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Effects of land quality, management and cropping systems on cassava production in southern western Nigeria

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The study was carried out to assess the effects of land quality, management and cropping system on cassava production in the derived savanna and rain forest of southwestern Nigeria. Soil quality was studied from farmers' fields which had been under cassava cultivation for at least ten (10) years. The yield data obtained from different crop mixtures and management practices were compared with the performance of cassava. The results showed great diversity of soils suitable for cassava production but good management and cropping system determined the yield. Maximum yield (78.5 $t.ha^{-1}$) of cassava was recorded on fertile, sandy clay loam soil (Apomu series, Eutric Luvisol) intercropped with maize, followed with cowpea in relay cropping. Lowest yield (3.3 $t.ha^{-1}$) was obtained on degraded low fertility compacted sandy soil of shante series (Albic Luvisol) under maize/cassava/crop mixture, with cashew. The results indicated that the more the use of appropriate agricultural input, management level and land requirement, the more the yield of cassava across the ecological zones studied.

Key word: Land quality, soil management, cropping systems.

INTRODUCTION

Cassava (*Manihot esculenta*) is one of the most important crops in Nigeria, playing a dominant role in the rural economy in the southern agro-ecological zones and is increasingly gaining importance in other parts of Nigeria. Very little attention has been given to the proper cultivation and soil requirement of the crop. This could be attributed to the ease with which the crop grows and secondly because of the position usually as the last crop in the traditional agricultural system before the land is left to fallow. Although reported yield vary considerably ranging from about 4 tons/ha to over 40 tons/ha depending on the cultivar cultural practices, climatic and soil conditions, it is only recently, with the need for more food in several countries and desire to produce more per unit area, that better understanding of the nutritional requirement of the crop is being considered.

Cassava is cultivated in all parts of Nigeria, but then, an effective and good understanding of soil and management is necessary to maintain sustainable production. However the trend of production shows steady increase of 2.7 percent per annum (FAO, 1982), hence care must be taken to maintain soil fertility and structure.

The observed decline in soil fertility under continuous cassava production has been attributed to nutrient loss/imbalance (Nair et al., 1988) by erosion as well as to crop removal. Also the crop removes large amounts of nutrients especially K and N in each root harvest (Asher et al., 1980). Therefore an effective management and good understanding of soil requirement is necessary to maintain sustainable production (Howeler, 1994). Good farming practices and rich/fertile soils using recommended varieties are essential to maintain sustainable production to meet the current high demand for cassava in Nigeria.

This project was designed to study the land quality, management and farming practices being used for cassava production in southwest Nigeria.

METHODOLOGY

The study areas

The study areas cut across rain forest and derived savanna with varying rainfall. Areas located in the derived savanna include Mo-

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gaji, Ogbomoso, Ajila, Afejewe, Obananko and Onilaru. The sites in the rainforest farms are Shagamu, Ewekoro, Abule Owe and Ikenne were studied. The soils in the savanna were underlain with rocks of basement complex while sandstone underly the rainforest soils except at Abule Owe. The rainfall is also between 1000 – 1400 mm with low elevation of 67 m at Shagamu which usually results in flooding. Temperatures of the zones vary from 28 - 33°C.

Site selection and sampling

Farmers' fields from two states in southwestern Nigeria located on the derived savanna (Oyo State) and rain forest (Ogun State) under cassava cultivation for at least 10 years were used for the study. Cassava is usually intercropped with maize. Fertilizer (NPK 15-15-15) was applied to maize in all the sites except at Onilaru. Organic manure at 5 tons/ha was applied to the soils at Abule Owe and Ewekoro. At Afejewe the intercrop was relayed with cowpea every year and stovers were ploughed into the soil the next growing season. The land preparation was by mechanization whereby the farm lands were ploughed twice and ridged except at Onilaru where all operations were done manually. After ploughing pre-emergence herbicide, primextra, was applied and it was also sprayed with post-emergence herbicide. The time of application depends on the rate of weed infestation. Light weeding was also carried out to supplement the herbicide. The maize spacing was 25 x 75 cm while cassava was introduced between six to eight weeks after maize was planted. The soil series were identified by minipits description. Surface and subsurface samples are collected up to 1 m depth since new cassava variety (30255) considered for the study is capable of rooting to that level. The average soil parameter within the rooting zone was used to assess the overall quality of the soils for cassava production and for fertility classification.

Plots of 20 x 20 m demarcated on farmers plots (in three replicates) were used for monitoring and yield data collection. One year after planting, cassava was harvested. Yields parameters taken include numbers of tubers/stand and yield in t/ha. The soil parameters determined include particle size by hydrometer method (Bouyoucous, 1962). Total N was determined colorimetrically. Soil organic matter was determined by dichromate oxidation procedure (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K, and Na) were extracted; Na+ and K+ were determined with flame photometer, while Ca^{2+} and Mg^{+} with Atomic Absorption Spectrophotometer. Suitability rating of the soil was done using the parametric method of Sys (1985). The parameters used for the land quality calculation include rainfall, length of growing season, mean temperature, slope, wetness, drainage, texture, volume of coarse materials, soil depth, fertility, cation exchange capacity, base saturation, and organic carbon. The sums of these were divided by the number of the parameters considered to determine their suitability. Analysis of variance was performed on the agronomic parameter.

RESULTS AND DISCUSSION

The soils

The major soil series identified at the savanna farms include Fashola, Temidire, Apomu and Shante series (Murdoch et al., 1976). These were classified as ferric luvisol, Euric luvisol and Albic luvisol, respectively (Table 1) (FAO, 1982). The soil from the rainforest includes Alagba, Fashola, Owode and Atan series (Moss, 1953; Murdoch et al., 1976). These have been classified according to FAO (1970) as Chromic Luvisol, Ferric Luvisol, Gleyic Luvisol, and Gleyic Cambisol, respectively.

Physical description of the soils

The soils from rainforest are formed from sandstone and basement complex. The sites on sandstone include Ikenne, Shagamu and Ewekoro and the soil series are Alagba, Atan and Owode, respectively (Moss, 1953). Fashola on basement complex occupied the mid slope of the landscape. The average physical and chemical properties to the rooting depth of 1 m are reported in Tables 2 and 5. Alagba series is loamy sand at the surface over sandy clay loam in the subsoil usually located at the upper to middle slope on the landscape. Owode series has similar physical characteristics but it was mottled. This indicated the fluctuation of water table within the profile. Atan is imperfectly drained with about three months of flooding. The physical property is also similar to the latter except for the flooding. Fashola series on basement complex is loamy sand to sand in texture and is underlain with hardpan at 50 cm depth.

The soil from the derived savanna includes Fashola, Shante, Temidire and Apomu series (Murdoch et al., 1976) (Table 4). The Fashola in this zone is similar to Fashola in the rain forest except that the latter is deeper while the former is underlain with hard pan at 30 cm depth. The recorded soils are usually situated at mid-lower slope position. Other series with hard pan include Temidire series at Ajila and Ogbomoso with hard pan in the derived savanna at 90 and 75 cm, respectively. The texture is loamy sand to sand at the subsoil above pan formation. Shante series (Onilaru) is sand to greater than 100 cm depth with no mottles, leached, with grey colour. Apomu series (eutric luvisol; Afeweje) is loam to sandy clay loam texture from surface to subsurface.

Chemical properties of the soils

The pH was generally at critical level of cassava which is 4.6 except at Ewekoro where it was slightly acidic to strongly acidic (Table 2). The soils were rated low, medium and high in levels of nutrients based on land/soil requirements for cassava by Sys (1985) (Table 2). Phosphorus values ranged from low to medium. However, at Ewekoro, P was medium with highest value of 9.95 ppm. This could be attributed to slightly acidic pH of 6.2 which is conducive for the release of P. In the other soils where P was low, pH is acidic to strongly acidic. It has been reported that in acid soils, P is fixed by acidic Fe, Al and Mn (Enwenzor et al., 1989). The slightly acidic pH could be attributed to effect of cement dust at Ewekoro. It has been reported that cement dust from Ewekoro has liming effect (Oluwatoyinbo et al., 1996).

The generally low CEC could be attributed to leaching of exchange bases from surface layers due to high precipitation in the rain forest and continuous use of acid-forming fertilizer/erosion in the derived savanna. N ratio is

Table 1. Summary of Soil/Landuse and suitability rating for cassava production.

Location	GPS Reading*	Farming system	Soil series	General comments	FAO classification	Suitability rating
Rainforest						
Ewekoro	$06^0\ 54^1\ 21^{11}$N $003^0\ 13^1\ 40^{11}$E	Cassava/maize intercrop	Owode	P is high	Gleyic Luvisol	S_{2fw}
Abule Owe	$07^0 13^1 45^{11}$N $003^0\ 28^1\ 11^{11}$E	Cassava/maize intercrop	Fashola	P is highly variable Moderate acidic plain land	Ferric Luvisol	S_{2g}
Shagamu	$06^0\ 47^1\ 50^{11}$N $008^0\ 28^1 24^{11}$E		Atan	Elevation 14 m The area is usually flooded during rainy season. Ridge will be required	Gleyic Luvisol	S_{2w}
Ikenne	$06^0\ 50^1 28^{11}$N $003^0\ 43^1 12^{11}$E	Cassava sole & Cassava/maize	Alagba	Low Elevation: 67m	Chromic luvisol	S_{2fc}
Savanna						
Mogaji	$7^0\ 52^1\ 30^{11}$N $3^0\ 59^1\ 10^{11}$E	Cassava/Maize Cashew,cassava	Temidire	Gravelly subsoil	Ferric Luvisol	S_{2f}
Onilaru	$8^0\ 10^1 40^{11}$N $4^0\ 10^1 25^{11}$E	Maize / cassava	Shante	Overused and inherent low fertility	Albic Luvisol	S_{2f}
Ogbomoso	$08^0\ 04^1 27^{11}$N $04^0 11^1 24^{11}$E	Cassava/ Maize Intercrop, sole cassava	Temidire	Rolling landscape slope 5 or > 5% erosion Control plan	Ferric luvisol	S_{2e}
Afeweje	$08^0 13^1 23^{11}$N $04^0\ 08^1 51^{11}$E	Cassava/ Maize	Apomu	Ridge, sandy loam soil erosion due to slope 3-5% lower slope	Gleyic Luvisol	S_1
Obananko	$4^0 49^1 49^{11}$N^1	Cassava/ Maize	Temidire	Gravelly subsoil	Ferric Luvisol	S_{2f}
Ajila	$7^0 22^1 30^{11}$N $3^0 50^1\ 20^{11}$E	Cassava/ Maize	Fasola	Gravelly subsoil	Ferric Luvisol	S_{2g}

Suitability rating according to Sys (1985).
S_2 = Moderately suitable; f = low CEC; g = gravelly; c = clayey; w: = seasonal high water table.
Soil series according to Mudoch et al. (1976).
*GPS: Global Positioning System reading taken at the centre of the field.

higher in all the soils which show slow release of nutrient from crop residue. The highest value of K was recorded at Abule-Owe and (0.9 Cmol kg^{-1} soil), followed by 0.89 Cmol kg^{-1} soil at Ikenne with the highest CEC. Hence, fertilizer with K should be avoided to avoid yield depression. The Zn and Cu level were high (Table 2). Low pH has been reported to cause micro nutrient toxicity in soils (Enwensol et al., 1989). In general, the overall soil properties of Ikenne was favourable except for N which was low and high clay content in the subsoil within the rooting zone (>25 cm). In

Table 2. Some selected average physical/chemical properties/nutritional requirement classification for cassava production.

Parameter	Abule-Owe	Ewekoro	Ikenne	Shagamu	Ogbomoso	Obananko	Onilaru	Mogaji	Afeweje	Ajila
Sand	75.9	75.9	71.8	79.1	79.8	76.46	83.83	82.8	65	71
Silt	18.3	9.6	11.67	7	8.93	11.6	8.93	9.6	20	14
Clay	5.8	14.5	16.53	13.86	11.26	11.93	7.27	7.6	25	15
pH	4.5^m	6.2^m	4.76^m	5.2^m	4.8^m	4.30^l	4.78^m	4.98^m	6.9^m	6.9^m
Ca	0.60^l	0.78^l	1.03^m	0.89^l	1.92^m	1.00^m	0.99^l	1.00^m	2.15^m	0.95^l
Mg	0.85^m	0.75^m	1.57^h	1.45^h	1.37^h	1.36^h	1.27^h	1.44^h	1.0^m	1.32^h
K	0.9^h	0.88^h	0.89^h	0.5l	0.18^m	0.17^m	0.14^l	0.15^l	$.27^h$	0.16^l
Na	1.0^m	0.96^m	1.07^m	0.96^m	1.40^m	0.80^m	0.84^m	1.20^m.	$.50^m$	1.15^m
H^+	0.65	0.09	0.35	0.43	0.79	0.87	0.67	0.37	.07	.06
CEC	3.38	2.4	5.12	3.5	4.77	4.17	3.9	4.09	3.39	3.95
BS	95.3	96	89.1	95.6	83.44	79.04	82.96	91.03	92.92	98.48
C (%)	0.26	0.19^l	0.78^m	0.40^l	0.22^l	0.30^l	0.12^l	0.25^l	1.40^m	0.60
N (%)	0.03	0.02	0.08	0.04	0.02	0.02	0.07	0.03	.10	0.06
Ave. P	4.5^m	9.95^m	5.45^m	4.0^l	3.33^l	2.83^l	4.33^l	4.00^l	12.1^m	4.5^m
Zn	7.1^h	7.6^h	6.97^h	7.26^h	7.60^h	6.77^h	6.90^h	6.10^h	3.5^m	2.5^m
Cu	3.0^h	3.87^h	3.07^h	3.37^h	4.10^h	2.67	2.17^h	1.85^h	0.56^m	1.3^m

l = Low; m = medium; h = high.
Approximate classification of soil chemical characteristics according to the nutritional requirement of cassava (Howeler, 1966a,b).
Parameters without superscript were not classified Howeler (1996).

Afeweje, both favourable physical and chemical properties were recorded. K is very low in sandy soils of Ewekoro/Shagamu but high in Ikenne with sandy clay subsoil. The capability of clay soil to maintain K intensity is high due to high exchangeable capacity. However, in the savanna, K is medium according to nutrient requirement of cassava (Sys, 1985). It has been reported that soils in the savanna has higher level of K than in the rain forest, but under continuous cultivation, they are rapidly depleted.

Cultural practices, cropping system and management

Planting of cassava is usually done on heaps in all the farms except at Onilaru in the derived savanna, where planting was on the flat soil. Herbicide was commonly used for weed control; hence the possibility of residue recycling is high. This could explain the sustainable level of cations especially in the derived savanna. The common farming system in all the zones was maize/ cassava intercrop. Maize and cassava are usually planted at the onset of rainfall; cassava remains on the field after maize is harvested. At Afeweje where high fertility was recorded, maize/cassava is usually followed by cowpea. Hence, erosion was not observed and N level is medium (Table 2). Its good performance could also be attributed to its light to medium texture (loam). It has been confirmed that cassava produce maximally on light to medium texture and fertile soil (PinoyFarmer.com, 2002).

Cowpea a leguminous crop has been known to contribute to soil fertility since it makes use of recycled maize residue. Inorganic fertilizer such as NPK 15-15-15 is commonly applied in the savanna with occasional use of straight fertilizer. While in the rain forest area (Ewekoro), inorganic fertilizer is also used but most farms that are close to poultry farms use poultry manure to improve soil fertility. N and C were also low in these soils hence high management will be required for good cassava production on soils from derived savanna. Such was reported at Ewekoro and Abule-Owe. Erosion was noticed as the major problem to monitor in the savanna due to the sandy mature of the soil and slope, which varies from 3 - 6%. In the rain forest, erosion was also noticed in spite of the plain-to-gently undulating nature of the terrain. This could be attributed to heavy rain splash which tends to loose soil structure before crops were fully established.

The farming system was different at Onilaru, which has been cultivation for more than 40 years. Cashew is being planted at 7 m apart in the maize/cassava mixture usually followed by yam/maize which are planted under the tree crop. Minimum tillage was the usual practice and crop residues were usually gathered at a spot on the field and burnt.

Yield, soil quality, management and cultural practices

The yield parameters were reported in Table 4. The yield parametres (t/ha) were significantly different across and within the ecologic zones; other parameters measured included number of tubers per stand and girth which were also significantly different. The highest yield of 78.9 t/ha was recorded at Afeweje, which met the soil fertility and

Table 3. Suitability rating (%) for cassava production.

Parameter	Abule-Owe	Ewekoro	Ikenne	Shagamu	Ogbomoso	Obananko	Onilaru	Mogaji	Afeweje	Ajila
Climatic										
Rainfall (mm)	95	95	95	95	95	95	95	95	95	95
Length of growing season (months)	95	100	95	95	85	85	85	85	85	85
Mean Temp. (t^0)	95	95	95	95	85	85	85	85	85	85
Topography										
Slope (%)	100	100	100	100	95	95	95	95	95	95
Wetness										
Drainage	100	95	100	60	100	100	100	100	100	100
Soil physical										
Properties										
Texture	60	85	85	85	60	60	60	60	60	60
Vol. of coarse Fragment	100	100	100	100	100	100	100	100	100	100
Soil depth (cm)	40	100	100	100	60	100	100	60	100	100
Fertility (f)										
CEC ($cmkg^{-1}$ clay)	25	25	25	25	25	25	25	25	85	25
Base saturation (%)	100	100	100	100	100	100	100	100	100	100
OM (%C)	40	25	85	85	40	40	25	40	100	100
Suitability rating	76.55	83.64	82.73	83.64	75.91	79.55	78.18	76.36	94.09	76.34

Table 4. Agronomic and yield parameters for each zone.

Location	Variety	Soil type	Texture	Yield (t/ha)	Ave. No./stand
Rainforest					
Ewekoro	TMS 30555	Owode	Loamy sand	38.36^a	11^a
Abule Owe	TMS 30555	Fashola	Loamy sand	30.13^b	10.5^a
Shagamu	TMS 30555	Atan	Loamy sand	$32.8.1^b$	7.9^b
Ikenne	TMS 30555	Alagba	Sandy loam	38.63^a	10.2^a
Derived savanna					
Mogaji	TMS 30555	Fashola	Loamy sand	30.33^b	6.8^a
Onilaru	TMS 30555	Shante	Sandy loam	2.76^d	3.3^b
Ogbomoso	TMS 30555	Temidire	Loamy sand	29.67^{bc}	7.4^a
Afeweje	TMS 30555	Apomu	Sandy clay loam	78.5^a	6.5^a
Obananko	TMS 30555	Temidire	Sandy loam	25.93^c	5.7^a
Ajila	TMS 30555	Temidire	Sandy loam	32.86^b	7.2^a

Values with same letter are significantly different at 0.05% probability.

physical requirement for good cassava production (Table 3). The lowest yield (3.3 t/ha) was recorded at Onilaru where fertility was low, heap was not used and the land intensively used (cashew and maize/cassava were planted on the same piece of land). Hence, small and few number of tubers were produced (Table 4).

There was positive response in yield to good management practices and soil quality and fertilizer/organic manure application. The response could be attributed to general low N in all the soils. This was confirmed by the report of Sittibusayo (1993) that cassava yields would drop without fertilizer since cassava is a nutrient exhauster. Where the surface loamy sand was overlaid with sandy – clay, like in Ewekoro, Ikenne and Shagamu, the number of tubers increased and size decreased, but bigger tubers are desirable for economic reasons. The farmers confirmed that the bigger tubers are more marketable than smaller tubers since more time will be required in the peeling of smaller tubers.

The clayey subsoil could be responsible for providing smaller tubers since tuberization was probably hindered. Tuberisation was probably hindered due to more energy

Table 5. Comparison of agronomic and yield parameters across the zones

Location	Variety	Soil Type	Texture	Yield (tha-1)	Ave. No./stand
Rainforest					
Ewekoro	TMS 30555	Owode	loamy sand	38.36[b]	11 [a]
Abule Owe	TMS 30555	Fashola	loamy sand	30.13[c]	10.5 [a]
Shagamu	TMS 30555	Atan	loamy sand	32.8.1[c]	7.9 [b]
Ikenne	TMS 30555	Alagba	sandy loam	38.63[b]	10.2 [a]
Derived Savanna					
Mogaji	TMS 30555	Fashola	loamy sand	30.33[c]	6.8 [bc]
Onilaru	TMS 30555	Shante	sandy loam	3.3[e]	3.3 [d]
Ogbomoso	TMS 30555	Temidire	loamy sand	29.67[bc]	7.4 [bc]
Afeweje	TMS 30555	Apomu	sandy clay loam	78.9[a]	6.5 [c]
Obananko	TMS 30555	Temidire	sandy loam	25.93[d]	5.7 [c]
Ajila	TMS 30555	Temidire	sandy loam	32.86 [c]	7.2 [bc]

Values with same letter are significantly different at .05% probability.

needed on clay soil than on loamy sandy soils underlain with hard pan in the savanna. It has been reported that pan may enhance spread of tubers laterally on the surface soils which is desirable for easy harvesting than deep rooted ones in sandy loam depending on the variety. Chemical properties played important role in cassava yield. Hence good combination of physical, chemical and cultural practices is essential for exceptional high yield above 50 t/ha

Generally, the overall yield was high (25.9 to 78.9 t/ha) except at Onilaru. The high yield could be attributed to good management practices, use of fertilizer, herbicides and organic manure in some cases (Abule-Owe and Ewekoro) couple with good cultural practice (cowpea in rotation) at Afejewe.

Suitability rating

The suitability rating of Sys (1985) was used and five major land qualities were considered. These include climate, topography, wetness, soil physical properties and fertility (Table 3). The suitability rating varied from highly suitable (S_1) at Afejewe to moderately suitable in other locations (Tables 1 and 3). The land qualities that were limiting include high gravel content in Fashola series, seasonal high water table in Atan series and Owode (S_{2w}) due to its low position on the topography, clay content in Alagba series (S_{2fc}), and general low CEC in almost all the soils except in Apomu (S_1) located at Afejewe where the highest yield was recorded. The moderate suitability rating (S_{2f}), recorded at Onilaru, produced much lower yield than other areas like Abule-Owe, Mogaji and Ogbomoso with comparable rating. This could be attributed to low input, poor management practices, land misuse and wrong crop mixtures. Hence, if land requirements parameters were appropriate, the management and cropping system will still determine or influence yield drastically.

Conclusion

The results showed great diversities of land qualities suitable for cassava production. Climate and topography revealed that elevations could be an issue as in Shagamu where flooding or water table rises to rooting zone. However, the range of rainfall suitable for cassava production contributed to growth of cassava in the rainforest and derived savanna with comparable yield. Although, the yields were good (except at Onilaru), the highest yield was recorded on light texture, well-drained soil with sufficient amount of nutrients as revealed at Afejewe.

The response could also be attributed to general low N in all the soils. The suitability rating was more than 76% in all the soils, but yield disparity occurred, which showed that good yield is a function of combination of other parameters like appropriate farming systems and cultural practices. The inclusion of cowpea in rotation and deep ploughing of soil at Afeweje and planting of cashew/yam intercrop at Onilaru coupled with soil compaction could have contributed to highest and lowest yield recorded in these soils, respectively. Hence, the more suitable the land quality, with adequate input and appropriate management, the higher the yield of cassava will be.

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