Soil Productivity Assessment of Soils in Orire Local Government Area of Oyo State for Cashew Production

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Abstract— Detailed soil survey was carried out on 106 acres of land with the major aim of evaluating the land for sustainable and profitable cashew Production in Agbanda, Orire Local Government Area of Oyo state, Nigeria. Soil properties such as: Soil Texture, Bulk Density, pH, Organic Carbon, Nitrogen, Potassium, Available Phosphorus, Ca, Mg, Fe, CEC, and climatic data on Temperature, and Rainfall. According to the degree of favorable environment for cashew crop (FAO, 1984), simple statistical weighting/ratings were used for all the variables leading to multi-criteria decision support approach. Three rating systems, like "1" as suitable, "2" as moderately suitable and "3" as unsuitable were used to rank all the variables.

The soil pH of all the sites was slightly acidic (4.48 – 6.5). Generally, all the soil samples tested were very low in essential nutrients especially total nitrogen and available phosphorus. The organic carbon and matter in the site have been greatly depleted. The samples equally have high concentrations of extractable Fe. From the analyzed results, the land was grouped to four mapping units, indicated as RRY1 (degraded land as a result of land clearing), RRY2 (land laden with plinthite), RRY3 (soils with no major constraints) and lastly RRY4 (soil with high water table content).

RRY3 Soil mapping unit was moderately suitable for cashew production with very little amendments to enhance productivity and sustainability. Soil mapping unit RRY2 which covers about 72.36% of the whole land was rated moderately suitable, however, it will require more amendment with addition of organic manure such as compost, farm residues, animal dungs fortified with NPK, Zinc and Sulphur. Soil mapping unit RRY1 was rated unsuitable because of the high level of sesquioxide that have reached an irreversible stage making penetration of plant roots, water and nutrient impossible. Therefore, it is advised that this zone should be for other farm activities such as farm houses equipment store and warehouses. While RRY4 soil unit could be used for planting other water loving crops such as vegetables, fruits, plantain and bananas.

In conclusion, if all the percussions are taking into cognizance, about 77.89% of the total land could be used for profitable and sustainable cashew production. The remaining areas of land (22.11%) need serious soil amendment to make them suitable for cultivation of the targeted tree crops.

Keywords— Detailed soil survey, Soil productivity, Soil mapping, Sustainability.

INTRODUCTION

Agricultural sustainability can be defined as the ability of a system to maintain stable levels of production and quality in the long term without compromising economic profitability or the sustainability of the environment. The conservation of soil quality is fundamental to agricultural sustainability (Okusami, et al., 1985). The soil provides, amongst other things, a substrate for plant anchorage, a buffered supply of essential mineral elements and water, a repository for carbon, a reservoir of functional biodiversity, and a filter for reducing the pollution of air and water by agrochemicals. However, Soil as a component of the natural medium that acquires its morphology and properties after a long and slow evolution reaching equilibrium with environmental conditions. Nevertheless, ever since humans during the Neolithic shifted from hunting and gathering to farming and herding, the soil has undergone intensive exploitation (Agbogun et al., 2020).

Nigeria's land masses are facing intensive competitive uses that very often lead to their misuse and degradation of land (Nuga and Akinbola, 2015), the potentials of agricultural land to be sustain agricultural production of a specific crop maximally needed basic understanding, there is the need to have a good understanding of the different alternative uses that a land can be put. Land use ought not to be based primarily on the needs and demands of the users, but rather on the understanding of the suitability of such a land for the intended use in order to achieve environmental sustainability (Ogunkunle, 2005).

There is an urgent need for evaluation of agricultural lands and associated planning, owing to problems faced in recent years in the form of increasing pressure on agricultural lands from other uses, coupled with increasing demand for agricultural products due to population growth (Esu, 2005). Unguided conversion of agricultural land to non-agricultural land or inappropriate land use systems (policies) will ultimately lead to environmental and socio- economic problems, including poverty and unsustainable use of land resources (Udoh et al., 2006). The agricultural produce value chain in Nigeria is in a period of growth, but there is still the need to provide growers and other stakeholders with information on land suitability which will make for sustainable management and production (Orimoloye, et al., 2010). Land Evaluation is a process of estimating the potential of land for alternative kinds of use (Dent and Young, 1981). According to (FAO, 2006) soil evaluation is the process of assessing the performance of land when the land is used for specified purposes. Conducting a land evaluation involves the integration of a number of factors including soil properties, climate and land use. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use (Soil Survey Staff, 2003). The results of a land evaluation exercise, therefore, serves as the basis for decision making by land use planners and other decision makers who have an influence on land use in a given region (Okusami, et al., 1985). The present study was aimed at assessing the suitability of soils in Orire local government area of Oyo state for cashew production vis-à-vis other potential crops and recommendations for its sustainability.

MATERIALS AND METHODS

The study site is located at kilometer 44, along Igbeti - Ogbomoso road, Orire Local Government Area of Oyo State on latitude 8038'N and longitude 4025'E. It covers an area of approximately 106.2 acres of land at Agbanda village, in the southern guinea savanna zone of Nigeria. The area has a transitional climate that falls between humid and fairly hot sub-humid tropical weather with marked wet and dry seasons. In between the two seasons is a short period of harmattan. The mean annual rainfall is about 1400mm with a weakly developed bimodal pattern of distribution, reaching peaks around July and September. The air temperature ranged between 25.8OC in August and 30.5 OC in March with the mean annual air temperature of about 27 OC, when 1OC estimation is added to the mean annual air temperature, it gives the approximate mean soil temperature of about 28 OC (Nimet, 2018).

The natural vegetation of the area can be described as the southern Guinean savanna (Obatolu, 1996) consisting of trees/shrubs with a more / less continuous cover of grasses. The most common trees are cashew at different stages of growth, locust bean (Parkia lappertoniana), sheabutter (Vitellaria paradoxa) and oil palm (Elaesis guinensis). The common grasses found in the area are Panicum maximum and Pennisetum sp. As at the time of this evaluation, the natural vegetation of the land has been disturbed due to continuous cultivation and re-planting of wild cashew by the former land users. Thus, the prevalent weed situation is now sunflower (Tithonia diversifonia, spear grass (Imperata cylindrical), tridex and spurge weed which are all strong weeds in the Guinean savanna zone of West Africa (Ogunwale and Azeez, 2000). The area is underlain by the pre-Cambrian basement complex rich in kaolinitic and sesquioxide minerals. Weathering had been deep and intensive, the landform of the area can be generally described as undulating with sloping downward direction from the northern, eastern and western sides forming a concave doom at the center. This created a long partially straight stream of water that dry up in the dry season with a consequential valley bottom that occupies about 5-10% of the whole landscape.

FIELD WORK

Soil identification and mapping was by the rigid grid method with the aid of the soil auger. A

predetermined format of 50 m ×50 m was adopted thus: Transverses were cut at 50 m apart along a predetermined baseline and observation points were at 50 m apart along the traverses (Olatunji, et al., 2017). Morphological properties were recorded at each point, including texture and slope, evidence of erosion, rock outcrop, etc. The points were then grouped on the basis of the recorded morphological features. Auger holes were made at each point down to a depth of 30 cm and soil was examined at each of 0–15 cm and 16–30 cm depths. Soil depth of 0-30 cm was chosen because the 0 – 15cm represent the average plough layer in the area, while the 16 – 30cm depth is the layer where clay particles accumulate following their eluviation from the upper layer.

Soil samples collected from the genetic horizons of each profile were air-dried and passed through a 2mm sieve. Particle size distribution was determined by the hydrometer method [Buoyoucos, 1962] after the removal of organic with hydrogen peroxide and dispersion sodium hexametaphosphate [Gee, and Or, 2002.]. The pH was determined with glass electrode pH meter in soil: water and soil: each at ratio 1: 1.

Exchangeable cations (calcium, magnesium, potassium and sodium) were extracted with neutral normal ammonium acetate (NH4OAc at pH 7.0). Calcium and magnesium in the ammonium acetate extract were determined by atomic absorption spectrophotometry, while potassium and sodium were determined by flame photometry. Cation Exchange capacity (CEC) was determined according to the procedure of Hossner (Hossner, 1972). Organic matter was determined by the wet oxidation method (Shamshuddin et al., 1995). Total nitrogen of the soil was determined using the macro Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus in the soil was determined using Bray P-1 method (Bray and Kurtz, 1945), The exchangeable acidity (H++Al3+) in the soil was extracted with 1M KCl (Thomas, 1982). Solution of the extract was titrated with 0.05M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of base (NaOH) used is equivalent to the total amount of exchangeable acidity (H++Al3+) in the aliquot. The summation of exchangeable bases (Ca2+, Mg2+, K+ and Na+) and total exchangeable acidity (H++Al3+) gave the effective cation exchangeable capacity (ECEC) (Juo et al., 1974). Percentage base saturation was calculated as the ratio between the sum of exchangeable bases and effective cation exchangeable capacity multiplied by 100. The micronutrients (Zn, Mn, Fe and Cu) were extracted with 0.1M HCl (Juo et al., 1974) and their concentrations in soil extracts were read on AAS. Data generated was subjected to descriptive statistics, coefficient of variation.

LOCATION SUB DIVISIONS

Based on the field observations, the land was divided into four groups according to their physical and morphological attributes. The area coverage of each of the categories as well as number of representative samples taken is given below (Table 1).

Table 1: *Sampling locations and number of samples.*

Mapping Units	Percentage Coverage
RRY1.	5.53%
RRY2	8.16%
RRY3.	72.36%
RRY4.	13.95%

- RRY1 – Degraded land as a result of land clearing
- RRY2 – Plinthite laden soil
- RRY3 – Soil without any physical impediments
- RRY4 – Water logged soil/ swampy soil

Table 2: *Soil texture suitability rating for Cashew*

TEXTURAL CLASSES	DESCRIPTION	RATING
Sands	More than 85% sand, 0 to 10% clay and 0 to 15% silt	1
Loamy Sands	70 to 91% sand, 0 to 12% clay and 0 to 30% silt	1
Sandy Loams	More than 43% sand, less than 7% clay and less than 50% silt	1
Sandy Clay Loam	More than 45% sand, 20 to 35% clay, less than 28% silt	2
Sandy Clay	45% or more sand and 35% or more clay	2
Loam	Less than 52% sand, 7 to 27% clay, 28 to 50% silt	2
Silt loam	Less than 12% clay and 50 to 80% silt	2
Clay Loam	20 to 45% sand and 27 to 40% clay	3
Silt	Less than 12% clay and 80% or more silt	3
Silty Clay Loam	Less than 20% sand and 27 to 40% clay	3
Silty Clay	40% or more clay and 40% or more silt	3
Clay	Less than 45% sand, 40% or more clay and less than 40% silt	3

1 = Suitable; 2 = Moderately Suitable and 3 = Unsuitable, Source: Widiatmaka et al., (2014).

Table 3: *Soil Physical properties suitability rating for cashew*

S/N	PROPERTIESS	DESCRIPTION	RATING
A.	Slope (%)	15 to 30	1
		< 15	2
B.	Water Holding Capacity		
	Very high	< 3	1
	High	3 to 5	1
	Moderate	5 to 10	2
	Low	10 to 15	3

	Very Low	> 15cm	3
C.	Bulk Density gm3	0.72 - 0.94	1
		0.94 - 1.14	2
		1.14-1.62	3
D.	Elevation (m)	140-300	1
		300-384	2
		385 and above	3
E.	Soil depth	40cm and above	1
		15.0cm – 21cm	2
		Below 7.0cm	3

1 = Suitable; 2 = Moderately Suitable and 3 = Unsuitable | Source: Widiatmaka et al., (2014)

***Table 4:** Soil Chemical properties suitability rating for Cashew*

	---------------------------**Rating**------------------------------------		
Soil property	1	2	3
pH	4.5 - 5.0	5 - 1, 5.2 - 6.5	>7.0
OC (%)	>1.0	0.8 - 1.0	<0.8
Av. P (ppm)	>15	5-15	<5
K (ppm)	>0.5	0.37 - 0.27	<0.1 - 0.27
N (%)	>0.7	0.5 - 0.7	<0.2
CEC (Cmol/kg)	>8.5-12.4	2.6 – 8.5	<2.6
Texture	S, SL, LS	SC, SCL	SiL, L, C, SiC,

Source: Widiatmaka et al., (2014). | 1 = Suitable; 2 = Moderately Suitable and 3 = Unsuitable

OC: organic carbon; Av.P: available phosphorus; K: potassium; N: nitrogen

C: clay; CL: clay loam; L: loam; LS: loamy sand; SC: sandy clay; SCL: sandy clay loam; SL: sandy loam; SiC: silty clay; SiCL: silty clay loam; SiL: silty loam

***Table 5:** Climatic factors suitability rating for Cashew*

S/N	**PROPERTIES**	**DESCRIPTION**	**RATING**
A.	Rainfall (mm/year)	987 to 2,247	1
		600 to 986	2
		<600	3
B.	Temperature (oC)	25 to 28	1
		29 - 36	2
		36 - 42	3

1 = Suitable; 2 = Moderately Suitable and 3 = Unsuitable | Source: Widiatmaka et al., (2014), Falade, (1977)

RESULTS OF ASSESSMENT OF LAND QUALITY FOR CASHEW PLANTATION

Land characteristics of each sites relevant to cashew plantation were evaluated based on the USDA (2003) and FAO (2006) guidelines. Soil properties mapping for suitability rating.

The soil test and evaluation covers a total of 106.2 acres which were divided to the following four mapping units based on the soil attributes.

a. Mapping Unit 1 (RRY1): At the entrance of the farm from the main road (Ogbomoso – Igbeti road) are lateralitic soils (RRY1) that occupies about 5.53% of the total land mass, out of which about 2% have been severally degraded. Figures 1 and 2 presents a diagrammatic representation of the site.
b. Mapping Unit 2 (RRY2): Soils with very high sesquioxides content. This class of soil has very high content of Fe and Al oxides that have hardened leading to plinthites formation. They are practically of no value in agricultural production, they are impermeable to water and plant root, its covers about 8.16% of the total farmland.

c. Mapping Unit 3 (RRY3): referred to soils with no physical impediments (RRY3), this soil group does not show any physical disability to crop production and covered 72.36% of the evaluated land.

d. Mapping Unit 4 (RRY4): The fourth category (RRY4) is the area of land that bordered the major stream, they are water logged and have high water table especially during the raining season and it covers about 13.95%.

ASSESSMENT OF LAND QUALITY FOR THE VARIOUS SOIL MAPPING UNITS FOR CASHEW PRODUCTION

The location of the study site is generally suitable for cashew been situated at the savanna transitional zone, both the precipitation and temperature were ideal for profitable cashew production.

Soil Mapping Unit 1: Soil mapping unit RRY1 This is a Degraded land as a result of land clearing. The surface soil was more of sandy loam (Table 6).

Table 6: *Soil mapping unit RRY1 (Degraded land) Physical and Chemical properties*

Properties	Mean	Suitability rating
Temperature	27oC	1
Rainfall	1200mm – 1400mm	1
Soil depth	90cm	1
CEC(Cmol/kg soil)	3.9	2
Textural class	Sandy loam	1
Bulk density	1.50 - 1.53	2
pH	5.28	2
Total Organic Carbon	0.79	2
N (%)	0.09	3
P (ppm)	5.2	2
K (Cmol/kg soil)	0.11	3
Fe (mg /Kg)	134.83	3

The surface soils textural class was sandy loam, indicating that it is suitable for cashew production. The pH values ranges from 4.63 to 5.65 with average value of 5.27, the organic matter had a mean value of 0.79% while %N ranges from 0.065 to 0.091 with mean of 0.09%. The available P have a mean value of 2.15ppm; K varied from 0.05 to 0.15 Cmol/kg with mean value of 0.1 04 Cmol/kg ; and extractable Fe ranges from 81.10 to 275.26 mg/kg with average value of 134.81mg/kg soil (Appendix 2). The pH, organic matter, available Phosphorous, iron and soil bulky density were moderately suitable; and macro nutrients (N, P and K) are relatively low and moderately unsuitable, while Fe content is excessively high. From these soil physical and chemical properties, it could be deduced that the soil of RRY1 was moderately suitable for cashew production. This moderately suitable mapping unit required amendments to improve its suitability for profitability of the farm.

SUGGESTION FOR IMPROVEMENT OF RRY1 SOIL

(i) Incorporation of organic materials such as compost and crop residues. These will increase soil organic matter and nutrients that were low.

(ii) Shallow cultivation to prevent destruction of soil structure and reduce soil compaction.

(iii) Application of mulch materials to prevent exposure of soil surface to solar radiation

(iv) Application of organic fertilizers to reduce iron toxicity.

(v) Addition of mineral fertilizers (NPK) during cultivation to augment soil fertility. A fertilizer dose of 500g N, 125g P2O5 and 125g K2O per tree per annum is recommended.

(vi) Periodic checking of soil pH and NPK status is also recommended.

Soil Mapping Unit 2 (RRY2) (Plinthic laden land).

The surface soils varied from sandy loam to loamy sand (Table 7). Table 7 summarized the physical and chemical properties of RRY2 in relation to its suitability for cashew production. The textural class varied between sandy loam and loamy sand. According to FAO (1984) and Widiatmaka et al., (2014), however, the site is not suitable for cashew production in view of the fact that, the soil depth is very shallow (less than 20cm) and the irreversible reaction of Fe oxide and Al oxide which had permanently become hardened and form hard pans (plinthic horizon) that will not allow the penetration of plant root and nutrients had taken place. These possess a major limitation to cultivation of cashew.

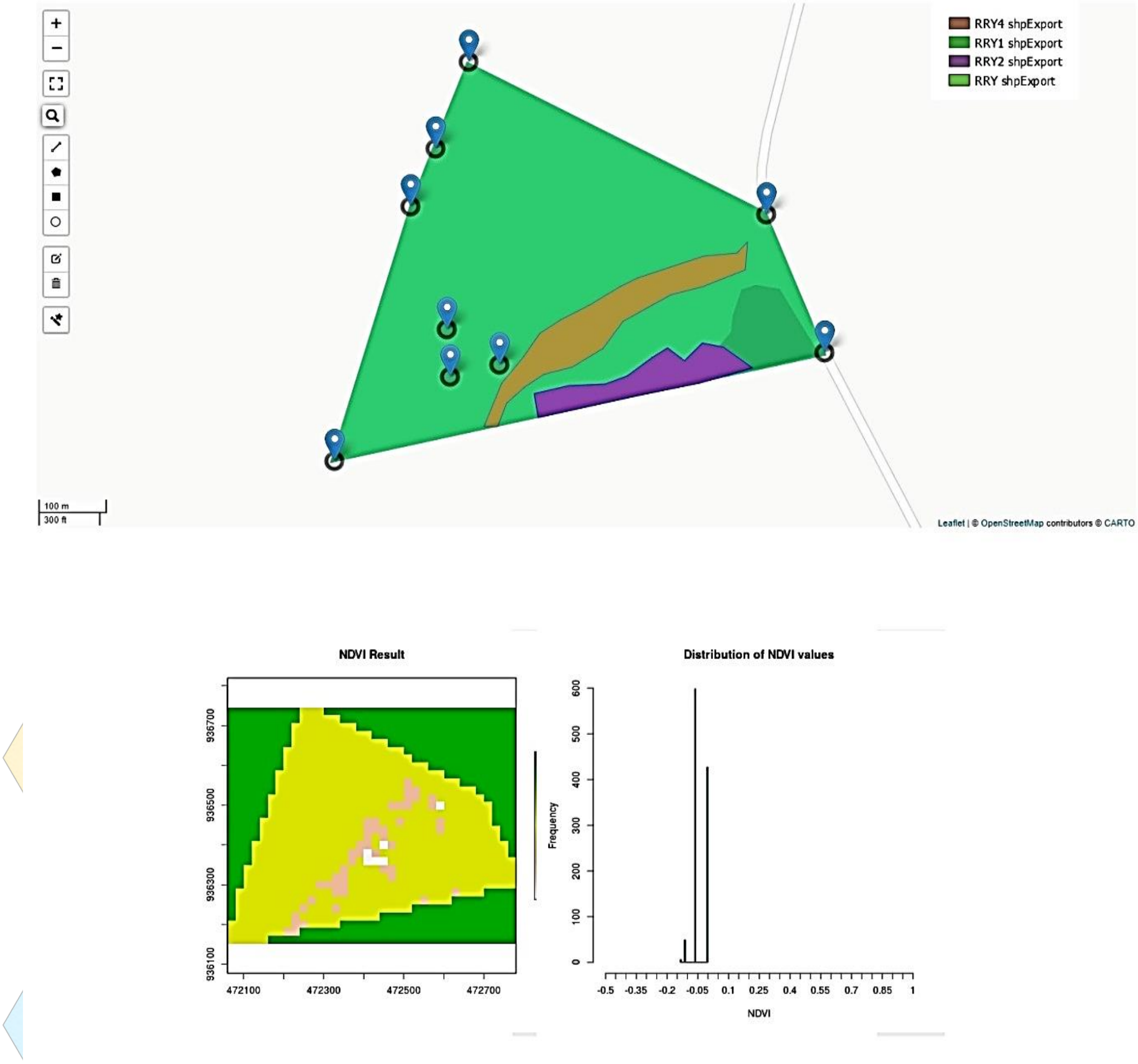

Figure 1: *CMAPIT GIS diagrammatic representation of the study site*

Note: RRY1 – Degraded land as a result of land clearing, RRY2 – Plinthite laden soil, RRY3 – Soil without any physical impediments, RRY4 – Water logged soil/ swampy soil.

The bulk density is on the average of 1.61g/m3. The average values for the soil pH, %OC, %N, P, and K are 6.03, 1.838, 0.2, 2.554 and 0.203 respectively. The Fe contents also varied from 54.53 to 326.14 mg/kg soil. The pH is moderately suitable, while organic carbon is suitable; macro nutrients (N, P and K) are low. The Fe content is very high. From these soil physical and chemical properties, it could be deduced that the soil of RRY2 is unsuitable for cashew plantation.

Table 7: *Soil mapping unit RRY2 Physical and Chemical properties*

Properties	**Range**	**Suitability rating**
Temperature	27oC	1
Rainfall	1200mm – 1400mm	1
Soil depth	25cm	3
CEC(Cmol/kg soil)	6.69	1
Textural class	Sandy loam	1
	loamy sand	1
Bulk density	1.51-1.65	3
pH	5.23-6.89	2

Total Organic Carbon	1.838	1
N (%)	0.2	3
P (ppm)	2.554	3
K (C mol/kg soil)	0.203	3
Fe	147.23	3

SUGGESTION FOR IMPROVEMENT OF SOIL MAPPING 2 (RRY2) SOIL

1. Cover cropping
2. Application of organic and mineral fertilizers will increase the available soil nutrients contents and improve the bulk density and water holding capacity.
3. Shallow rooted arable crops.
4. This can also serve as the farm house and implement zone, parking lot, farm shed, etc.

Soil mapping unit 3 (RRY3) soil properties suitability

The mean values for major soil physical and chemical parameters for RRY3 are as summarized in the Table 8.

Table 8: *Soil mapping unit RRY3 Physical and Chemical properties*

Properties	Range	Suitability rating
Temperature	27oC	1
Rainfall	1200mm – 1400mm	1
Soil depth	95cm	1
CEC(Cmol/kg soil)	6.69	1
Textural class	Sandy loam	1
	loamy sand	1
Bulk density	1.51-1.69	3
Ph	4.48 - 6.19	2
Total Organic Carbon	1.312	1
N (%)	0.145	3
P (ppm)	1.327	3
K (C mol/kg soil)	0.094	3
Fe	110.178	3

Textural class: Sandy loam to loamy Sand. These soil textures which were moderately suitable cover an average of 72% of the entire area. The bulk density ranges from 1.51 to 1.69; pH 4.48 - 6.19, while the means values for OC, N, P and K are 1.312, 0.145, 1.327 and 0.094 respectively. The mean of iron content (110.178mg/kg soil) is also very high. The pH is moderately suitable, while organic matter, macro nutrients (N, P and K) are low. The Fe content is very high. From these soil physical and chemical properties, it could be deduced that the soils of RRY3 are moderately suitable for cashew production.

SUGGESTION FOR IMPROVEMENT OF RRY3 SOIL MAPPING UNIT

(i) Application of organic matter to improve the pH and bulk density
(ii) Application of NPK fertilizer to improve the soil nutrients. Fertilizer that contain nitrogen, phosphorus, and zinc should be applied to increase performance and yield. For best results, a slow-release fertilizer with a NPK 8-3-9 ratio should be used.
(iii) This combination contains all the nutrients that a cashew tree needs.
(iv) Incorporation of organic materials such as compost and crop residues. These will increase soil organic matter and nutrients that were low.
(v) Periodic checking of soil pH and NPK status is also recommended.
(vi) Application of mulch materials to prevent exposure of soil surface to solar radiation
(vii) Application of organic fertilizers to reduce iron toxicity.

The suggestions above will help sustain, maintain and improve the soil fertility for profitable cashew production.

Soil mapping unit RRY4 soil properties suitability

The mean values for major soil physical and chemical parameters for RRY3 are as summarized in Table 9.

Table 9: *Soil mapping unit RRY4 Physical and Chemical properties*

Properties	**Range**	**Suitability rating**
Temperature	27oC	1
Rainfall	1200mm – 1400mm	1
Soil depth	75cm	1
CEC(Cmol/kg soil)	2.09	1
Textural class	Sandy loam	1
	loamy sand	1
	Sand	3
Bulk density	1.53-1.7	3
pH	4.92 - 5.97	2
Total Organic Carbon	1.276	1
N (%)	0.138	3
P (ppm)	1.074	3
K (C mol/kg soil)	0.064	3
Fe (mg/kg)	110.03	3

Textural class: Sand, Sandy loam to loamy Sand. The mapping unit is majorly water channels and always with high water table for more than 8 months of a planting season. Its covers an average of 14% of the entire area. The bulk density ranges from 1.53to 1.7; pH, 4.92 - 5.97, while the means values for OC, N, P and K were 1.276, 0.138, 1.074, and 0.064 respectively. The mean of iron content (110.03mg/kg soil) was also very high.

The pH is moderately suitable, while organic matter, macro nutrients (N, P and K) are low while the Fe content is very high. The area covered by this soil mapping unit are not suitable for the production cashew as a result of high water level. Cashew requires soil that is well drained and does well even in a dry environment. Therefore, it is advised that this area of land should be used in cultivation of other water loving crops such as: Palm tree, Plantain, Bananas, rice, vegetables and some spices which could bring economic returns. Nitrogen fertilizers should be applied frequently in small doses rather than large infrequent application to reduce the effect of soil erosion and leaching. The organic matter component should be improved upon, especially in mapping unit RRY1 and RRY3.

Exchangeable K values was highest at RRY2 (0.203 Cmol/kg) which was incidentally unsuitable in some other aspect, it was lowest in RRY4 (0.063 Cmol/kg) where leaching and washing away of soil nutrient is highest. Thus, the amelioration of potassium deficiency in soils is very necessary and could be by application of straight K fertilizer such as Muriate of potash (KCl) or compound fertilizer containing K.

It was obvious that P has the best chance to be available in the soil at slightly acidic reaction when the pH value ranged from 6.0 to 6.5, at a soil pH value higher than 6.5 fertilizers P is precipitated (fixed) by Ca and Mg. At a soil pH of 5.0 or less fertilizer P will be fixed by Al and Fe. The acidic nature of soils of the study area (pH 4.48 to 6.5; pH in H20) shows an indication of possible fixing of P by Al and Fe (Olatunji et al., 2012). Phosphate fertilizers are better applied frequently in small doses instead of large infrequent applications.

These are the nutrient elements that are required in smaller qualities by crops, Iron, Copper. Zinc and manganese are considered in this soil productivity evaluation. Iron and Mn content of the soils are high enough that application of Fe and Mn straight fertilizer may not be necessary. However, presence of substantial amount of Fe in soil at acidic pH (appendix 2) could be detrimental to soil productivity because of the possibility of Iron - phosphorus fixation (Olatunji et al., 2012). The zinc content of the soil is generally low, hence the need for Zn-containing fertilizer application. This could be in form of straight Zn fertilizer such as ZnSO4 which also supply sulphur to the soil in addition to Zn. This fertilizer (ZnSO4) has the potential of further acidification of the soil, hence should be avoided as much as possible. The alternative is the application of compound fertilizer containing some levels of S and Zn

CONCLUSION AND RECOMMENDATION

Compound fertilizer NPK 15: 15: 15 at 400kg per hectares i.e. 8 bags per hectares plus 5kg of ZnSO4 per hectare. OR 400kg of NPK 15: 15: 15 + S + Zn. However, NPK fertilizer 20 : 10 : 10 + S + Zn contains less amount of P, hence recommended rate for this type of fertilizer is 350kg NPK 20 : 10 : 10 + S + Zn plus 50kg of single superphosphate (SSP) i.e. 7 bags of NPK 20 : 10 : 10 + S + Zn and 1bag of SSP in order to prevent

P deficiency symptoms in maize. A compound fertilizer containing S and Zn would be preferred because ZnSO4 has potential of increasing soil acidity. It is imperative to apply sufficient amount of Organic fertilizers to supply adequate quantity of the major Nutrients (NPK) to enhance crops growth and yield. This is because the values of these elements are found to be low in all the soil samples in the mapping units, this will also correct soil pH. Appropriate soil conservation measures such as green manuring, cover cropping and mulching are required to improve the sustainability of the soils.

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Appendix 1: *Physical Soils properties of the study site*

Location	Bulked Sample No	Sand %	Silt %	Clay %	Textural class	Field capacity	Bulk density g/m3
RRY1	12	63	23	14	Sandy loam	0.21	1.5
	13	69	18	13	Sandy loam	0.21	1.5
	14	61	26	13	Sandy loam	0.2	1.53
	15	83	12	5	Sandy loam	0.21	1.51
Mean		69	19.75	11.25	Sandy loam	0.21	1.51
RRY2	11	60	30	10	sandy loam	0.21	1.55
	21	85	8	7	loamy sand	0.15	1.65
	25	79	15	6	loamy sand	0.16	1.66
	35	85	7	8	loamy sand	0.16	1.63
	40	75	17	8	sandy loam	0.17	1.61
Mean		81	11.75	7.25		0.16	1.6375
RRY3	16	63	30	7	loamy sand	0.14	1.69
	18	67	8	25	sandy loam	0.21	1.51
	22	81	13	6	loamy sand	0.15	1.66
	23	73	19	8	sandy loam	0.18	1.61
	24	81	12	7	loamy sand	0.16	1.64
	26	81	12	7	loamy sand	0.16	1.61
	27	79	15	6	loamy sand	0.16	1.66
	28	83	12	5	loamy sand	0.14	1.69
	29	55	37	8	sandy loam	0.21	1.57
	32	75	18	7	sandy loam	0.17	1.63
	36	59	32	9	sandy loam	0.41	1.56
	37	75	18	7	sandy loam	0.17	1.63
	39	83	9	8	loamy sand	0.16	1.62
	41	69	22	9	sandy loam	0.19	1.58
	42	85	9	6	loamy sand	0.15	1.67
	45	85	9	6	loamy sand	0.15	1.67
	47	83	9	8	loamy sand	0.16	1.62
	48	87	7	6	loamy sand	0.14	1.67
Mean		85	8.5	6.5		0.15	1.6575
RRY4	17	59	35	6	sandy loam	0.2	1.53
	19	83	10	7	loamy sand	0.15	1.64
	20	83	11	6	loamy sand	0.15	1.67
	30	79	13	8	loamy sand	0.16	1.62
	31	79	15	6	loamy sand	0.16	1.66
	33	75	19	6	sandy loam	0.17	1.65

	34	83	10	7	loamy sand	0.15	1.64
	38	85	8	7	loamy sand	0.15	1.65
	43	89	6	5	sand	0.13	1.7
	44	79	14	7	loamy sand	0.16	1.64
	46	85	9	6	loamy sand	0.15	1.67
Mean		84.5	9.25	6.25		0.1475	1.665

Appendix 2: *Soil Chemical properties of the Study Site*

Location	**sample no**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**Mn**	**Fe**	**Cu**	**Zn**	**Avail. P**	**pH**	**% O.C**	**% N**
		(mg/kg)				(Cmol/kg)	(g/kg)				(mg/kg)			
RRY1	12	2.21	0.68	0.05	0.07	3.01	23.39	275.36	6.64	130.8	5.99	4.63	0.406	0.05
	13	3.56	1.86	0.17	0.06	5.65	108.82	62.2	4.42	398.16	1.07	5.25	0.992	0.11
	14	3.17	1.42	0.15	0.03	4.77	144.45	120.66	13.31	20.61	0.78	5.58	1.178	0.13
	15	1.52	0.59	0.05	0.03	2.19	94.84	81.1	5.53	11.04	0.78	5.65	0.589	0.07
Mean		2.61452	1.138707	0.10422	0.04819	3.90564	92.8722	134.83	7.47248	140.151	2.15721	5.2775	0.79125	0.09
RRY2	11	4.01	1.47	0.24	0.04	5.75	87.16	54.53	3.31	176.15	1.22	5.97	1.86	0.21
	21	6.14	2.04	0.48	0.04	8.7	130.27	82.87	4.42	92.42	7.14	6.89	3.193	0.35
	25	1.98	0.76	0.08	0.03	2.86	121.02	92.32	4.42	92.42	0.5	6.06	0.93	0.1
	35	6.79	2.4	0.2	0.05	9.44	79.49	87.59	4.42	7.53	1.8	5.95	2.852	0.31
	40	2.21	0.68	0.05	0.06	3	28.9	326.14	6.64	22.2	0.78	5.25	0.377	0.04
Mean		4.2807	1.47098	0.20332	0.04467	5.99967	89.9195	147.23	4.97273	53.6444	2.55448	6.0375	1.838	0.2
RRY3	16	3.04	0.85	0.12	0.03	4.04	113.74	78.74	6.64	96.41	2.08	5.99	2.294	0.25
	18	3	1.08	0.09	0.03	4.21	117.08	70.47	6.64	30.45	0.64	5.92	1.55	o.17
	22	1.09	0.37	0.07	0.03	1.56	46.61	125.97	2.2	20.61	0.78	5.74	1.426	0.16
	23	2.6	0.86	0.06	0.04	3.55	115.51	79.92	4.42	168.98	0.78	5.8	1.55	0.17
	24	1.61	0.71	0.11	0.03	2.46	104.68	134.24	3.31	101.4	2.37	6.05	0.31	0.03
	26	2.78	1.05	0.12	0.04	3.99	125.75	119.48	5.53	69.5	3.24	6.19	2.79	0.31
	27	1.37	0.46	0.11	0.07	2.01	17.87	305.48	3.31	30.85	0.5	5.29	0.434	0.05
	28	1.85	0.62	0.1	0.03	2.61	86.97	90.54	4.42	42.81	2.37	6.13	2.046	0.23
	29	5.32	2.77	0.14	0.14	8.37	20.24	371.61	6.64	45.6	8.87	5.84	2.79	0.31
	32	1.2	0.52	0.06	0.09	1.87	16.1	173.21	6.64	120.83	0.5	5.47	1.085	0.12
	36	5.16	2.31	0.12	0.14	7.73	66.1	205.1	6.64	20.61	0.78	5.54	3.074	0.34
	37	2.17	0.85	0.15	0.05	3.22	52.91	114.75	4.42	37.62	1.07	5.48	1.274	0.14
	39	3.84	1.02	0.16	0.03	5.05	126.34	97.04	4.69	36.03	4.54	6.12	2.059	0.23

	41	3.02	1.15	0.17	0.12	4.46	23.58	382.83	4.42	40.02	0.78	4.48	2.494	0.27
	42	2.3	0.79	0.09	0.03	3.2	115.9	101.17	5.53	22.2	0.78	5.73	0.754	0.08
	45	1.96	0.74	0.14	0.03	2.88	69.05	81.69	3.31	20.61	1.8	5.61	1.537	0.17
	47	1.54	0.4	0.07	0.08	2.1	6.46	190.34	3.31	17.42	1.65	5.16	1.247	0.14
	48	1.48	0.44	0.08	0.03	2.02	42.09	67.52	2.2	12.63	1.07	5.6	1.711	0.19
Mean		1.82089	0.59354	0.09406	0.04306	2.55154	58.3753	110.178	3.58398	18.2136	1.32657	5.525	1.31225	0.145
RRY4	17	1.13	0.45	0.07	0.09	1.74	12.56	258.83	4.42	26.99	0.64	5.24	1.302	0.14
	19	2.93	1.2	0.11	0.04	4.28	88.74	68.7	5.53	15.82	0.93	5.73	2.015	0.22
	20	1.76	0.7	0.1	0.03	2.59	89.13	61.02	3.31	39.74	11.04	5.97	1.457	0.16
	30	0.85	0.47	0.1	0.06	1.48	34.21	133.06	5.53	19.01	1.36	5.6	1.798	0.2
	31	2.24	0.79	0.12	0.05	3.2	99.76	84.05	5.53	30.85	1.8	5.93	0.434	0.05
	33	0.68	0.39	0.05	0.12	1.24	5.47	159.63	5.53	20.21	0.5	5.47	0.93	0.1
	34	1.33	0.5	0.05	0.03	1.91	83.03	85.82	2.2	11.04	0.5	5.55	0.62	0.07
	38	1.96	0.64	0.09	0.03	2.73	68.46	66.93	5.11	14.23	0.78	5.69	0.609	0.07
	43	0.89	0.37	0.04	0.05	1.35	3.7	178.53	4.42	19.01	0.78	5.19	1.131	0.12
	44	1.28	0.72	0.05	0.11	2.16	1.54	125.38	5.53	11.04	2.08	4.92	1.508	0.16
	46	1.52	0.51	0.08	0.03	2.14	53.7	69.29	2.2	15.82	0.64	5.61	1.856	0.2
Mean		1.41247	0.56261	0.06357	0.05375	2.09239	31.8507	110.03	4.31307	15.0238	1.07376	5.3525	1.276	0.1375

Appendix 3: *Soil Chemical properties across the soil profiles*

Location	**Depth (cm)**	**Horizon designation**	**Ca**	**Mg**	**K**	**Na**	**Mn**	**Fe**	**Cu**	**Zn**	**Avail. P**		**O.C**	**N**
				mg/kg				g/kg			mg/kg		%	%
Udic Paleustalfs														
RRY1	0-17	Ap	3.54	1.08	0.22	0.03	103.11	44.49	5.53	33.24	0.50	6.3	2.389	0.26
	18-76	AB	1.85	0.46	0.09	0.03	70.43	47.44	7.75	19.01	0.50	6.33	1.953	0.22
	77-139	B1	2.82	2.16	0.34	0.05	45.83	32.68	5.53	147.75	0.64	5.47	1.457	0.16
Udic Paleustalfs														
RRY3	0-19	Ap	5.14	4.26	0.07	0.15	68.66	133.65	12.19	82.95	0.93	5.91	1.24	0.14
	20-75	AB	2.08	0.79	0.07	0.03	95.82	108.26	5.53	36.43	1.36	5.98	1.581	0.17
	76-98	B1	1.70	0.43	0.05	0.05	51.14	66.34	3.31	9.44	0.93	5.73	1.24	0.14
	99-132	B2	1.54	0.84	0.05	0.06	46.22	66.93	4.42	28.58	0.78	5.91	1.508	0.17
Aquic Haplustults														
RRY4	0-20	Ap	2.56	0.82	0.09	0.03	88.34	59.25	7.75	200.58	0.93	6	1.55	o.17
	21-55	AB	2.34	1.30	0.04	0.15	14.92	214.54	8.86	19.01	0.64	5.71	1.24	0.14
	56-97	B	1.11	0.72	0.03	0.12	4.88	104.13	4.42	11.04	1.36	6.2	2.17	0.24