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Quality Assessment and Suitability Evaluation of Soils under Tuber-based Cropping System in Katsina Ala Local Government Area, Benue State, Nigeria

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ABSTRACT: Crop yields together with economic and social benefits of farming depend in part on land management and soil quality. Soil management and cropping systems have long-term effects on agronomic and environmental functions. This study aimed at assessing soils under yam-based cropping systems for quality and suitability so as to enhance sustainable production. The study was carried out in Katsina Ala local government area of Benue state where yam is a major crop. Sixteen modal profile were dug, described for characterization and suitability evaluation. Ten cluster locations were selected and twenty soil samples randomly collected within each cluster. The soils were subjected to laboratory analyses and results subjected descriptive statistics. Suitability of the soils for yam, citrus and groundnut were evaluated using parametric approach and soil quality of the area was assessed using Relative Soil Quality Indices (RSQI). The soils encountered are sandy to silty in nature with some having plinthite at depth. The soils, classified as Alfisol, Entisol and Inceptisol are moderately (S2) to highly suitable S1) for the three crops and have moderate to high quality for crop production with percentage soil quality index ranging from 60. 37 to 74.31 %. Soils of the study site are of good quality and are suitable for production of yam, citrus and groundnut. However, because yam is a great feeder and tropical soils are fragile making them prone to degradation, there is need for maintenance of soil fertility through organic matter management for sustainable use.

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Soils perform numerous functions in support of agro ecosystems. They provide a substrate for supporting plant growth, a reservoir for many nutrients essential for plant growth, a filter maintaining air quality through interactions with the atmosphere, storage and purification medium for water as it passes through the soil, and a site for biological activity involved in the decomposition and recycling of waste products. Increasing human population is placing greater demand on soil resources, and as a result degradation is taking place in many regions of the world. The challenge therefore is to increase crop yields and to minimize soil degradation and environmental pollution simultaneously. Soil improving cropping systems have been suggested as a strategy to halt soil degradation and environmental pollution recently. Cropping systems refer to a combination of crop types, crop rotation, and associated management techniques. There are many different crop types, crop rotations and management techniques, and hence also many cropping systems, but the diversity greatly depends on local socio-economic and environmental conditions. In agricultural systems, soil and crop management decisions will affect soil quality, crop yield and soil nutrient dynamics (Mikha, *et al*., 2005). Such decisions include cropping systems, residue management, and the intensity and frequency of tillage. Cropping systems can have both detrimental and beneficial effects on soil quality; and reports from various authors have shown this. For instance, Bowman, *et al*. (1999) measured a 20 % increase in soil organic carbon in the surface soils of continuously cropped no-till managed dryland systems, which previously were managed under conventionally tilled wheat fallow. They correlated the increase in soil organic carbon to greater annual crop yield (greater annual carbon as crop residue). Similarly, Pikul*, et al*., (2001) measured significantly greater soil organic carbon in continuous corn than in a corn-soybean rotation near Brookings, South Dakota Also, Wienhold *et al.,* (2006) observed that a reduction in both tillage and fallow combined with crop rotation has resulted in improved soil functions (e.g., nutrient cycling). However, Oluwatosin, *et al*., (2008) observed that important soil quality indicators such as organic carbon and microbial biomass decreased with arable cultivation in a 12 year chronosequence of native cropping system in Ilupeju-Ijan. Yam

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(Dioscorea spp) is a tuber crop grown throughout the tropics (Andres, *et al*., 2017). It is traditionally planted as the first crop after a long after a long fallow as it is considered to require a high soil fertility (Diby, *et al*., 2011). Intercropping or rotating yams with legumes (both herbaceous and woody) are alternative ways to supply the crop with nitrogen, increase tuber yield and provide stakes (Maliki, *et al*., 2012a). Due to the conflicting results from different authors on the effects of management decisions on soil quality and particularly the fact that yam is heavy feeder and the fragile nature of tropical soils, there is need to periodically assess soil quality of yam-based cropping systems. This study aimed at assessing soils under yam-based cropping systems for suitability and quality to ensure sustainable use.

MATERIALS AND METHODS

Study Site: The study was carried out in Katsina Ala local government area of Benue State on latitude 7° 00' – 7° 30' N and longitude 9° 20' – 9° 50' E in the middle belt area of Nigeria. It has an area of 2.402 km^2 and a population of over 304,400 (Federal Republic of Nigeria, 2006). Katsina Ala local government area has a tropical climate characterized by seasonal rainfall (between 900 and 1200mm), high temperature, high wind speed and humidity. The environment is noted for two distinct seasons of rainy and dry periods in a year. The area is essentially agrarian; hence, highly influenced by the pattern of rainfall. There are two distinct seasons: wet and dry. April to October is the wet season with the highest mean monthly rainfall in September and dry season during the months of November and March. The temperature of the area like most tropical environment is generally high and characterized by minimum fluctuations. The maximum temperature (33 °C) is recorded in the month of March, while the minimum is usually in December (25.6 °C). The pattern of evapotranspiration is directly related to temperature; that is, the higher the temperature, the higher and the evapotranspiration rate. There is usually a direct correlation between rainfall / temperature status and relative humidity of an area. The study site is underlain by both igneous and sedimentary rocks. The igneous rocks include basement extrusive consisting essentially of biotite hornblende granite locally outcrop within the sedimentary deposits. They are Precambrian to Jurassic in age. Recent alluvial deposits are found along the valleys of the rivers and other low-lying areas. These consist of gravels, sand, silts and clays. The vegetation in the study area is Guinea Savannah type, characterized by grasses with few scattered shrubs and trees. Commonly cultivated crops include yam, cassava, guinea corn, maize, millet, groundnut, soybean, benniseed, rice, melon, and other vegetable crops. Trees crops such as mango, palm trees, citrus, cashew and other economic trees are also found in the areas. The crop mostly produced is yam (26%) followed by soya bean (16%), groundnut and rice (8.67% each) (Ajon, *et al*., 2014)

Field Work: In addition to the ancillary data that were collected, collated and digitized, reconnaissance survey was also carried out to locate the different sites. The sites were characterized such that land use, terrain analysis, soil conditions (crusting, flooding, compaction, etc), vegetation and hydrological properties were evaluated. From the terrain analysis, soils in areas identified as intensively cultivated were characterized. This involved mapping of soil types up to series level using free method of survey. Sixteen (16) modal profiles representing the soil types encountered in the areas were dug, described and sampled, with the depth depending on the peculiarity of the soil types (e.g. water table and lithology barriers). All necessary environmental information relating to the site characteristics and soil morphology were also recorded according to the FAO guideline (FAO, 2006). The soils are majorly sandy in texture and mostly have the problem of hardpan which is the key management issue in sustainable production. Cluster samples were collected for soil quality assessment by selecting 10 clusters. Twenty random samples were collected within each cluster at 0 – 20cm depth. The soil samples were air-dried and crushed to pass through a 2.00 mm mesh sieve and subjected to laboratory analyses using standard procedures. The results of cluster samples were subjected to descriptive statistics.

Soil Quality Assessment: Soil quality Index was determined using Relative Soil Quality Index (RSQI) by Pham *et al.*, (2015). This approach is based on the integration of individual index q_i of n surveyed parameters to form a formula which simplifies the SQ assessment at each monitoring point. RSQI is calculated by the following formula:

$$\mathrm{RSQI} = 100\left(1 - \frac{Pk}{Pn}\right) \quad (1)$$

Where,

$$P_k = \sum_{i-1}^{k} W\,(qi - 1) \quad (2)$$

$$P_m = \sum_{i=1}^{m} Wqi + \sum_{i-1}^{m} W(1 - qi) \quad (3)$$

$$P_n = P_m + P_k \quad (4)$$

This method clearly shows that RSQI depends on the relative ratio P_k/P_n. The higher the value of the ratio, the smaller the value of RSQI. Thus, the SQ is poorer. To calculate RSQI in formula (2), we first need to calculate individual soil quality index (q_i) and weighting factors (both temporary (W*) and permanent/final (W) weighting factors) as follows:

$q_i = C/C^*$

Where C = Actual indicator value and C* is the critical value of the indicator.

To calculate the temporary weighting factors W* and the final weighting factor W. W* accounts for the importance which presents the relationship between each parameter *i*; and *j* is the number of parameters of each examination group. The final weighting factor is determined through the temporary weighting factor W*. There are four groups of soil processes being considered in this assessment (Fertility, Nutrient retention, Water movement and Toxicity level) with their indicators as seen in table 1. The formula to calculate W of parameter 1 for each group is as given below:

$$W^* = \frac{\sum_{i=1}^{j}(C*1----C*n)}{n \times C*1}, \quad (5)$$

Where C*1 is the critical value of indicator 1 in the group, C*n is the critical value of the nth indicator in the group and n is the number of indicators of each group. For example, there are 2 indicators (bulk density and saturated hydraulic conductivity) in water movement group (*n* = 2)

$$W^*1(B.D) = \frac{1.65+3.6}{2 \times 1.65} = 1.59$$

$$W^*2(Ksat) = \frac{1.65+3.6}{2 \times 3.6} = 0.729$$

The final weighting factor of each indicator for each group is calculated by the following formula:

$$W = \frac{W*}{\sum_1^n W*} \quad (6)$$

For the above example, final weights for the two indicators are calculated thus:

$$W^*1\ (B.D) = \frac{1.59}{1.59+0.7\ 2\ 9} = 0.686$$

$$W^*2\ (Ksat) = \frac{0.7\ 2\ 9}{1.59+0.7\ 2\ 9} = 0.314$$

To calculate Pk $\{P_k = \sum_{i-1}^{k} W\ (qi-1)\}$ for a particular soil type, the permanent weight (W) for each indicator is multiplied by (qi – 1) then the results are summed up for all the indicators.

To calculate Pm $\{P_m = \sum_{i=1}^{m} Wqi + \sum_{i-1}^{m} W(1-qi)\}$ for a particular soil type, the product of qi and W are summed for all the indicators and added with the sum of W and (1 – qi) for all indicators.

Suitability evaluation: The suitability of each soil type for yam, citrus and groundnut was assessed by parametric approach using the land qualities given by Sys et al (1991) This is a method that assesses the suitability of the land on a continuous scale instead of discreet classes. To assess a particular pedon, a parametric approach was used to of the relevant land characteristics/qualities for the land use type was used to estimate the overall limitation effect. Each pedon was placed in suitability class by matching its characteristics with the requirements. The aggregate suitability index was obtained by rating all the land qualities considered. In this study, six land quality groups: climate©, topography (t), soil physical properties (s), wetness (w), nutrient retention (n) and nutrient availability (f) were considered.

RESULTS AND DISCUSSION

Soil performs a lot of functions and soil quality can change in response to use and management. Soil management and cropping systems have long-term effects on soil quality, soil nutrient dynamics and soil chemical properties. Crop combination or cropping systems can degrade, improve or sustain soil quality. The essence of this study is to assess quality of soils under tuber-based cropping systems in Katsina Ala local government area of Benue state. Table 1 shows the physical properties of the soils. Most of the soils are sandy with very high coarse sand which decreases down the profile although not in a definite manner. The flood plain soils (PL, PVL1, PVL2 and PVL3) have very high silt content with value up to above 600 g/kg. Bulk density is moderate to high with very high values (above the critical value) in soils with high silt and clay contents. The chemical properties of the soils are shown on Table 2. The soils are moderately acidic to near neutral with pH in water ranging from 5.11 to 7.25 and pH in KCl from 3.89 to 6.12. The pH values decrease down the profile except in few of the soils. However, exchange acidity values are low, so acidity will not necessarily pose a problem to crop production on the soils. Exchangeable bases are adequate indicating that the exchanged sites are well saturated with basic cations. However, cation exchange capacity values are generally low ranging from 5.85 to 3.44 with highest values at the top and decreased down the profile. Organic carbon values are low to moderate with highest values at the top and decreased down the profile. Available phosphorus values moderate to high with highest values at the top and decreased down the profile but not in definite manners. The values of micronutrients are adequate except for Fe values which are very low.

Table 1: Some Physical Properties of the Soils

Profile/ Location	**Depth (cm)**	**Particle size g kg^{-1}**					**BD (Mg m^{-3})**	**PR (kP)**	**AWC$_{vol}$**	**TP**
		Gravel	**CS**	**FS**	**Silt**	**Clay**				
Dystric Haplustept										
PAC 1 (Tse Mande)	0 - 12	-	661	161	158	20	1.59		0.062	0.39
	12 - 40	-	674	151	148	27	1.75		0.075	0.41
	40 - 63	-	588	172	165	75	1.59			
	63 - 123	-	566	194	90	150	1.83			
	123 - 170	150	440	190	90	280	1.76			
Typic Haplustept										
PAC 3 (Ugba)	0 - 23	-	705	185	90	20	1.56	25.9	0.027	0.39
	23 - 50	-	666	204	95	35	1.62	4.3	0.025	0.38
	50 - 101	150	587	153	100	160	1.64	63.8		
	101 - 159	727	728	122	55	95	1.65	171.9		
	159 - 189	650	690	55	95	160	-	-		
Typic Ustipsamment										
PAL 1 (Sati Agric)	0 - 9	-	677	153	135	35	1.55	193.6	0.033	0.40
	9 - 20	50	601	201	163	35	1.51	171.9	0.028	0.37
	20 - 37	773	624	116	165	95	1.46	139.5		
	37 - 86	750	483	197	100	220	1.79	323.4		
Albic Haplustept										
PAL 2 (Ango)	0 - 21	-	625	220	145	10	1.44	171.9	0.012	0.43
	21 - 39	182	579	262	104	55	1.75	226.0	0.024	0.25
	39 - 80	636	622	159	158	61	1.92	334.2		
Ultic Haplustalf										
PAL 3 (Agudu mbasu)	0 - 25	-	711	139	140	10	1.63	20.5	0.034	0.36
	25 - 52	-	607	194	163	36	1.74	42.2	0.027	0.27
	52 - 108	136	561	219	60	160	1.74	42.2		
	108 - 162	227	461	158	121	260	1.77	74.6		
	162 - 171	100	419	156	145	280	-	-		
Dystric Ustipsamment										
PL (Otsaazi)	0 - 23	-	66	174	540	220			0.108	0.58
	23 - 81	-	161	279	370	190	1.42		0.023	0.36
	81 - 116	-	18	302	520	160	1.24			
	116 - 185	-	35	445	238	282	1.22			
Typic dystrustept										
PLX (Abaji)	0 - 12	-	371	290	289	50	1.37	63.8	0.038	0.41
	12 - 23	-	328	292	330	50	1.60	193.6	0.028	0.36
	23 - 62	-	40	570	251	139	1.77	204.4		
	62 - 86	182	339	261	241	159	1.86	453.1		
	86 - 118	700	10	590	282	118	-	-		
Typic Haplustalf										
PN1 (Bagu)	0 - 15	-	685	205	100	10	1.58	37.8	0.038	0.39
	15 - 30	-	673	170	147	10	1.61	20.5	0.030	0.37
	30 - 46	-	700	110	170	20	1.73	85.4		
	46 - 90	-	651	31	238	80	1.71	107.0		
	90 - 184	-	541	159	70	230	1.63	128.7		
	> 184	150	657	105	90	148	1.79	345.0		
Typic Plinthustalf										
PN2 (Aba Daodu)	0 - 20	-	667	175	124	34	1.54	42.2	0.033	0.43
	20 - 34	-	523	157	130	190	1.76	74.6	0.029	0.29
	34 - 70	182	360	150	171	319	1.79	171.9		
Dystric Haplustrept										
PN3 (Ubaya)	0 - 22	-	577	244	139	40	1.62	9.7	0.035	0.32
	22 - 49	46	482	318	125	75	1.70	107.0	0.090	0.32
	49 - 71	-	495	225	120	160	1.79	128.7	0.080	0.28
Plinthic Kanhaplustalf;										
PN4 (Tse Atuluku)	0 - 23	-	528	310	120	42	1.66	42.2	0.100	0.34
	23 - 43	-	445	205	290	60	1.83	107.0	0.034	0.24
	43 - 71	39	420	275	180	125	1.83	193.6		
	71 - 102	-	412	178	175	235	1.95	540.7		
	102 - 128	-	405	210	145	240	-	-		
Dystric Haplustept										
PN5 (Tse Ali)	0 - 17	-	632	210	138	20	1.49	53.0	0.024	0.34
	17 - 48	273	599	181	145	75	1.68	139.5	0.032	0.27
	48 - 64	667	658	147	155	40	1.92	626.2		

Table 1: Some Physical Properties of the Soils (Continue)

Profile/ Location	Depth (cm)	Particle size g kg^{-1} Gravel	CS	FS	Silt	Clay	BD ($Mg\ m^{-3}$)	PR (kP)	AWC_{vol}	TP
				Aquic Haplustrept						
PAC2 (Amaafu I)	0 - 16	-	600	120	260	20	1.27	63.8	0.041	
	16 - 31	-	542	198	220	40	1.64	128.7	0.029	
	31 - 46	-	526	234	220	20	1.74	323.4		
	46 - 82	-	541	179	240	40	1.80	518.0		
	82 - 115	36	558	182	220	40	-	-		
	115 - 152	69	557	163	240	40	-	-		
				Aquic ustipsamment						
PVL1 (Amaafu II)	0 - 26	-	38	312	512	138	1.37	269.3	0.017	0.42
	26 - 50	-	375	445	125	55	1.41	290.9	0.034	0.39
	50 - 76	-	58	297	500	145	1.07	85.4		
	76 - 100	-	120	320	420	140	1.28	150.3		
	100 - 141	-	22	258	530	190	1.25	107.0		
	141 - 189	-	101	174	545	180	1.10	74.6		
				Oxyaquic Ustifluvient						
PVL2 (Tyopav)	0 - 13	-	21	204	656	119	1.44	453.1	0.074	0.45
	13 - 38	-	41	139	510	310	1.52	355.8	0.061	0.41
	38 - 72	-	242	118	381	259	1.75	431.5	0.046	0.33
	72 - 100	13	401	144	295	160	-	-		
				Aquic Ustipssament.						
PVL3 (Afaaka Ayua)	0 - 9	-	220	400	350	30	1.42	139.5	0.125	0.36
	9 - 27	-	223	337	380	60	1.63	150.3	0.024	0.32
	27 - 67	-	561	139	240	60	1.69	42.2		
	67 - 91	-	360	255	285	100	1.62	85.4		
	91 - 145	-	544	136	225	95	1.90	518.0		

Table 3 shows the mean physical and chemical properties of the cluster samples. Just like in the profile samples, the soils are moderately acidic to near neutral with pH ranging from 5.22 to 6.42. Exchange acidity values are low which will make acidity of little or no effect to crop production. Bulk density ranged from 1.15 to 1.55 g/cm3 lower than the critical value for crop production. Saturated hydraulic conductivity ranged from 0.77 to 24.16 cm/min. % sand is high in all the clusters except in clusters one and seven with high silt content. Clay content is low to moderate in all the clusters. Organic carbon is generally low except cluster one which have value of 5.20 %. Total N values are also generally low and followed the same trend as organic carbon. Available Phosphorus values are low to moderate to high with mean values ranging from 6.57 to 28.99 mg/kg and the highest value is also found in cluster one. Cation exchange capacity values are also low with the highest value (4.45) also in cluster one. Sodium adsorption ratio (SAR) values are low and within permissible range. Available iron values are adequate and also within permissible range. The interactions of soil chemical, physical and microbiological properties define a particular soil's quality and determine how effectively the soil performs ecosystem functions. Although, the values of exchangeable bases are adequate, cation exchange capacity are low. This may be due to the fact that both the clay content and organic carbon values which are responsible for ion exchange are low. Soil organic carbon which is one of the important measures of soil quality because it enhances soil nutrient supplying capacity, soil structure and C sequestration is generally low. Thus, there will be rapid loss of soil nutrients because both the clay content and organic carbon which are responsible for nutrient and water holding are low. Sullivan *et al* (2019) submitted that heavier-textured soils (e.g. clay and clay loam) are better able to protect organic matter from decomposition (thereby have higher nutrient and water holding capacity) than light-textured soils (e.g. sandy loam and loamy sands). To further support this, the limitations to suitability of the soils for the three crops varied from soil physical characteristics to nutrient availability. Some of the soils are shallow with plinthite at depth thereby preventing them from being highly suitable for deep rooted crops like citrus. Although, nutrient availability is not expected to be a limiting factor in basement complex soils. However, the nature of tropical soils does not encourage organic matter build-up because of high rate of decomposition and low activity clay, hence; low organic matter content can lower the level of other characteristics. This is in line with the submission of Merrington *et al.* (2006) on important roles of organic matter. The percentage overall soil quality of the soils are shown on table 4. The soils are of moderate to high quality with values ranging from 60.37% to 74.31%. The values are result of interactions between all the indicators of crop production which are low to moderate to high.

Table 2: Chemical Properties of the Soils

Profile	Depth (cm)	pH (H_20)	pH (KCl)	Exchangeable bases cmol kg^{-1}				H^+	CEC	SAR (cmol kg^{-1})0.5	OC (g kg^{-1})	AvP (mg kg^{-1})	Zn (ppm)	Fe (ppm)	Mn (ppm)	CEC_{clay}
				Na	Ca	K	Mg									
Dystric Haplustept																
PAC1	0 - 12	6.05	5.73	0.27	2.59	0.35	0.69	0.11	4.01	0.43	3.10	22.23	0.30	0.20	11.10	200.50
(Tse	12 - 40	6.46	5.79	0.20	2.57	0.17	0.66	0.09	3.69	0.44	2.82	20.00	0.10	0.20	10.70	136.67
Mande	40 - 63	6.74	5.57	0.12	2.56	0.19	0.69	0.07	3.63	0.46	0.51	8.24	0.10	0.20	5.40	48.40
	63 - 123	5.11	4.37	0.14	2.67	0.25	0.83	0.15	4.04	0.46	0.98	9.27	0.10	0.20	7.10	26.93
	123 - 170	5.38	4.21	0.14	2.7	0.25	0.96	0.14	4.19	0.48	0.93	18.71	0.10	0.10	0.50	14.96
Typic Haplustept																
PAC3	0 - 23	6.25	5.26	0.22	2.65	0.21	0.73	0.11	3.92	0.44	1.12	20.60	0.20	0.20	11.90	196.00
(Ugba)	23 - 50	6.16	5.12	0.07	2.56	0.15	0.63	0.11	3.52	0.46	0.27	7.90	0.10	0.30	12.60	100.57
	50 - 101	6.24	5.03	0.09	2.69	0.23	0.69	0.11	3.81	0.45	0.13	10.04	0.10	0.20	4.60	23.81
	101 - 159	5.54	4.10	0.04	2.58	0.23	0.69	0.13	3.67	0.47	0.23	10.64	0.20	0.10	2.70	38.63
	159 - 189	5.23	3.89	0.02	2.45	0.23	0.89	0.15	3.74	0.54	0.37	9.10	0.10	0.10	1.20	23.38
Typic Ustipsamment																
PAL1	0 – 9	6.51	5.48	0.14	2.62	0.25	0.79	0.08	3.88	0.47	1.47	20.25	0.20	0.30	9.60	110.86
(Abaji)	9 – 20	6.34	4.97	0.09	2.58	0.25	0.73	0.09	3.74	0.47	0.47	13.82	0.20	0.40	5.80	106.86
	20 – 37	6.23	4.84	0.03	2.26	0.29	0.83	0.11	3.52	0.57	0.69	19.22	0.20	0.30	2.70	37.05
	37 – 86	5.95	4.83	0.08	2.63	0.25	0.73	0.11	3.80	0.46	1.14	10.56	0.20	0.20	4.40	17.27
Albic Haplustept																
PAL2	0 – 21	7.25	5.84	0.37	2.68	0.33	0.79	0.05	4.22	0.42	1.22	31.32	1.00	0.30	10.20	422.00
(Ango	21 – 39	6.71	5.29	0.18	2.54	0.27	0.69	0.07	3.75	0.46	0.58	16.65	0.30	0.40	8.70	68.18
	39 – 80	6.88	5.40	0.12	2.50	0.12	0.63	0.07	3.44	0.46	0.30	9.01	0.30	0.30	5.60	56.39
Ustic Haplustalf																
PAL3(Ag	0 – 25	6.13	5.66	0.25	2.64	0.33	0.79	0.11	4.12	0.45	1.25	22.23	0.40	0.30	11.70	412.00
udu	25 – 52	6.29	5.48	0.16	2.59	0.25	0.73	0.11	3.84	0.46	1.26	20.68	0.20	0.20	7.60	106.67
mbasu)	52 – 108	6.36	5.26	0.15	2.69	0.29	0.76	0.09	3.98	0.45	0.21	19.91	0.10	0.20	4.40	24.88
	108 – 162	6.61	5.43	0.13	3.01	0.66	0.89	0.08	4.77	0.43	0.91	9.18	0.30	1.40	2.10	18.35
	162 – 171	6.85	5.52	0.16	2.99	0.66	0.79	0.07	4.67	0.38	0.21	10.64	0.20	0.20	1.30	16.68
Dystric Ustipsamment																
PL	0 – 23	4.85	3.88	0.19	3.03	0.51	0.99	0.17	4.89	0.43	2.56	20.51	0.70	1.20	13.60	22.23
(Otsaazi)	23 – 81	5.78	4.17	0.58	3.06	0.12	0.76	0.12	4.64	0.34	0.50	13.47	0.50	1.00	7.20	24.42
	81 – 116	5.91	4.23	0.19	3.06	0.12	0.53	0.11	4.01	0.36	0.26	23.77	0.50	0.90	6.20	25.06
	116 – 185	5.78	4.08	0.23	3.10	0.14	0.73	0.12	4.32	0.53	0.78	19.65	0.70	1.00	6.10	15.32
Typic Dystrustept																
PLX	0 - 12	6.48	5.63	0.23	2.83	0.23	0.59	0.09	3.97	0.39	1.23	19.82	0.70	0.60	16.10	79.40
(Abaji)	12 - 23	6.32	4.93	0.10	2.87	0.15	0.53	0.09	3.74	0.39	0.67	8.16	0.40	0.80	18.70	74.80
	23 - 62	5.88	4.77	0.09	2.82	0.14	0.51	0.12	3.68	0.39	0.54	9.70	0.20	0.60	7.70	26.47
	62 - 86	5.80	4.53	0.10	2.9	0.17	0.79	0.12	4.08	0.41	0.38	24.20	2.50	0.40	8.00	25.66
	86 - 118	6.56	5.64	0.18	2.93	0.27	0.73	0.08	4.19	0.41	0.39	21.71	0.40	0.50	20.40	35.51
Typic Haplustalf																
PN1	0 - 15	6.96	6.12	0.46	2.91	0.33	0.66	0.06	4.42	0.36	0.35	20.34	0.40	0.30	20.90	442.00
(Bagu)	15 - 30	6.23	5.51	0.21	2.78	0.25	0.56	0.10	3.90	0.39	0.16	11.76	0.30	0.60	24.70	390.00
	30 - 46	6.78	5.48	0.13	2.79	0.14	0.46	0.07	3.59	0.39	0.46	11.59	0.20	0.50	16.10	179.50
	46 - 90	6.19	5.08	0.13	2.8	0.17	0.56	0.1	3.76	0.41	0.70	23.34	0.10	0.40	14.70	47.00
	90 - 184	6.06	5.02	0.54	2.96	0.14	0.79	0.11	4.54	0.37	0.70	10.73	0.20	0.30	3.00	19.74

	> 184	5.81	4.74	0.46	2.88	0.15	0.76	0.12	4.37	0.38	0.20	23.60	0.20	0.30	2.40	29.53
Typic Plinthustalf																
PN2	0 - 20	5.89	5.45	0.73	2.91	0.44	0.86	0.12	5.06	0.36	0.66	12.71	0.40	0.50	13.80	148.82
	20 - 34	5.32	4.35	0.46	2.89	0.33	0.83	0.14	4.65	0.39	0.48	10.81	0.20	0.50	5.10	24.47
	34 - 70	5.17	4.01	0.45	2.9	0.32	0.99	0.15	4.81	0.41	0.46	27.80	0.20	0.30	2.00	15.08
Dystric Haplustept																
PN3 (Ubaya)	0 - 22	5.84	5.21	0.79	2.91	0.38	0.96	0.12	5.16	0.37	0.72	21.45	0.40	0.50	9.80	129.00
	22 - 49	6.11	4.91	0.06	2.86	0.27	0.93	0.10	4.22	0.46	0.70	9.44	0.20	0.50	5.60	56.27
	49 - 71	5.94	4.83	0.57	2.91	0.21	1.02	0.11	4.82	0.41	0.34	11.07	0.20	0.60	2.40	30.13
Plinthic Kanhaplustalf																
PN4 (Tse Atuluku)	0 – 23	6.23	5.67	0.78	2.91	0.36	0.99	0.10	5.14	0.38	0.58	12.36	0.60	0.50	12.30	122.38
	23 – 43	6.35	5.45	0.52	2.91	0.38	0.99	0.09	4.89	0.41	0.70	22.23	0.20	0.60	15.90	81.50
	43 – 71	6.21	5.08	0.62	2.96	0.27	0.89	0.1	4.84	0.38	0.18	13.56	0.10	0.60	8.50	38.72
	71 – 102	5.41	4.26	0.79	2.98	0.44	1.06	0.14	5.41	0.38	0.38	20.25	0.20	0.70	9.80	23.02
	102 – 128	5.50	4.31	0.81	2.98	0.38	1.06	0.14	5.37	0.37	0.41	20.77	0.10	0.50	7.70	22.38
Dystric Haplustept																
PN5 (Tse Ali)	0 – 17	6.29	5.68	0.83	2.99	0.38	0.96	0.1	5.26	0.36	0.22	21.20	0.10	0.50	7.20	263.00
	17 – 48	6.55	5.63	0.71	2.88	0.21	0.93	0.08	4.81	0.39	0.33	12.62	0.20	0.40	10.60	64.13
	48 – 64	6.79	5.96	0.93	3.02	0.39	1.42	0.7	6.46	0.41	0.16	24.46	0.20	0.80	10.30	161.50
Aquic Haplustept																
PAC2 (Amaafu I)	0 - 16	5.54	4.40	0.79	2.87	0.38	1.02	0.13	5.19	0.38	1.17	23.51	0.40	0.90	3.50	259.50
	16 - 31	5.68	4.29	0.62	2.82	0.21	0.96	0.13	4.74	0.40	0.32	11.93	0.30	0.80	1.10	118.50
	31 - 46	5.82	4.25	0.65	2.82	0.21	0.93	0.12	4.73	0.40	0.61	17.34	0.20	0.70	0.70	236.50
	46 - 82	5.59	4.43	0.03	2.6	0.17	0.66	0.13	3.59	0.46	0.34	13.39	0.20	0.60	0.60	89.75
	82 - 115	6.32	4.65	0.89	2.48	0.14	0.63	0.09	4.23	0.36	0.26	18.62	0.00	0.40	0.80	105.75
	115 - 152	6.12	4.49	0.03	2.51	0.14	0.59	0.1	3.37	0.47	0.15	20.60	0.00	1.40	1.00	84.25
Aquic Ustipsamment																
PVL1 (Amaafu II)	0 – 26	4.68	4.47	0.49	3.01	0.31	0.73	0.69	5.23	0.36	2.41	30.46	0.00	1.20	24.40	37.90
	26 – 50	5.86	4.40	0.11	2.84	0.16	0.59	0.12	3.82	0.41	0.36	11.50	1.40	1.30	19.10	69.45
	50 – 76	5.13	4.05	0.23	3.01	0.36	1.06	0.15	4.81	0.44	2.07	40.16	0.20	1.10	18.10	33.17
	76 – 100	5.19	3.88	0.34	2.95	0.16	0.86	0.15	4.46	0.41	0.83	26.62	0.90	1.20	14.00	31.86
	100 – 141	5.07	3.76	0.78	2.93	0.24	0.99	0.16	5.10	0.37	0.68	28.53	0.40	1.10	5.50	26.84
	141 – 189	4.89	3.76	0.79	2.8	0.21	0.62	0.6	5.02	0.34	0.35	11.61	0.50	1.30	4.80	27.89
Oxyaquic Ustifluvent																
PVL2 Tyopav	0 - 13	5.06	4.33	0.85	2.85	1.06	0.93	0.16	5.85	0.37	1.74	8.60	0.30	1.00	7.00	49.16
	13 - 38	5.36	3.84	0.18	2.72	0.51	0.83	0.14	4.38	0.45	0.28	40.14	0.30	0.80	5.40	14.13
	38 - 72	5.70	3.90	0.64	2.7	0.71	1.06	0.13	5.24	0.43	0.28	13.11	0.00	0.70	15.50	20.23
	72 - 100	6.48	4.68	0.92	2.68	0.62	1.06	0.09	5.37	0.39	0.57	6.01	0.10	1.10	8.30	33.56
Aquic Ustipsamment																
PVL3 (Afaaka Ayua)	0 - 9	6.17	5.26	1.04	2.97	0.58	0.99	0.1	5.68	0.35	0.95	26.08	0.00	1.10	12.70	189.33
	9 - 27	6.31	4.4	0.89	2.71	0.31	0.63	0.09	4.63	0.33	0.36	9.83	0.80	0.70	5.70	77.17
	27 - 67	6.03	4.55	0.96	2.66	0.21	0.56	0.11	4.50	0.32	0.24	5.60	0.20	1.60	2.40	75.00
	67 - 91	5.63	4.27	0.87	2.96	0.33	1.32	0.13	5.61	0.41	0.31	11.47	0.40	0.60	2.70	56.10
	91 - 145	6.26	4.81	0.69	2.75	0.17	0.53	0.1	4.24	0.34	0.32	4.92	0.00	1.10	3.10	44.63

Table 3: Mean Physical and Chemical Properties of the Clusters

C/N		pH (H2O)	% Sand	% Silt	% Clay	Na cmol/Kg	Ca cmol/Kg	K cmol/Kg	Mg cmol/Kg	H+	CEC	SAR Cmol//Kg	Av. Fe	%OC	%N	Av.P (ppm)	B.D	Ksat
1	Mean	5.22	34.8	46.78	18.42	0.35	2.14	0.64	1	0.32	4.45	1.16	0.94	5.2	0.23	28.99	1.15	24.16
	STD	0.43	7.81	6.82	3.25	0.29	1.07	0.37	0.26	0.26	1.32	1.72	0.299	1.6	0.05	12.06		
	CV	12.1	4.5	6.9	5.7	1.2	2.0	1.7	3.8	1.2	3.4	0.7	3.1	3.3	4.6	2.4		
2	Mean	5.91	77.3	10.08	12.62	0.21	2.47	0.37	0.72	0.11	3.88	0.64	0.44	0.29	0.02	7.74	1.5	0.77
	STD	0.24	2.36	2.92	1.67	0.17	0.81	0.11	0.1	0.01	0.84	0.66	0.19	0.13	0.01	3.27		
	CV	24.6	32.8	3.5	7.6	1.2	3.0	3.4	7.2	11.0	4.6	1.0	2.3	2.2	2.0	2.4		
3	Mean	6.08	72.85	13.21	13.95	0.24	2.86	0.38	0.5	0.11	4.08	0.37	0.73	1.05	0.05	11.42	1.43	3.48
	STD	0.41	4.7	4.89	1.97	0.15	0.06	0.11	0.08	0.02	0.27	0.02	0.17	0.61	0.01	5.06		
	CV	14.8	15.5	2.7	7.1	1.6	47.7	3.5	6.3	5.5	15.1	18.5	4.3	1.7	5.0	2.3		
4	Mean	6.27	70.92	13.22	15.86	0.28	2.56	0.33	0.66	0.1	3.92	0.49	0.79	0.7	0.04	17.57	1.46	1.73
	STD	0.4	4.16	7.03	5.78	0.21	0.6	0.1	0.17	0.02	0.72	0.3	0.26	0.63	0	10.19		
	CV	15.7	17.0	1.9	2.7	1.3	4.3	3.3	3.9	5.0	5.4	1.6	3.0	1.1	0.0	1.7		
5	Mean	6.11	71.84	15.47	12.69	0.33	2.37	0.25	0.78	0.1	3.84	0.63	1.02	0.52	0.03	20.83	1.51	2.14
	STD	0.41	4.14	5.38	1.78	0.17	0.8	0.07	0.05	0.02	0.79	0.68	0.21	1.16	0	6.78		
	CV	14.9	17.4	2.9	7.1	1.9	3.0	3.6	15.6	5.0	4.9	0.9	4.9	0.4	0.0	3.1		
6	Mean	6.42	75.07	11.77	13.16	0.31	2.74	0.27	0.76	0.09	4.17	0.43	0.91	0.31	0.03	9.24	1.55	1.58
	STD	0.53	3.34	3.99	1.67	0.28	0.41	0.1	0.08	0.03	0.41	0.1	0.17	0.18	0.01	11.83		
	CV	12.1	22.5	2.9	7.9	1.1	6.7	2.7	9.5	3.0	10.2	4.3	5.4	1.7	3.0	0.8		
7	Mean	5.57	54.54	32.32	13.14	0.15	2.65	0.37	0.8	0.13	4.1	0.55	1.91	0.82	0.06	11.26	1.44	3.3
	STD	0.23	15.61	13.27	4.13	0.12	0.66	0.17	0.11	0.01	0.85	0.36	0.96	0.26	0.01	6.4		
	CV	24.2	3.5	2.4	3.2	1.3	4.0	2.2	7.3	13.0	4.8	1.5	2.0	3.2	6.0	1.8		
8	Mean	6.01	73.05	14.93	12.01	0.2	2.39	0.22	0.68	0.11	3.6	0.61	0.72	0.39	0.03	6.75	1.54	2.14
	STD	0.5	3.82	3.13	1.63	0.2	0.8	0.03	0.08	0.03	0.88	0.46	0.2	0.09	0.01	8.16		
	CV	12.0	19.1	4.8	7.4	1.0	3.0	7.3	8.5	3.7	4.1	1.3	3.6	4.3	3.0	0.8		
9	Mean	6.4	70.1	17.46	12.44	0.18	2.21	0.27	0.76	0.09	3.51	0.77	0.85	0.53	0.04	16.27	1.52	2.41
	STD	0.41	3.03	3.38	2.08	0.18	0.97	0.07	0.12	0.02	1.12	0.59	0.2	0.21	0	10.89		
	CV	15.6	23.1	5.2	6.0	1.0	2.3	3.9	6.3	4.5	3.1	1.3	4.3	2.5	0.0	1.5		
10	Mean	6.42	68.8	18.47	12.73	0.23	2.49	0.37	0.55	0.09	3.73	0.47	0.58	1.09	0.06	12.66	1.43	4.21
	STD	0.26	4.1	4.18	1.23	0.2	0.64	0.12	0.14	0.01	0.71	0.17	0.18	0.24	0.01	12.41		
	CV	24.7	16.8	4.4	10.3	1.2	3.89	3.1	3.9	9.0	5.3	2.8	3.2	4.5	6.0	1.0		

The suitability indices of the soils for yam, citrus and groundnut are shown on table 5. The soils are highly to moderately suitable for the three crops with limitations varying from soil physical characteristics to nutrient availability. Some land use can cause soil quality to aggrade while some make soil quality to degrade. Thus, quantitative soil quality assessments are useful in optimizing land use plans and can help land managers to measure the levels of sustainability of different management systems. The soils assessed are of moderate to high quality (60.37 to 74.31 %) indicating that the values of the soil quality indicators are moderate to high. Although the soil quality indices ranged from moderate to high, there is a general tendency that the quality will decrease with use over time. This is because tuber crops (especially yam) are crops that require high soil fertility and quality for sustainable production and the soils are fragile in nature (being sandy with low organic carbon) and therefore prone to degradation. Abdoulaye *et al.*, (2014) identified low soil quality and inadequate plant nutrition as part of the constraints of yam production. With increased rate of land degradation and rapid climate change, it becomes urgent to research into feasible and efficient options to sustainably increase yam production (Montanarella *et al*., 2016; FAO, 2017). However, the cropping systems in the study area which comprises of yam, citrus and groundnut can help in minimizing rate of soil degradation. This is because yam and groundnut are creeping crops that can form canopy cover on the soil which will reduce direct impact of wind and raindrops on the soil, thereby preventing soil erosion. In addition, it helped in weed suppression and eventually provide organic matter after harvest. Also, citrus will provide break against wind and raindrops thereby preventing erosion as well. It has been proven that soil quality degradation in the developing tropical ecosystems can be minimized through appropriate soil and crop management systems.

Table 4: Percentage Soil quality of the clusters using RSQI

Cluster Number	Pk	Pm	Pn	Overall S.Q (%)
1	7.542	16.899	24.44	69.14
2	2.41	3.67	6.08	60.37
3	1.529	4.32	5.85	73.86
4	2.998	5.06	8.058	62.80
5	2.043	4.0396	6.083	66.42
6	2.93	6.24	9.17	68.05
7	1.56	4.20	5.76	72.92
8	2.17	4.02	6.19	64.94
9	1.92	4.04	5.96	67.79
10	1.544	4.47	6.01	74.31

Sofi, *et al.* (2016) discovered that inclusion of legumes in the apple orchard recorded highest soil quality index across all treatments in an experiment to assess soil quality under different cropping systems in northwest Himalaya-India. Soil improving cropping systems have been suggested as a strategy to halt soil degradation and environmental pollution. Pikul et al., (2001) measured significantly greater soil organic carbon in continuous corn than in a corn-soybean rotation. In continuous corn, more total carbon was fixed over time when compared to a corn-soybean rotation.

Table 5: Suitability Indices of the Soils for Yam, Citrus and Groundnut

Soil Type	Suitability Indices		
	Yam	Citrus	Groundnut
Dystric Haplustept	S1	S1	S1
Typic Haplustept	S2(f)	**S1**	**S1**
Typic Ustipsamment	S2(f,s)	S2(s)	S1
Albic Haplustept	S1	S2(s)	S1
Ustic Haplustalf	S1	S1	S1
Dystric Ustipsamment	S1	S1	S1
Typic Dystustept	S2(f)	S2(s)	S2(f)
Typic Haplustalf	S1	S1	S1
Typic Plinthustalf	S2(f,s)	S2(s)	S1
Dystric Haplustept	S2(f,s)	S2(s)	S1
Plinthic Kanhaplustalf	S1	S2(s)	S1
Dystric Haplustept	S2(f)	S2(s,f)	S2(f)
Aquic Haplustept	S1	S1	S1
Aquic Ustipsamment	S1	S1	S1
Oxyaquic Ustifluvient	S1	S2(s)	S1
Aquic Ustipsamment	S2(f)	S2(s,f)	S2(f)

**S1 is Highly Suitable, *S2 is Moderately Suitable, *f is fertility limitation, *s is soil physical properties limitation*

Conclusion: Tuber production especially yam require good quality soils with high fertility. Soils encountered in Katsina Ala local government are sandy/silty with moderate soil fertility and quality due to the moderate to low organic matter content. However, the cropping systems in the area are such that prevent exposure of the soils to direct impact of agents of erosion as well as encourage organic matter incorporation into the soil. Hence, the cropping systems in the study area should be encouraged

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