthite constitute an impermeable layer which accounts for the perched water table.

The soils of Unit III have higher pH values and are exclusively for rice cultivation due to seasonal flooding and poor drainage.

The soils of Units I and III have moderate pH values with low to very low exchangeable bases. For these reasons, these soils can be cultivated with cowpea. Other crops like maize, yam, and soybean can be planted.

4. CONCLUSION

4.1 Soil Related Constraint to Cowpea

The soils of Units I and II can be used for cowpea production or for cultivation of other crops such as soybean root and tuber crops if seedbeds are raised a little higher.

The “A” horizon of the soil units had predominantly weak fine crumb structure. This could be attributed to their low level of organic matter and sandy texture of the soil. This limitation can be corrected by increasing the organic matter content of the soil by incorporating crop residues. Some parts of the study area (Soil Unit III) were seasonally flooded. This area can be used exclusively for rice cultivation because of the drainage. Owing to their sandy nature, poor soil structure, lack of vegetation cover, the study area is moderately susceptible to water erosion. Adequate agronomic practices such as crop rotation, contour ridging, mulch farming and incorporation of organic matter should be adopted to combat soil erosion.

The soils of University of Agriculture Makurdi Teaching Research Farm were imperfectly drained with mottles below 100 cm depth. They also had a perched water table which is seasonal in soil Unit III. This is the reason why there is seasonal water logging on the soil surface.

The soils were low in organic carbon content, exchangeable bases, cation exchange capacity and high base saturation. Soils of Unit I were classified as Typic Paleustalfs/Eutric Gleysols. Soils of unit II were classified as Typic Halplstalfs/Eutric Gleysols, and soils of unit III were classified as Typic Kandiaqualifs/Gleyic Luvisols.

The major agricultural constraint of these soils is the presence of plinthite within 150 cm of the soil surface. These materials cause perched water table and is the reason for the water-logged conditions of the lower part of the mango orchard.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18512