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Land use and soil type influence on soil quality: A comparison between tree and arable crops in basement complex soils

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Land degradation has become a great concern for sustainable land management. There is therefore the need to monitor land use impact on the soil to prevent degradation. This study was set up to assess soil quality under tree and arable uses and their impacts on the soils capacity. Four farmlands (cocoa, cashew, cassava and maize) on three soil types (Apomu, Ibadan and Iwo series) were selected within Aiyedire local government area of Osun State. In each location, ten points were located and soil samples collected at 0 - 30 cm depth. The samples were subjected to laboratory analysis of selected indicators. The indicators' values were combined into indices using soil management assessment framework for physical, chemical and overall soil quality. The indices were subjected to analysis of variance and the means separated least significant differences. Physical, chemical and overall soil quality indices ranged from 58 to 90% with the highest value under cocoa plantation on Apomu Series. Both land use and soil type have significant effect on physical, chemical and overall soil quality. Arable crops especially maize degrades soil quality quickly. Also, soils located at the lower slope are enriched with nutrients and should be well managed for sustainable use.

Key words: Soil quality, land use, degradation, sustainable.

INTRODUCTION

Soil is a fundamental resource base for agricultural production systems. Besides being the main medium for crop growth, soil functions to sustain crop productivity, among other functions and soil quality describes the soil's ability to perform these critical functions (Doran and Zeiss, 2000). It has biological, physical and chemical properties, which are both inherent and dynamic and can change as a result of some natural processes and in response to use. Natural or inherent capacity of soil to support crops varies, and depreciates with use. The rate of depreciation also varies depending on the kind of use and the soil properties that are most affected.

For long in Nigeria, land use was based on trial-and-error approach. This has led to waste of money and

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efforts. Many large-scale farms in Nigeria folded up after 2 or 3 years of cropping due to lack of adequate information on the potentials of the soil for the particular kind of use. This has also led to land degradation which although may be slow and gradual, is very costly and difficult to correct; while some are even rapid and catastrophic. For instance, loss of organic matter through topsoil removal by bulldozing can take several decades to remedy. So, it is important that land users prevent degradation rather than try to 'cure' it after it had commenced.

Farmers have been concerned on how to keep their soil in good condition because they understand that soil quality has a direct impact on crop performance. Land managers also need information on dynamic soil properties to test whether their system of land use and management are sustainable or whether change is required. They are also concerned that the properties are not being degraded by the use and management practices. The success in soil management to maintain soil quality depends on an understanding of how the soil responds to use and management over time. For this reason, recent interest in soil quality assessment has been stimulated by increasing awareness on the critical functions of the soil in production of food and fibre, maintenance of environmental quality (Doran and Parkin, 1994). On the other hand, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, fertility depletion is the fundamental cause for the declining per capital food production in Sub-Saharan African countries (Sanchez et al., 1997). The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (He et al., 1999). Maddonni et al. (1999) also reported that land use affects basic soil processes such as erosion, soil structural stability, nutrient cycling, leaching, carbon sesquestration, and other similar physical and biochemical processes. Soil degradation due to inappropriate land use system is threatening the livelihood of millions of people in many African countries.

This study therefore aimed at assessing the effects of soil type, arable and tree crops land use on soil quality.

MATERIALS AND METHODS

Study site

The study was conducted within Aiyedire and Egbedore Local Government Areas in Osun State, Southwestern Nigeria under four agricultural land use types (Cocoa, Cashew, Cassava and Maize). The study locations fall within longitudes 4° 10'' E and 4° 30'' E and latitudes 7° 30'' N and 7° 45''N of the equator (Figure 1).

The climate of the study sites can be described as humid to sub-humid tropical with distinct dry and wet seasons. The dry season runs from early November to the end of March or early April, while the wet season is from end of March or early April to about middle of November. There are two rainfall peaks in June and September with dry spell in August (August break) which produces the bimodal rainfall pattern in southwestern Nigeria. The average annual rainfall is 1279 mm. The mean annual temperature ranged between 26 and 32°C, relative humidity is high and ranged between 60 and 90% at 16.00 hours.

The soils of the study sites are formed on Crystalline Basement Complex rocks with granite gneiss as dominant parent rock. There is a very strong geological and geomorphological influence on the pattern of soil distribution in the study sites. Vegetation also contributes to the pattern of soil development in the area. The soils encountered at the sites were classified majorly into Iwo association (Smyth and Montgomery, 1962). The vegetation of the study site is derived savannah.

Selection of indicators (minimum data set)

The indicators used as minimum data set for soil quality assessment were selected by modifying the approaches of Cameron et al. (1998), Merrington et al. (2006) and Gugino et al. (2007).

Field study

For each of the four land uses, one farmland was chosen for the study. The soil map of Southwestern Nigeria prepared by Smyth and Montgomery (1962) was used as base map to identify the soil types. Auger soil examination was done to ascertain the information on the map. One soil profile pit each was dug on each farmland, described and sampled for laboratory analysis to further confirm the information on the map.

In each of the locations, ten sampling points were located and soil samples were collected at 0 - 30 cm depth. The samples were air-dried, passed through 2 mm sieve and subjected to laboratory analysis of the selected indicators.

Soil quality assessment

The values of soil quality indicators were then combined into a quantitative index using the framework for evaluating indicators of soil quality by Andrews et al. (2004) called soil management assessment framework (SMAF). This technique uses the principle that soil quality can only be assessed by a combination of different properties or indicators based on the critical values of the indicators and the soil processes relevant to crop productivity (Nearing et al., 1990). In this study, six soil processes relating to crop productivity (nutrient availability, nutrient retention, root penetration, biotic environment, water entry capacity and ability to resist degradation) were identified; relative weights were also assigned based on the level of importance. Soil quality indicators relating to each process were identified and given weights as well (Nearing et al., 1990). For this study, the six processes, minimum data sets, their relative weights for both tree and arable crops are shown on Tables 1 and 2.

All weights within each level summed up to 1.0 and 100% equivalent. The different processes and indicators were combined using Standard Scoring Functions (SSF) which enables users to convert numerical or subjective ratings to unitless values on a scale of 0 - 1. All indicators affecting a particular process were grouped together, given scores and relative weights based on relative importance. After scoring each indicator, the value was multiplied by the appropriate weight producing a matrix that was summed to provide the soil quality rating for crop productivity as follows:

Figure 1. Study locations for the four land use types.

Table 1. Soil processes, minimum data set for tree crop production and their relative weights.

Soil processes	Relative weights	Soil quality indicators	Relative weights
Nutrient availability	0.25	Active carbon	0.35
		pH	0.35
		Base saturation	0.30
Nutrient retention	0.25	Cation exchange capacity	0.35
		Organic matter	0.35
		Texture	0.30
Root penetration	0.20	Bulk density	0.5
		Effective soil depth	0.5
Biotic environment	0.10	Potentially mineralizable N	1
Degradation resistance	0.20	Aggregate stability	1

Q = q.s.p(1) X wt. +……….+ q.s.p(n) X wt (1)

Where, Q = Overall soil quality index for crop productivity; q.s.p (1) = soil quality rating for soil process 1; q.s.p (n) = soil quality rating for nth process, and The value of Q for each location was also expressed as percentage.

RESULTS

Table 3 shows the values of soil quality indicators assessed under cocoa and cashew plantations in each of the soil types. Under cocoa plantations, pH is 5.7 for

Table 2. Soil processes, minimum data sets for arable crop production and their relative weights.

Soil processes	Relative weights	Soil quality indicators	Relative weights
Nutrient availability	0.25	Active carbon	0.30
		pH	0.25
		Base saturation	0.25
		Available phosphorus	0.20
Nutrient retention	0.25	Cation exchange capacity	0.35
		Organic matter	0.35
		Texture	0.30
Root penetration	0.20	Bulk density	1
Biotic environment	0.10	Potentially mineralizable N	1
Degradation resistance	0.20	Aggregate stability	1

Table 3. Average values of soil quality indicators under cocoa and cashew plantations.

Indicators	Ibadan series		Apomu series		Iwo series	
	Cocoa (Typic Kanhapludalf)	Cashew (Arenic Paleudalf)	Cocoa (Aquic Dystrudept)	Cashew (Typic Kanhapludalf)	Cocoa (Typic Dystrudept)	Cashew (Typic Kandiudalf)
pH	5.7	6.0	5.9	6.3	6.5	6.1
Active C	7.4	7.2	13.0	17.35	10.1	5.1
PMN	1.1	1.0	1.35	2.5	1.1	0.8
Avail. P	3.5	7.3	3.85	12.5	1.7	4.25
Base Sat.	94.2	92.5	98.3	98.5	97.5	96.1
CEC	8.5	9.2	15.45	12.5	8.2	11.2
Bulk D.(g/cm^3)	1.25	1.45	1.3	1.35	1.3	1.4
ESD (cm)	178	153	162	155	150	181
Porosity (m^3/m^3)	0.5	0.45	0.5	0.4	0.55	0.5
Aggt. Stab. (%)	86.5	68.2	80.5	70.5	86.5	86.1
Texture	SCL	SL	LS	SL	SCL	SL
WHC	0.4	0.3	0.35	0.3	0.35	0.35
Org. C (g/kg)	15.1	14.4	22.1	33.6	14.5	8.4

Ibadan Series, 5.9 for Apomu Series and 6.5 for Iwo series indicating that the soils are slightly acidic to near neutral. Active carbon ranged between 7.4 g/kg (Ibadan Series) to 13.0 g/kg under Iwo Series. PMN ranged between 1.1 g/kg to 1.35 g/kg and follow the same trend as active carbon. Available phosphorus is very low ranging between 1.7 and 3.85 mg/kg with highest value under Apomu series. Base saturation is generally high (94.2 to 98.3%) indicating that the exchange sites are well occupied with basic cations. CEC is low to moderate (8.2 to 15.45 cmol/kg soil) with the highest value under Apomu Series. Porosity ranged between 0.5 and 0.55 m^3/m^3, aggregate stability ranged between 80.5 and 86.5%, organic carbon is moderate to high and ranged between 14.5 and 22.1 g/kg with the highest value under Apomu Series. WHC ranged between 0.35 and 0.40 and texture is loamy sand to sandy clay loam. Similar trend was obtained under cashew plantations with all the indicators.

Table 4 shows the values of soil quality indicators under cassava and maize fields in each of the soil types. Under cassava fields, pH ranged from 5.6 to 6.3, active carbon ranged from 4.3 to 17.3 g/kg with the highest value under Apomu Series. PMN follow the same trend as active carbon and ranged from 0.8 to 2.3 g/kg. Available phosphorus which is very low ranged between 2.45 and 7.5 mg/kg. Organic carbon is low to high ranging from 8.4 to 34.2 g/kg, Base saturation is high (93.5 to 97.3%) and CEC is low to high (2.6 to 16.3 cmol/kg) with the highest value under Apomu Series. Porosity is 0.4 to 0.5 m^3/m^3; aggregate stability ranged from 60.5 to 68.2%, WHC is 0.3 and texture varied as loamy sand to sandy clay. Values of soil quality indicators under maize fields follow the same trend with cassava fields but are lower.

Table 5 shows the aggregate physical, chemical and

Table 4. Average values of soil quality indicators under cassava and maize.

Indicator	Ibadan		Apomu		Iwo	
	Cassava (Dystric Eutrudept)	Maize (Typic Kanhapludalf)	Cassava (Arenic Eutrudept)	Maize (Typic Kanhapludalf)	Cassava (Typic Kandiudalf)	Maize (Oxic Haplustept)
pH	6.1	5.6	6.3	5.9	5.6	6.0
Active C	4.8	2.2	17.3	1.7	4.3	2.2
PMN	1.5	0.5	2.3	0.4	0.8	0.3
Avail. P	7.5	2.1	2.45	1.85	2.5	5.7
Base Sat.	93.5	88.9	97.3	92.6	95.0	80.3
CEC	16.3	4.6	6.3	1.45	2.6	1.65
Bulk D.(g/cm^3)	1.4	1.3	1.3	1.35	1.5	1.5
ESD (cm)	180	127	115	158	140	180
Porosity (m^3/m^3)	0.5	0.5	0.5	0.5	0.4	0.4
Aggt. Stab. (%)	68.2	71.2	60.5	69.2	62.1	68.2
Texture	SC	SL	LS	LS	SC	SL
WHC	0.3	0.3	0.3	0.35	0.3	0.3
Org. C (g/kg)	8.4	8.5	34.2	12.4	9.7	5.5

Table 5. Aggregate physical, chemical and overall soil quality index for each of the farms under Apomu soil series (%).

S/N	Physical quality (%)				Chemical quality (%)				Overall soil quality (%)			
	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize
1	90	81	76	62	79	78	77	58	85	78	77	61
2	85	80	77	62	80	72	75	57	85	76	73	60
3	85	79	75	61	80	75	68	58	87	77	72	60
4	88	78	77	60	79	71	74	61	86	73	77	61
5	87	78	77	62	80	72	69	57	84	77	75	59
6	80	80	69	65	84	71	60	62	85	76	64	64
7	84	79	65	65	82	71	58	60	85	74	62	62
8	84	81	62	63	82	72	61	62	84	78	63	63
9	88	79	64	65	78	71	60	60	83	75	62	62
10	88	80	63	66	80	72	62	61	84	76	64	64

overall soil quality index for each of the farms under Apomu soil series. Physical soil quality index ranged from moderate to high (60 to 90%) with the highest value under cocoa plantation and the lowest value under maize field. Chemical soil quality is lower (57 to 84%) and follow the same trend as physical index. Overall soil quality index also follow the same trend with physical and chemical indices, ranging between 59 and 87%.

Aggregate physical, chemical and overall soil quality index for each of the farms under Iwo Series are shown on Table 6. All the indices follow the same trend as in Apomu series and ranged as: Physical (59 to 90%), chemical (58 to 84%) and overall (60 to 89%).

Aggregate physical, chemical and overall soil quality index for each of the farms under Ibadan Series are shown on Table 7. Similar trend with that of Apomu and Iwo series was also obtained with Ibadan series and they ranged as: Physical (62 to 90%), chemical (58 to 82%) and overall (60 to 89%).

Land use has highly significant effect on soil physical, chemical and overall quality (Table 8 and Figures 2 to 4). Similarly, soil type has highly significant effect on soil physical, chemical and overall quality (Table 9 and Figures 2 to 4).

DISCUSSION

The essence of this study is the assessment of soil quality as a means of (a) establishing its capacity to function for crop production and (b) monitoring the impact of land use and/or management on this capacity. From the results, soil quality indices ranged from moderate to high which could be as a result of the fact that all the soil

Table 6. Aggregate physical, chemical and overall soil quality index for each of the farms under Iwo soil series (%).

S/N	Physical quality (%)				Chemical quality (%)				Overall soil quality (%)			
	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize
1	90	78	67	62	80	76	65	58	87	67	60	61
2	89	79	65	61	80	76	65	60	89	65	58	60
3	90	81	72	59	81	77	69	60	86	66	61	61
4	87	80	75	63	79	79	69	58	87	67	60	61
5	88	82	69	60	80	80	66	59	89	66	62	60
6	80	80	64	61	84	78	62	59	86	76	61	65
7	85	79	68	63	82	78	66	60	84	74	64	62
8	84	79	71	64	84	79	65	60	84	76	60	62
9	80	80	70	62	84	79	66	58	86	75	62	62
10	84	81	69	62	80	80	60	59	86	75	61	63

Table 7. Aggregate physical, chemical and overall soil quality index for each of the farms under Ibadan soil series (%).

S/N	Physical quality (%)				Chemical quality (%)				Overall soil quality (%)			
	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize	Cocoa	Cashew	Cassava	Maize
1	89	80	65	69	80	70	60	60	87	71	64	65
2	89	79	62	65	79	70	60	59	89	73	62	62
3	90	75	68	70	80	69	59	59	86	70	63	62
4	87	77	67	64	82	67	65	60	87	73	62	63
5	88	75	70	64	82	69	64	58	89	72	64	61
6	90	74	66	62	78	69	59	61	88	67	60	63
7	89	77	67	67	78	65	59	58	88	67	61	65
8	88	77	67	66	77	64	60	59	87	72	62	65
9	89	76	65	62	80	63	64	62	85	75	61	61
10	89	78	68	63	79	64	64	59	86	74	59	61

Table 8. Effect of land use on soil physical quality, soil chemical quality and overall soil quality.

Treatment	Physical quality (%)	Chemical quality (%)	Overall soil quality (%)
Cocoa	86.7	80.4	86.1
Cashew	78.7	72.6	72.7
Cassava	68.7	64.4	63.9
Maize	68.1	59.4	62.0
LSD	142***	1.45***	1.48***

quality indicators assessed are of moderate to high values.

Soil quality was generally higher under tree crops (cocoa and cashew) than the arable crops (cassava and maize). This may be due to the fact that tree crops produce debris which when decomposed helps to improve the levels of some of the soil quality indicators. For instance, organic matter is improved, and will positively influence aggregate stability, water holding capacity, and reduce compaction and erosion (Pagliai et al., 1998). Solomon et al. (2002) also reported that a change in organic matter content of the surface soil significantly influenced other key soil properties. Soil organic matter play key roles in soil function, determining soil nutrient status, water holding capacity and susceptibility of soil to degradation (Feller et al., 2001). In addition, soil organic matter may serve as a source or sink to atmospheric CO_2 (Lal, 1997) and an increase in the soil carbon content is indicated by a higher microbial biomass and elevated respiration (Sparling et al., 2003). It

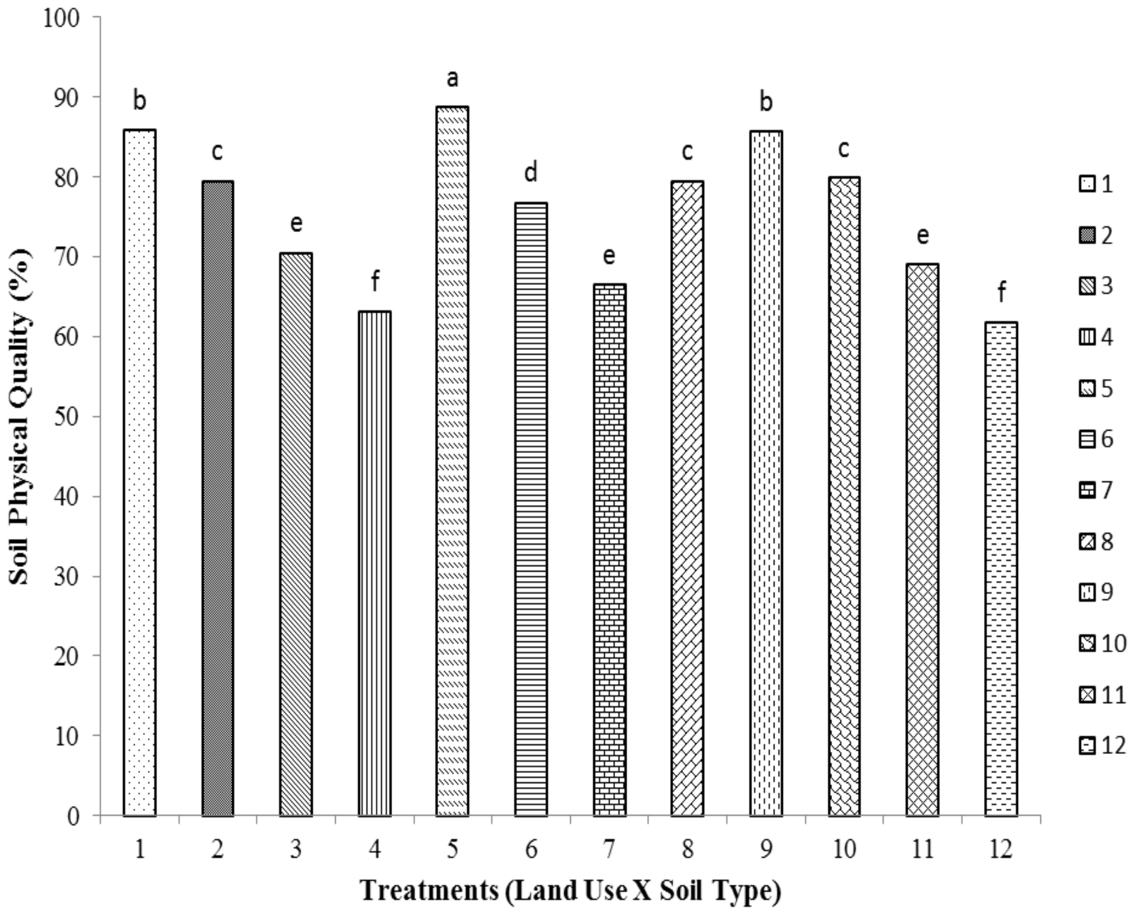

Figure 2. Effect of land use and soil type on soil physical quality. 1, Soil quality index of Apomu series under cocoa plantation; 2, soil quality index of Apomu series under cashew plantation; 3, soil quality index of Apomu series under cassava field; 4, soil quality index of Apomu series under maize field; 5, soil quality index of Ibadan series under cocoa plantation; 6, soil quality index of Ibadan series under cashew plantation; 7, soil quality index of Ibadan series under cassava field; 8, soil quality index of Ibadan series under maize field; 9, soil quality index of Iwo series under cocoa plantation; 10, soil quality index of Iwo series under cashew plantation; 11, soil quality index of Iwo series under cassava field, and12, soil quality index of Iwo series under maize field.

Table 9. Effect of soil type on soil physical quality, soil chemical quality and overall soil quality.

Treatment	Physical quality (%)	Chemical quality (%)	Overall soil quality (%)
Ibadan	74.8	69.7	72.8
Apomu	77.9	66.9	70.8
Iwo	74.0	71.0	69.9
LSD	1.23***	1.26***	1.28***

is also the principal reserve of nutrients such as N in the soil and some tropical soils may contain large quantities of mineral N in the top 2 m depth (Havlin et al., 2005). Furthermore, tree crops produce large amount of biomass which cover the soil surface and prevent the direct impact of raindrops on the soil surface. This is supporting the submission of Paudel et al. (2011) that perennial vegetation enhances soil organic matter accumulation and minimizes topsoil disturbance. Also, the canopies produced by tree crops can also protect the topsoil from the direct impact of raindrops which can detach the soil particles and result in soil erosion. With the arable crops (cassava and maize) however, soil quality was better under cassava farm than under maize. This could be due to the fact that maize is a nutrient miner and requires high input and management practices

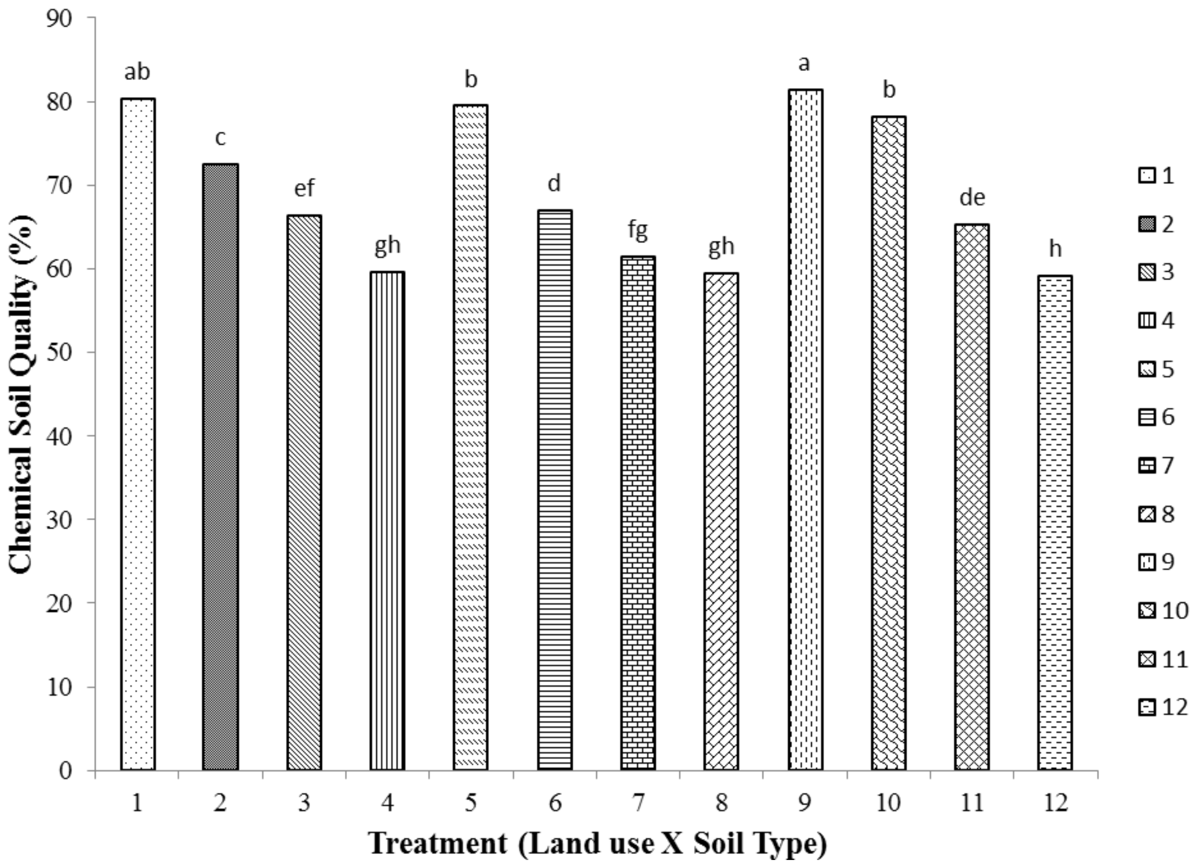

Figure 3. Effect of land use and soil type on soil chemical quality. 1, Soil quality index of Apomu series under cocoa plantation; 2, soil quality index of Apomu series under cashew plantation; 3, soil quality index of Apomu series under cassava field; 4, soil quality index of Apomu series under maize field; 5, soil quality index of Ibadan series under cocoa plantation; 6, soil quality index of Ibadan series under cashew plantation; 7, soil quality index of Ibadan series under cassava field; 8, soil quality index of Ibadan series under maize field; 9, soil quality index of Iwo series under cocoa plantation; 10, soil quality index of Iwo series under cashew plantation; 11, soil quality index of Iwo series under cassava field, and12, soil quality index of Iwo series under maize field.

while cassava is hardy. It has been established that continuous cultivation of arable crops especially maize degrades soil properties faster than tree crops (Bonanomi et al., 2011).

Generally, Apomu series recorded higher soil quality index than the other two soil types (Ibadan and Iwo Series). This could be due to the fact that Apomu Series is usually located at the lower slope of the toposequence which make it possible for organic matter and other nutrients deposition resulting into high nutrient level, low bulk density, good tilth and water holding capacity. Oluwatosin, et al. (2003) also submitted that lower slope soils are usually enriched with materials transported from the uplands.

Conclusions

The concern for sustainable land management has necessitated the need to put in place efficient assessment method that will make monitoring of land use impact on land resources possible in order to prevent land degradation. This study was set up to assess soil quality under tree and arable land uses and their impacts on the soils capacity. Four farmlands (cocoa, cashew, cassava and maize) on the three soil types (Apomu, Ibadan and Iwo Series) were selected within Aiyedire local government area of Osun State. Soil management assessment framework was used to assess the physical, chemical and overall soil quality. The soil quality indices were subjected to analysis of variance and means separated least significant differences. Physical, chemical and overall soil quality indices ranged from moderate to high with the highest value occurring under cocoa plantation on Apomu series and the lowest under maize field. Both land use and soil type have significant effect on soil physical, chemical and overall quality. Arable crops especially maize will degrade soil quality quickly if not well managed. Also, soils located at the lower slope are enriched with nutrients and should be well managed

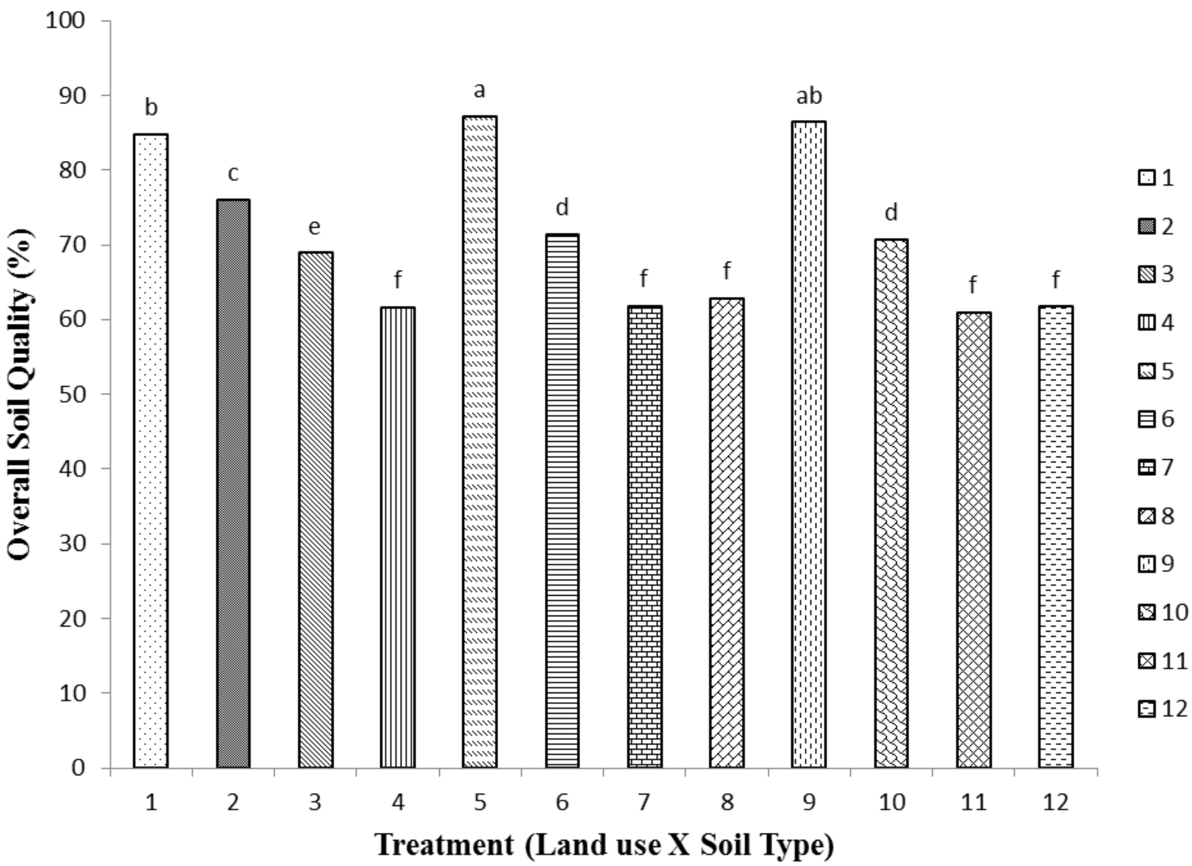

Figure 4. Effect of land use and soil type on overall soil quality. 1, Soil quality index of Apomu series under cocoa plantation; 2, soil quality index of Apomu series under cashew plantation; 3, soil quality index of Apomu series under cassava field; 4, soil quality index of Apomu series under maize field; 5, soil quality index of Ibadan series under cocoa plantation; 6, soil quality index of Ibadan series under cashew plantation; 7, soil quality index of Ibadan series under cassava field; 8, soil quality index of Ibadan series under maize field; 9, soil quality index of Iwo series under cocoa plantation; 10, soil quality index of Iwo series under cashew plantation; 11, soil quality index of Iwo series under cassava field, and12, soil quality index of Iwo series under maize field.

for sustainable use.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Andrews SS, Karlen DL, Cambardella CA (2004). The soil management assessment framework: a quantitative soil quality evaluation method. Soil Sci. Soc. Am. J. 68:1945-1962.

Bonanomi G, D'Ascoli R, Antignani V, Capodilupo M, Cozzolino L, Marzaioli R, Puopolo G, Rutigliano FA, Scelza R, Scotti R, Rao MA, Zoina A (2011). Assessing soil quality under intensive cultivation and tree orchards in Southern Italy. Appl. Soil Ecol. 47(3):184-194.

Cameron K, Beare MH, McLaren RP, Di H (1998). Selecting physical, chemical and biological indicators of soil quality for degraded or polluted soils. Proceedings of 16th World Congress of Soil Science. Montpellier, France, Symposium. P. 37.

Doran JW, Parkin TB (1994). Defining and assessing soil quality for a sustainable environment. SSSA Spec. Public. 35:1-21.

Doran JW, Zeiss MR (2000). Soil health and sustainability: managing the biotic component of soil quality. Appl. Soil Ecol. 15:3-11.

Feller C, Balesdent J, Nicolardot B, Cerri C (2001). Approaching functional soil organic matter pools through particle-size fractionation. Examples for tropical soils. In: Lal, R., Kimble, K.M. and Follet, R.F. (eds). Assessment methods for soil carbon. Adv. Soil Sci. pp. 53-67.

Gugino BK, Idowu OJ, Schindelbeck RR, Van Es HM, Wolf DW, Thies JE, Abawi GS (2007). Cornel soil health assessment training manual. Edition 1.2. Cornel University, Geneva, NY.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL (2005). Soil fertility and nutrient management: An introduction to nutrient management. 7th edition. P. 515. Pearson/Prentice Hall. Upper Saddle River, NJ.

He ZI, Alva AK, Calvert DV, Li YC, Banks DJ (1999). Effects of N fertilization of grapefruit trees on soil acidification and nutrient availability in a Riviera fine sand. Plant Soil 206:11-19.

Lal R, Blum WEH, Valentin C, Stewart BA (1997). Methods for assessment of soil degradation. CRC Press P. 576.

Maddoni GA, Urricariet S, Ghersa CM, Lavado RS (1999). Assessing soil fertility in the rolling Pampa, using soil properties and maize characteristics. J. Agric. Res. Sci. 91:280-286.

Merrington G, Fishwick S, Barraclough D, Morris J, Preedy N, Boucard T, Reeve M, Smith P, Fang C (2006). The development and use of soil quality indicators for assessing the role of soil in environmental interactions. Environmental Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol. P. 241.

Nearing MA, Deer-Ascough L, Laflen JM (1990b). Sensitivity analysis of the WEPP hillslope profile erosion model. Trans. ASAE. 33:839-849.
Oluwatosin GA, Adeyolanu OD, Idowu OJ (2003). Soil quality and sustainability: an experience from osun basin of southwestern Nigeria. Land 7(3):215-233.
Pagliai M, Rousseva S, Vignozzi N, Pivanelli C, Pellegrini S, Miclaus N (1998). Tillage impact on soil quality: Soil porosity and related physical properties. Ital. J. Agron. 1(2):11-20.
Paudel BR, Udawatta RP, Anderson SH (2011). Agroforestry and grass buffer effects on soil quality parameters for grazed pasture and row-crop systems. Appl. Soil Ecol. 48(2):125-132.
Sanchez PA, Sheperd KD, Soule FM, Place RJ Buresh AMN, Izac AU, Mokwunye FR, Kwesiga CG, Ndiritu WPL (1997). Soil fertility replenishment in Africa. An investment in natural resources capital. In: Buresh RJ, Sanchez PA, Calnoun F (eds.), SSSA Spec. public. 51:1-46.
Smyth AJ, Montgomery RF (1962). Soil and Land Use in Central Western Nigeria. Government Printer, Ibadan, Nigeria. P. 265.
Solomon DF, Fritzsche F, Tekalign M, Lehmann J, Zech W (2002). Soil organic matter composition in the subhumid Ethiopian highlands as influenced by deforestation and agricultural management. Soil Sci. Soc. Am. J. 66:68-82.
Sparling G, Liburne L, Vojvodic-Vukovic M (2003). Provisional target for soil quality indicators in New Zealand. Landcare Research, Palmerston North, New Zealand. P. 224.