Eludoyin Adebayo Oluwole[1*], Yetunde Mary Adelere[2], Olusegun Olufemi Awotoye[3]

[1] Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria
[2] Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria
[3] Department of Crop Protection and Environmental Biology, Obafemi Awolowo University, Ile-Ife, Nigeria
[*]**Corresponding author:** oaeludoyin@yahoo.com

CHARACTERISTICS AND QUALITY OF SOILS UNDER SELECTED FARMING PRACTICES IN SOUTHWESTERN NIGERIA

ABSTRACT. This study compared soil properties and quality under five different farm practices in a part of the southwest Nigeria. The study indicated that fewer soil properties accounted for more percentage change in total variance at the fallow and mono-cropping plots than at the forest, crop rotation and alley farming systems. It also showed that soils under fallow and mono-cropping systems exhibited the lowest quality values among the farm practices system studied. The study recommends improved soil management approaches in plots under mono-cropping practices, and extensive soil recovery programmes for fallow lands.

KEY WORDS: Agricultural practices; Soil physical and chemical attributes, Soil quality index; *Plinthic luvisol*.

CITATION: Eludoyin Adebayo Oluwole, Yetunde Mary Adelere, Olusegun Olufemi Awotoye (2018) Characteristics and quality of soils under selected farming practices in southwestern Nigeria. Geography, Environment, Sustainability, Vol.11, No 3, p. 111-125
DOI-10.24057/2071-9388-2018-11-3-111-125

INTRODUCTION

The physio-chemical properties of soils have been attributed to natural and anthropogenic causes; the natural causes being mostly related to the underlying bedrocks, and the anthropogenic causes to land management practices (Wienhold et al. 2004; Yoo et al. 2006; Verachtert et al. 2009). Many studies on the indices of soil degradation, including nutrient losses, deterioration in soil quality and soil pollution, showed that poor farmland management can pose significant threats to food security in many regions of the world (Malhi et al. 2001; Lavelle et al. 2001; Liebig et al. 2004).

The effects of soil quality on food security can be overwhelming in countries where adequate agricultural technology and environmentally sustainable practices are limited. Recently, the Food and Agriculture Organization of the United Nations (FAO 2010) advocated for advancement of conservation agriculture practices – practices which involves minimal mechanical soil disturbance, minimum tillage and no-tillage systems, direct seeding, mulching, crop rotations and mixed farming. Such advocate is probably because farming activities have become sensitive to the need for environmental sustainability. Whereas, developed countries, such as the United Kingdom through research-support policies offer guide to farmers on environmental sustainability (Tilman et al. 2001; Withers and Lord 2002; European Environment Agency 2003; Carabias-Martinez et al. 2003; Horsey 2006; Lane et al. 2006; DEFRA 2009; Eludoyin 2013), many farmers in the sub-Saharan Africa countries, including Nigeria, still practice indigenous land management schemes, despite changing climatic factors, competition for land for non-agricultural purposes and many other factors (Scholes et al. 1994, Luoga 2000).

In many sub-Saharan Africa, including Nigeria, practices such as continuous cropping, mono-cropping and mixed cropping are common; relatively new and more organized practice is the alley cropping system. The alley cropping system is an agroforestry practice of hedgerows with annual crops, and was probably introduced to the Nigerian agricultural practices in the 1970s through the International Institute for Tropical Agriculture, Ibadan (Kang et al. 1981). The hedgerows (typically *Gliricidia sepium* and *Leucaena leucocephala*) are usually pruned before planting the annual crop, and then periodically to prevent shading of the crops from sunlight (Oyedele et al. 2009). Whereas many studies have shown that many parts of the southwest Nigeria are characterized by fragile soils with poor nutrient status and quality, and that which require care in their management (Lal 2005; Oenema et al. 2006), recent studies have suggested that the assumed poor soil quality may be corrected if information on the practices of farming in the area is improved, as is elsewhere – when compared with agricultural productive heavy clay soils of the *Stagni-vertic* or *Stagni-eutric* Cambisols soil groups in the southwest England (Harrod and Hogan 1981) and drained soils (Eludoyin 2013).

The objectives of the present study are (i) to compare the soils under five common farming practice systems (alley cropping, crop rotation, mono-cropping, fallow or shifting cultivation) with that of relatively undisturbed forested sub-region in the study area; and (ii) determine the quality of the soils under selected farm practice systems using the soil quality index (SQI) approach. The SQI approach has been found relevant to soil assessment in tropical areas (Doran and Parkin 1994; Bremer and Ellert 2004; Bastida et al. 2008; Ezeaku 2011; Awotoye et al. 2011; Armenise et al. 2013; Ibrahim et al. 2014; Mukherjee and Lal 2014). The main hypothesis is that soil characteristics and quality vary significantly with farming practices in the area. The study is aimed at contributing to the discussion that land management rather, than natural factors are main causes of the poor soil quality and productivity in the sub-Saharan Africa.

STUDY AREA

The study area, plots of farmlets in of Leventis Farms are in the southwestern Nigeria (7° 40′N - 7° 48′ N, 4° 10′E - 4° 45′ E) (Fig. 1), and underlain by the Iwo soil association (Smyth and Montgomery 1962) or Plinthic luvisols of FAO/UNESCO (1974)'s classification. The World Reference Base for Soil Resources of FAO (2006) classified the Plinthic luvisols as Fe-rich, humic, and capable of changing irreversibly to a layer with hard nodules, a hardpan or irregular aggregates on exposure to repeated wetting and drying. The Plinthic luvisols soil covers about 60 million ha, globally, and is associated with the rainforest area where it supports food and tree crops (Ekanade 1991; FAO 2006). The study area is underlain by the basement complex geology, rich in gneisses and schists. The schist belt in Ilesa area is a black-arc basin where there is a subduction of an ocean slab into the mantle while the gneisses have resulted from part of the rocks that have metamorphosed into banded gneisses from which granite gneisses were derived (Oyinloye 1998). Both schists and gneisses, being metamorphic–having been subjected to varying degrees of pressure and temperature- are associated with slow weathered and fragile soils.

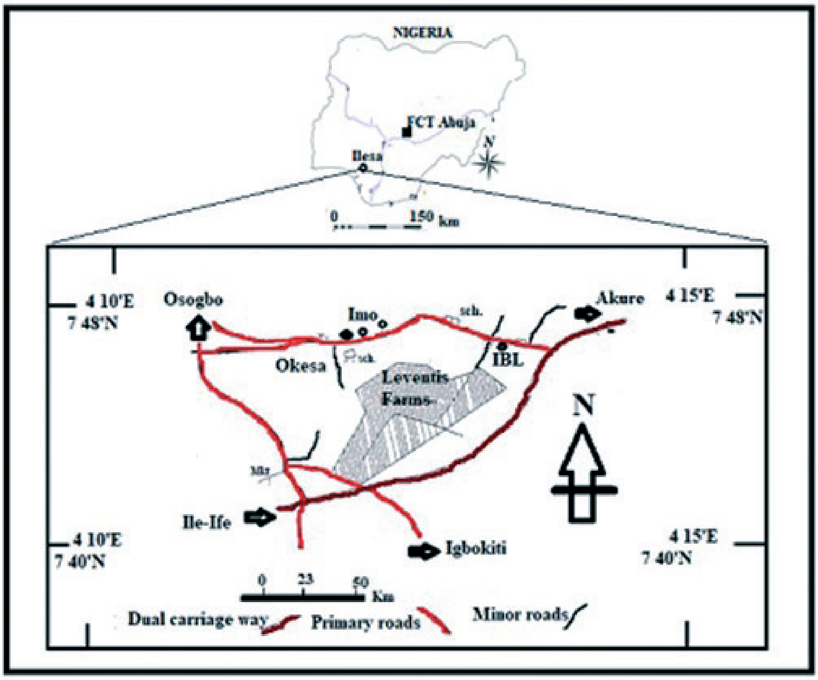


Fig. 1. The study area in Leventis Farms, Ilesa, Osun State, southwest Nigeria

Annual rainfall in southwest Nigeria averages 2500 mm with over 90% of occurring between April and October; average monthly temperatures vary between 22.5°C and 31.2°C while average relative humidity is about 76.1 %, annually. The general relief of the area is plain, varying between 360 m and 400 m above the mean sea level.

The Leventis Farms was created in 1988, and the Farms with the 'control' site had been under the indigenous farming system which was characterized by a mix of fallow or shifting cultivation, mixed cropping and crop rotation based on the perception of individual farmers. Since 1988, when the farmlands were cleared for cultivation, the 'control' site was left fallow and allowed to regrow as forest (secondary regrowth). In other words, until the use of the farmlands as experimental sites, the area was under similar farming (at individual farmer's discretion, however) practices.

MATERIALS AND METHODS

Data collection

First, plots under different farming practice systems (alley cropping, mono-cropping, crop rotation and a fallow that has been part of a shifting cultivation practice) were identified in the entire experimental fields in the study area. Also, part of the Farms that is relatively undisturbed and treated as an agro-forestry system (since 1988) was identified for selection as 'control'. Identified plots are as follows:

a. Alley plot: about 4 years old and comprised of hedgerows intercropped with *Zea mays*. The hedgerows were 2 m apart, and the *Zea mays* was planted in a single row between them.

b. Mono-cropping plot has been under cultivated for 10 years, also with *Zea mays*

c. Fallow plot: about 3 years old. Dominant plant species were *Chromoleana odorata, Sida acuta, Mucuna pruriens and Pennisetum purpureum*

d. Crop rotation was cultivated with melon, maize and cassava, in order of cultivation, based on the lifecycle of the crops; and

e. the 'Control', the relatively undisturbed forest plot (since 1988) with species of *Gmelina arborea, Acacia nilotica, Tectona grandis, Azadirachta indica, Elaeis guineensis, Ficus exasperate, Parkia biglobosa; grasses were Chromoleana odorata, Pennisetum purpureum* that appear are well maintained.

A 45 by 45 m spread-out portion was randomly carved out at the centre of each plot, and further delineated into three (15 by 15 m subplots). Each of the subplots was further divided into 3 by 5 grids for soil sampling, such that soil samples (a triplicate-composite sample for physiochemical analysis and another with a 5.5 by 10 cm cylindrical corer) were obtained from each grid. Subsequently, 45 composite soil samples each were obtained with the aid of soil auger, each at 0 – 15 cm, 15 – 30 cm soil layers in each of the five plots and another 45 samples using the cylindrical corer for determination of soil bulk density. The soil samples were collected in labelled black polyethylene plastic bags, and taken for laboratory analysis at the Soil Laboratory, Department of Soil and Land Resources and Management, Obafemi Awolowo University, Ile-Ife, Nigeria.

Laboratory analysis

The composite soil samples were first were divided into two subsets; one set for determination of particle-size distribution by Hydrometeric method in a Bouyoucos cylinder (as described by Gee and Bauder 1986), and the other air-dried, sieved (2 mm) and analysed for pH, soil organic matter (SOM), total N, organic carbon (OC), available P (AP), exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+, cation exchange capacity (CEC), NO_{3-} and NH_4, exchangeable acidity (EA) and SO_4^{2-}. The pH was determined as pH in H_2O and pH in KCl with a standardized pH meter (Page et al. 1986), SOM by the loss on ignition method (Motsara and Roy 2008) and OC by Walkley-Black method (Walkley and Black 1934). The total N was determined after digestion with Technicon AAII (Technicon Instrument Corporation 1971) while concentrations of AP were determined at 640 nm wavelength of an Atomic Absorption Spectrophotometer (AAS) (Bray and Kurtz 1945). The exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ were determined with AAS at their respective wavelength values while CEC was determined with Flame Photometer (Uehara and Gillman 1981). Concentrations of $NO_{3-}N$ and $NH_{4-}N$ were determined by weighing and centrifuging using Technicon AAII (Technicon Instrument Corporation 1971) whereas the EA was extracted with 1M KCl as described by Thomas (1982). Lastly, SO_4^{2-} was determined by weighing, filtration and centrifuging (Daji 1970).

In addition, bulk density was determined as described by the International Organisation for Standardisation, ISO 11272 (ISO 1998) as the ratio of oven-dried (after 24 hours at 105°C) soil samples to volume of the core (after the volume of materials greater than 2 mm and other organics that were removed had been subtracted) (1)

$$Bulk\ density = \frac{Ms}{Vt - Wt} \quad (1)$$

Where
Ms = Mass of oven-dried soil
Vt = Total volume of the cylindrical core
Wt = Volume of solids greater than 2mm plus that of litter or vegetation taken in by the corer. The ***Wt*** was determined by water displacement method, such that volume of materials larger than 2 mm and removed organics were estimated from the volume of water displaced, in a water cylinder

Porosity was determined in terms of the percentage of the ratio of the bulk density and particle density (Brady and Weil 2008).

Data analysis

Data were analyzed in the IBM SPSS 12 for descriptive statistics, variance, Factor and Principal Component Analysis. Principal Component Analysis (PCA) was used to reduce the factors of the parameters, and to deduce those which significantly ($p \leq 0.05$) contributed to spatial variations in each field. The SQI was computed following the listed steps:

i. 'Minimum data sets' (MDS) were determined for each farm site. The MDS are variables which exhibits significant (95%) between-plots difference and possessed eigenvalue greater than 1.0 after rotated under the Varimax normalization procedure for PCA. The MDS were considered to have ranged in the 10% of the highest component loading, and be non-redundant (i.e. exhibits high correlation with other variables) (Armenise et al. 2013).

ii. The MDS were then transformed into unit scores ranging from 0 to 1 (1 represents the optimum level for the index), accounting for their contribution to soil functions, and scored as either 'more is better' (when increasing values suggest high quality) or 'less is better' (when increase in variable values is associated with declining quality) (Wymore 1993).

iii. Subsequently 'less is better' was used to assess the physical properties particle size (percentage sand, bulk density, acidity and porosity) whereas nutrients (including AP, total N, organic matter content and carbon) were assessed with the 'more is better' index.

iv. Scores were then used to generate the SQI values for each plot using equation 2

$$SQI = \sum_{i}^{n} W \times S \quad (2a)$$

W = the weighting factor

$$W = \frac{\% VE}{Sum\, of\, the\, \% VE} \quad (2b)$$

S_i = MDS score

VE = Variable Explained (for variables with at least 1.0 Eigenvalue)

Furthermore, mean stocks of selected nutrient variables were described as recommended by Kiely et al (2010) (equation 3)

$$Stock = bulk\, density \times N \times d \quad (3)$$

N = concentration of selected variable

d = soil depth at which samples were taken.

RESULTS

Soil characterisation

Table 1 shows the mean values and variations of selected variables at both 0 – 15 cm and 15 – 30 cm soil strata at the different farm plots. The soils are generally characterised by low acidity (pH value of 6 – 8), CEC (1.0 – 10 cmolc kg^{-1}), organic matter (1.1 – 5.1 g kg^{-1}), and by particle sizes varying from medium to coarse-texture sandy-clay-loam or loamy-sand soil types when plotted on the FAO soil texture chart (Jeffery et al. 2010). The soil bulk density was in the range of 1.1 – 1.6 g cm^{-3}. Also, the 15 – 30 cm soil layers was generally more acidic than the 0 – 15 cm layer, and pH values were generally higher at the forest plot than either the plots used for mono-cropping, rotation or fallow. Except for the percentage sand, silt and clay, exchangeable cations and other nutrients were more concentrated in the 0-15 cm layer than at 15 – 30cm layer, except for the plot for mono-cropping (for cation exchangeable capacity) and pH.

Fig. 2 shows that nitrogen stock at the 0 – 30 cm soil stratum was more at the fallow and forest plots while organic carbon stock was more at forest plot despite that the plot for alley cropping exhibited richer organic matter contents than the other cultivated soil plots. Available phosphorus was dominant among the selected chemical variables, although the results of the regression analysis done to establish significant prediction of one nutrient by the other only showed that the organic matter content is a significant predictor of the organic carbon and total N in the area (R^2 = 0.43 and 0.63, respectively, R^2 = 0.39 in the relationship between organic matter and available P) (Table 2).

Furthermore, Fig. 3 shows that fewer soil properties (out of the selected) also accounted for more fractions of the total variance at the fallow and mono-cropping plots (75% and 59%, respectively) that at the forest, crop rotation and alley cropping plots, suggesting lesser diversity in the nutrient inputs in the latter plots (fallow

Table 1. Mean distribution and coefficient of variation (%, in parenthesis) of selected variables across plots at the 0-15 cm and 15- 30 cm soil depths

	Alley cropping		Crop rotation		Fallow		Forest		Mono-cropping	
	0-15 cm	15 – 30 cm	0-15 cm	15 – 30 cm	0-15 cm	15 – 30 cm	0-15 cm	15 – 30 cm	0-15 cm	15 – 30 cm
% sand	70 (6)	72 (6)	78 (4)	74 (5)	75 (8)	78 (2)	65 (5)	63 (7)	86 (7)	77 (5)
% silt	8 (19)	10 (6)	7 (51)	6 (53)	5 (60)	6 (28)	8 (31)	12 (47)	7 (57)	5 (58)
% clay	22 (20)	18(26)	15 (43)	20 (16)	20 (29)	16 (16)	27 (22)	25 (6)	13 (42)	18 (33)
pH (water)	7.4 (7)	6(8)	6.5 (5)	5.8 (7)	7.1 (6)	6.4 (5)	8.4 (5)	6.6 (2)	7.6 (8)	6.4 (3)
pH (KCl)	6.5 (5)	5.5(7)	6.1 (7)	5.4 (7)	6.4 (5)	6.0 (3)	7.8 (5)	6.1 (3)	7.1 (7)	6.0 (3)
Exchangeable acidity (cmol$_c$ kg^{-1})	0.02 (50)	0.02(20)	0.03 (33)	0.03 (3)	0.02 (50)	0.02 (20)	0.01 (100)	0.01 (20)	0.01 (100)	0.01 (20)
Bulk density (g cm^{-3})	1.5 (20)	1.2(17)	1.6 (13)	1.2 (8)	1.4 (29)	1.4 (36)	1.2 (17)	1.1 (27)	1.5 (13)	1.3 (23)
Porosity (%)	5.5 (13)	5.4(7)	5.6 (32)	5.5 (11)	4.8 (14)	7.2 (29)	7.7 (29)	7.2 (141)	7.5 (23)	4.1 (7)
Cation exchange capacity (cmol$_c$ kg^{-1})	5.7 (24)	3(37)	5.3 (30)	3.3 (45)	5.8 (55)	3.5 (80)	11.3 (39)	5.7 (46)	4.7 (24)	4.8 (15)
K^+ (cmol$_c$ kg^{-1})	0.4 (8)	0.2(20)	0.4 (25)	0.2 (50)	0.4 (10)	0.2 (35)	0.4 (25)	0.2 (20)	0.3 (133)	0.2 (20)
Na^+ (cmol$_c$ kg^{-1})	0.2 (5)	0.1(200)	0.2 (100)	0.2 (20)	0.2 (50)	0.1 (20)	0.2 (10)	0.1 (30)	0.1 (20)	0.1 (10)
Ca^{2+} (cmol$_c$ kg^{-1})	4.1 (15)	2.3 (30)	3.2 (19)	1.9 (21)	3.1 (10)	1.5 (13)	5.6 (9)	3.1 (23)	3.2 (16)	1.7 (24)
Mg^{2+} (cmol$_c$ kg^{-1})	0.9 (22)	0.5 (20)	0.8(25)	0.4 (25)	0.9 (4)	0.5 (4)	0.9 (11)	0.5 (20)	0.8 (13)	0.9 (6)
NH^{4+}- N (cmol$_c$ kg^{-1})	0.1 (200)	0.2 (50)	0.1 (10)	0.2 (50)	0.1 (30)	0.2 (50)	0.1 (10)	0.2 (50)	0.1 (40)	0.1 (100)
Total N (g kg^{-1})	1.4 (7)	0.7 (29)	1.3 (8)	0.8 (13)	2.5 (12)	0.9 (11)	2.4 (4)	1.0 (20)	0.8 (13)	0.5 (120)
Available P (cmol$_c$ kg^{-1})	4.5 (22)	3.8 (26)	3.9 (5)	3.3 (12)	3.0 (10)	2.5 (16)	4.1 (5)	3.7 (3)	3.4 (21)	2.8 (18)
Organic C (g kg^{-1})	2.2 (9)	0.7 (29)	1.2 (25)	1.0 (20)	1.4 (29)	1.3 (38)	3.4 (15)	2.1 (10)	1.3 (23)	1.6 (19)
Organic matter (g kg^{-1})	4.1 (10)	1.6 (25)	3.4 (18)	1.6 (31)	3.7 (11)	1.6 (25)	5.1 (14)	2.1 (24)	2.9 (34)	1.1 (27)
NO_{3-} - N (mg kg^{-1})	0.1 (30)	0.3 (33)	0.1 (30)	0.2 (50)	0.1 (20)	0.3 (33)	0.2 (20)	0.3 (33)	0.1 (100)	0.1 (100)
SO_4^{2-} - S (mg kg^{-1})	0.1 (10)	0.4 (3)	0.2(15)	0.4 (25)	0.2 (5)	0.4 (25)	0.2 (10)	0.4 (50)	0.3 (33)	0.2 (50)

and mono-cropping) than the former plots. Fig. 3. Distribution of the eigenvalues of variables that explained the highest fraction of the total variance across selected plots. Total variance explained is provided in parenthesis for each plot

Soil quality assessment

The results of the SQI indicated that whereas the forest plot showed higher SQI values than the other plots; fallow and monocropping plots with the lowest SQI

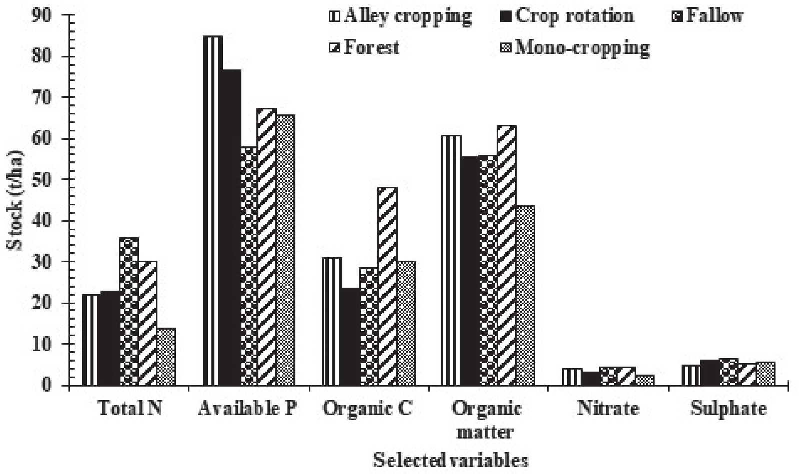


Fig. 2. Mean stock of selected soil variables under the different farm practices

Table 2. Relationship among selected soil nutrients in the study area

Organic matter				Organic carbon			Total N		Available P
Organic carbon	Total N	Available P	NO_{3^-} -N	total N	Available P	NO_{3^-} -N	Available P	NO_{3^-} -N	NO_{3^-} -N
1.17x+0.83 (R^2 = 0.47)	2.08x (R^2 = 0.63)	1.33x–1.95 (R^2 = 0.39)	- 5.87x+ 3.78 (R2 = 0.17)	0.64x + 0.84 (R^2 = 0.33)	0.55x - 0.31 (R^2 = 0.20)	-0.47x + 1.71 (R^2 = 0.003)	0.30x + 0.18 (R^2 = 0.07)	-1.90x+1.57 (R^2 = 0.06)	0.24x + 3.2 (R^2 = 0.07)

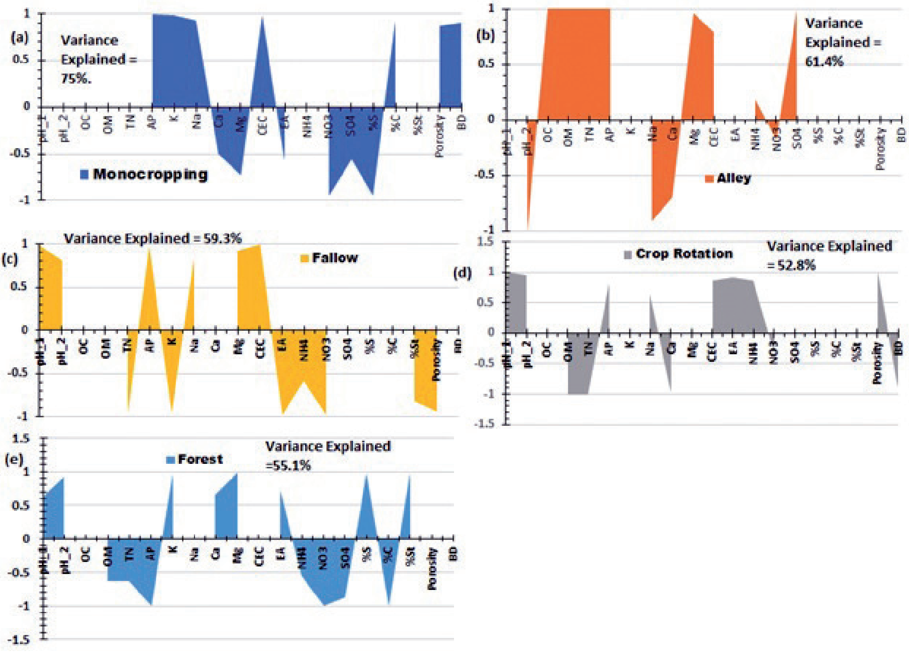
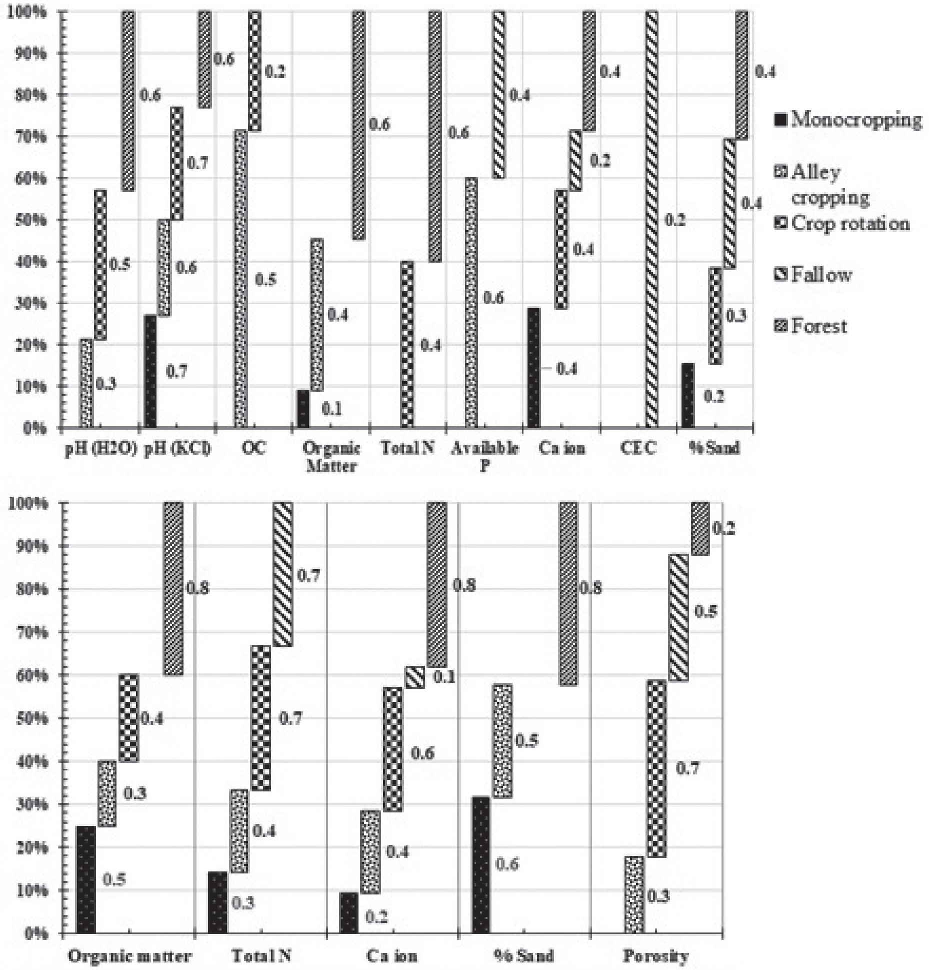


Fig. 3. Distribution of the eigenvalues of variables that explained the highest fraction of the total variance across selected plots. Total variance explained is provided in for each plot

values at both 0 -15 cm and 15 – 30 cm soil depth were with the poorest soil quality (Fig. 4). Whereas the alley cropping method produced a lower SQI aggregate than the soils under crop rotation at 0 – 15 cm, it appeared to be better at 15 – 30cm layer. Fig. 4. Soil quality index (SQI) scores and quality rank of selected farm practices

DISCUSSION

This study showed that the study area is generally characterized with above 60% of sandy soil components and less than 15% of silt, low acidity, CEC and organic matter, which are features of fragile or structurally weak soils (Bady and Weily 2002; Vijith et al. 2012). This result is not surprising as it previous studies (e.g. Lal 2005; Oenema et al. 2006) have argued



Farming practices	Average		0-15 cm		15 – 30 cm	
	Values	Rank	Values	Rank	Values	Rank
Fallow	1.3	5	1.2	5	1.3	5
Mono-cropping	1.5	4	1.4	4	1.6	3
Crop rotation	2.4	2	2.3	3	2.4	2
Alley cropping	2.2	3	2.4	2	1.9	3
Forest	2.8	1	2.8	1	2.8	1

Fig. 4. Soil quality index (SQI) scores and quality rank of selected farm practices

that the soils in the region, as typical of many tropical African soils, are fragile and requires care (especially for agricultural purposes). The soil attributes may have linked with the geology, which is gneiss – and schist – rich metamorphic rock of the basement complex geology that are characterized by slow weathered and fragile soils (Oyinloye 1998). The parts of the soils in the present study area is in the group of coarse-texture sandy-clay-loam or loamy-sand, and the results of the study showed that about 63%, 47% and 39% of the total nitrogen, organic carbon content and available P, respectively, in the soils were accounted for by the distribution of the organic matter. These results suggest that the soils in the area would benefit from sufficient use of organic matter. Soils with low organic matter contents often exhibit low carbon nitrogen and available P (van Breemen et al. 1983; Blackwell et al. 2010; Awotoye et al. 2011; Marschner 2012). Also, the stock (product of bulk density and concentration per soil depth) of the investigated variables (especially organic carbon, total nitrogen, nitrate and available P) in the soil indicated more deposits of available P and organic matter, and this suggests that the organic matter content contains more available P than organic carbon and total Nitrogen.

In terms of the soil quality, soils under the different farm practices exhibited different level of quality; the lowest rated being Fallow system. Existing studies (e.g. Mendoza-Vega and Messing 2005) have indicated that fallowing practice may have lost its sustainable relevance in the face of increasing urbanization and population-induced pressure on land resources, and as shorter (than the previously known 5-10 years) period of fallow now cause fallow land not to regain full restoration of its fertility. In addition, the second lowly rated practice, mono-cropping has been discouraged in many ecosystems because it is found to be characterized by lesser quantity of soil microbial biomass and soil enzymes than the more effective practices of alley cropping and crop-rotation (Acosta-Martinez et al. 2004; Tian et al. 2005; Liang et al. 2004). Mono-cropping is an important cropping practice in West Africa, and in the present study area, it was a 10-year period of the continuous maize cultivation. In general. forest, alley cropping, and crop rotation practices ranked 1 – 3, in the five practices examined in this study, suggesting that the soils under such practices exhibited quality better than those under fallow and mono-cropping practices. The results of the SQI obtained in this study is in line with the reports from other parts of Nigeria (e.g. Awotoye et al. 2011; Ezeaku. 2011; Ibrahim et al. 2014) that show the soils to be fragile and very reactive to management methods.

Main limitations of this study is the inability of the researchers to access long-term farm records, which studies have argued to be useful for assessing management roles (e.g. Minae et al. 2008; Rothamsted Research 2009; Eludoyin 2013; Eludoyin et al. 2017). The problem of poor historical data is not peculiar to the study area as Minae et al. (2008) argued that farm data systems in many sub-Saharan African countries comprise fragmented and disjointed multi-source that may greatly be subjective. In addition, the procedure for the SQI will be further investigated, especially since it involves some subjective ranking (e.g. categorization into 'less or more is better') (Bremer and Ellert 2004).

CONCLUSION AND RECOMMENDATIONS

The study compared soil properties and quality under five different farm practices in a part of the southwest Nigeria. The results showed disparity among the soils under the farm practices, and based on available records. The study showed that dominant cultivation practice system exacerbated the condition of the already fragile soils in the region. The results of the SQI also indicated that fallow and mono-cropping possessed the lowest quality values among the farm practices system studied. The main hypothesis that soil characteristics and quality vary significantly with farming practices in the area is accepted for this study. The study recommends improved soil management approach for the area, and extensive soil recovery programmes for the already depleted soils, because poor soil may herald difficulty for sustainable food production, given the unsound agricultural technology in many parts of the sub-Saharan Africa.

REFERENCES

Acosta-Martinez V., Zobeck T. M., Allen V. (2004). Soil microbial. chemical and physical properties in continuous cotton and integrated crop-livestock systems. Soil Sci. Soc. Am. J., 68, 1875–1884.

Adesina A. A. and Zinnah M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agric. Econ., 9, 4, 297-311.

Andrews S.S., Karlen D.L., Cambardella C.A. (2004). The soil management assessment framework: a quantitative soil quality evaluation method. Soil Science Society of America Journal. 68, 1945–1962.

Andrews S.S., Mitchell J.P., Mancinelli R., Karlen D.L., Hartz T.K., Horwath W.R., Pettygrove G.S., Scow K.M., Munk D.S. (2002). On-farm assessment of soil quality in California's Central Valley. Agronomy Journal. 94, 12–23.

Armenise E., Redmile-Gordon M.A., Stellacci A.M., Ciccarese A., and Rubino P. (2013). Developing a soil quality index to compare soil fitness for agricultural use under different managements in the Mediterranean environment. Soil & Tillage Research, 130, 91–98.

Awotoye O.O., Ogunkunle C.O., and Adeniyi A.S. (2011). Assessment of soil quality under various land use practices in a humid agro-ecological zone of Nigeria. African Journal of Plant Science, 5, 10, 565-569.

Bastida F., Zsolnay A., Hernández T., and García C. (2008). Past, present and future of soil quality indices: A biological perspective. Geoderma, 147, 159–171.

Blackwell M.S.A., Brookes P.C., de la Fuente-Martinez N., Gordon H., Murray P.J., Snars K.E, Williams J.K., Bol R., and Haygarth P.M. (2010). Phosphorus Solubilization and Potential transfer to surface waters from the soil microbial biomass following drying–rewetting and freezing–thawing. In: Sparks, D.L. (Ed.) Advances in Agronomy, 106, 1-35.

Blake G. R. (1965). Bulk density. In: Black, C.A. (Ed.). Methods of Soil Analysis. Am. Soc. Agron, 9, 374-399.

Brady N.C. and Weil R.R. (2008). The nature and properties of soil (14th Ed.). Prentice Hall. Upper Saddle River, N.J., Chapter 4.

Bray H. R. and Kurtz L.T. (1945). Determination of total. organic, and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Bremer E. and Ellert K. (2004). Soil Quality Indicators: a review with implications for agricultural ecosystems in Alberta, Unpublished report for Alberta Environmentally Sustainable Agriculture Soil Quality Program, Alberta Agriculture, Food and Rural Development, Alberta, Canada, 38p.

Carabias-Martinez R., Rodriguez-Gonzalo E., Fernindez-Laespada M. E., Calvo-Seronero L., Sanchez-San R. F. J. (2003). Evolution over time of the agricultural pollution of waters in an area of Salamanca and Zamora (Spain). Water Research 37, 928-938.

Carlin B. P. and Louis T.A. (2009). Texts in Statistical Science, Bayesian methods for data analysis (3rd Edition). CRC Press, Taylor and Francis Group, USA, 520p.

Daji J. A. (1970). A Textbook of Soil Science. JK Publishers, Bombay India, 380 p.

Department for Environment, Food and Rural Affairs, DEFRA (2007). ECSFDI England Catchment Sensitive Farming Delivery Initiative Technical Services Team. ECSFDI Evaluation. Final Report Department for Environment, Food and Rural Affairs. Available at http://archive.defra.gov.uk/foodfarm/landmanage/water/csf/documents/ecsfdi-phase1-report.pdf, 34p.

Department for Environment, Food and Rural Affairs, DEFRA (2009). Protecting our Water, Soil and Air. A Code of Good Agricultural Practice for farmers, growers and land managers. DEFRA, 124 p.

Donald P. F., Pisano G., Rayment M.D., Pain D.J. (2002). The Common Agricultural Policy, EU enlargement and the conservation of European's farmland birds. Agriculture, Ecosystems & Environment, 89: 167-182.

Doran J.W. and Parkin T.B. (1994). Defining and assessing soil quality. SSSA special publication, 35, 3-3.

Ekanade O. (1991). Degradation of the physical elements of the rural environment resulting from tree crops cultivation in the Nigerian cocoa belt, Singapore Journal of Trop. Geo. 12, 2, 82-94.

Eludoyin A. O. (2013). Modelling the hysteretic patterns of solute concentration-discharge relationships and their significance for hydrological pathways at the farm scale, Doctoral Thesis, University of Exeter, Exeter, United Kingdom. Available at http://hdl.handle.net/10871/15374.

Eludoyin A.O., Griffith B., Orr R., Bol R., Quine T. A. and Brazier R.E. (2017). An evaluation of the hysteresis in chemical concentration-discharge (C-Q) relationships from drained, intensively managed grasslands in Southwest England. Hydrological Sciences Journal–Journal des Sciences Hydrologique, 62, 1243-1254.

European Environment Agency (2003). Europe's environment: the third assessment. Environmental Assessment Report No. 10 European Environment Agency, Copenhagen, 341 p.

Ezeaku P.I. (2011). Soil quality as influenced by land use and management in the southern guinea savanna of Nigeria, Nig. J. Soil & Env. Res., 9, 1-11.

Feder G., Just R. E., and Zilberman D. (1985). Adoption of agricultural innovations in developing countries: A survey. Econ. Dev. & Cult. Cha., 255-298.

Food and Agriculture Organization of the United Nations (FAO) (2005). The importance of soil organic matter. Key to drought-resistant soil and sustained food and production, Food and Agriculture Organization of the United Nations. 95 p.

Food and Agriculture Organization of the United Nations (FAO) (2010). Climate-smart agriculture, The Hague conference on agriculture, food policies, practices and financing for food security, adaptation and mitigation security and climate change, 3 October- 5 November 2010. Available at www.fao.org/climatechange, 48 p.

Gee G. W. and Bauder J. W. (1986). Particle-size analysis, In: Klute A. (Ed). Methods in Soil Analysis, Part 1, Physical and Mineralogical Methods, American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA, 383– 409.

Glanz J. (1995). Saving our soil: solutions for sustaining earth's vital resource. Boulder, USA.

Horsey S. (2006). Case studies aimed at reducing diffuse water pollution from agriculture in England. Department for Environment, Food and Rural Affairs, Water Quality Division: London, available at http://www.adlib.ac.uk/resources/000/245/958/dwpa-report.pdf, 103p.

Ibrahim Y. E., Nuraddeen A. M., and Abubakar A. R. (2014). Factors affecting soil quality maintenance in northern Katsina State, Nigeria. Science World Journal. 9, 4, 39-45.

Jeffery S., Gardi C., Jones A., Montanarella L., Marmo L., Miko L., Ritz K., Peres G., Römbke J., and van der Putten W. H. (Eds.). (2010). European Atlas of Soil Biodiversity. European Commission, Publications Office of the European Union, Luxembourg, 130p.

Kang B. T., Wilson G. F., Sipkens L. (1981). Alley cropping maize (Zea mays L.) and Leucaena (Leucaena leucocephala LAM) in Southern Nigeria. Plant Soil 63, 165–197.

Kiely G. McGoff N, Eaton J., Leahy P., Xu X., and Carton O. (2010). Soil C: Measuring and modeling of soil carbon stocks and stock changes in Iris soils. Environmental Protection Agency, EPA Report Strive Vol. 35, 132p.

Lal R. (1989). Conservation tillage and sustainable agriculture: tropics vs. temperate environment. Adv. Agron. 42, 85-197.

Lal R. (2003). Soil erosion and the global carbon budget. Environment International 29, 437-50.

Lal R. (2005). No-till farming and environment quality. In: Simpósio sobre Plantio direto e Meio ambiente; Seqüestro de carbono e qualidade da agua, pp. 29–37. Anais. Foz do Iguaçu, 18–20.

Lane S. N., Brookes C. J., Heathwaite A. L., Reaney S. M. (2006). Surveillant science: challenges for the management of rural environments emerging from the new generation diffuse pollution models. Journal of Agricultural Economics, 57: 239–257.

Lavelle P., Barros E. and Blanchart E. (2001). SOM Management in the Tropics: Why Feeding the Soil Macrofauna? Nutrient Cycling in Agroecosystems, 61, 1-2, 53–61.

Liebig M. A., Tanaka D. L., Wienhold B. J. (2004). Tillage and cropping effects on soil quality indicators in the northern Great Plains. Soil Till. Res., 78, 131–141.

Luoga E. J. (2000). Subsistence use of wood products and shifting cultivation within Miombo woodland of eastern Tanzania, with special notes on commercial uses. South African Journal of Botany 66, 72-85.

Malhi S.S., Grant C.A., Johnston A.M., Gill K.S. (2001). Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: A review. Soil Till. Res., 60, 101–122.

Marschner H. (2012). Marschner's mineral nutrition of higher plants. Academic press, San Diego, USA. 672 p.

Mclean E. O. (1965). Aluminum In: Black C.A. (Ed.). Methods of soil analysis, Part II. Am. Soc. Agron., Madison, Wisconsin. USA No. 9, 978-998.

Mendoza-Vega J. and Messing I. (2005). The influence of land use and fallow period on the properties of two calcareous soils in the humid tropics of southern Mexico. Catena, 60, 3, 279-292.

Mestdagh I., Lootens P., Cleemput V.E., and Carlier L. (2008). Variation in organic-carbon concentration and bulk density in Flemish grassland soils. J. Plant Nutr. Soil Sci. 169, 616–622.

Minae S., Baker D. and Dixon J. (2008). Status of farm data systems and farmer decision support in sub-Saharan Africa, FAO, Rome.

Motsara M. and Roy R. N. (2008). Guide to laboratory establishment for plant nutrient analysis Food and Agriculture Organization of the United Nations.

Mukherjee A and Lal R. (2014). Comparison of soil quality index using three methods. Plos One 9, 8, 1-15.

Oenema O., Janssen B. H., Smaling E., and Hoffland E. (2006). Nutrient management in tropical agroecosystems. Editorial. Agriculture, Ecosystems and Environment 116, 1–3.

Oyedele D. J., Awotoye O. O. and Popoola S. E. (2009). Soil physical and chemical properties under continuous maize cultivation as influenced by hedgerow trees species on an alfisol in South Western Nigeria. African Journal of Agricultural Research, 4, 7, 736-739.

Oyinloye A.O. (1998). Geology, geochemistry and origin of the banded and granite gneisses in the basement complex of the Ilesha area, southwestern Nigeria. Journal of African Earth Sciences 28 (4): 633 – 641.

Page A. L., Miller R. H., Keeney D. R. (1986). Methods of Soil Analysis. Part 2. Chemical and Microbial Properties, 2nd ed., Agron. Monog. 9. ASA and SSSA, Madison, WI.

Rothamsted Research (2009). Long-term Experiments: Guide to the classical and other long-term experiments, datasets and sample archive. Lawes Agricultural Trust, Rothamsted Research, Harpenden, UK, 52 p.

Scholes M. C., Swift M. J., Heal O.W., Sanchez P. A., Ingram J. S. I., and Dalal R. C. (1994). Soil Fertility Research in Response to the Demand for Sustainability. In: Woomer P. L., Swift M. J. (Eds.). The Biological Management of Tropical Soil Fertility. Wiley, Chichester, 1-14.

Technicon Instrument Corporation (1971). Nitrate and Nitrite in Water, Industrial Method No. 32– 69W. Technicon Instrument Corporation, Tarrytown, New York, USA.

Throop H. L., Archer S. R., Monger H. C., Waltman S. (2012). When bulk density methods matter: implications for estimating soil organic carbon pools in rocky soils. Journal of Arid Environments 77, 66-71.

Tian G., Kang B. T., Kolawole G. O., Idinoba P. and Salako F. K. (2005). Long-term effects of fallow systems and lengths on crop production and soil fertility maintenance in West Africa. Nutr. Cycl. Agroecosyst. 71, 139-150.

Tilman D., Cassman K. G., Matson P. A., Naylor R., Polasky S. (2002). Agricultural sustainability and intensive production practices. Nature 418, 671–677.

Uehara G. and Gillman G. (1981). The mineralogy, chemistry, and physics of tropical soils with variable charge clays. Westview Press, Boulder, Colorado, USA.

van Breemen N., Mulder J., and Driscoll C. T. (1983). Acidification and alkalinization of soils. Plant and soil, 75, 3, 283-308.

Verachtert E., Govaerts B., Lichter K., Sayre K. D., Ceballos-Ramirez J. M., Luna- Guido M. L., Deckers J., and Dendooven L. (2009). Short term changes in dynamics of C and N in soil when crops are cultivated on permanent raised beds, Plant Soil 320, 281–293.

Vijith H., Suma M., Rekha V. B., Shiju C., Rejith P. G. (2012). An assessment of soil erosion probability and erosion rate in a tropical mountainous watershed using remote sensing and GIS. Arab J Geosci, 5, 797–805.

Walkley A. and Black I. A. (1934). An Examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37, 29-38.

Wienhold B. J., Andrews S. S., and Karlen D. L. (2004). Soil Quality: A review of the science and experiences in the USA. Environ. Geochem. Hlth. 26: 89-95.

Withers P. J. and Lord E. I. (2002). Agricultural nutrient inputs to rivers and groundwater in the UK: policy, environmental management and research needs. Science of the Total Environment 282, 9-24.

Wymore A.W. (1993). Model-based systems engineering: an introduction to the mathematical theory of discrete systems and to the tricotyledon theory of system design. CRC Press, Inc., Boca Raton, FL.

Yoo G. Y., Nissen T. M., and Wander M. M. (2006). Use of physical properties to predict the effects of tillage practices on organic matter dynamics in three Illinois soils. J. Environ. Qual. 35:1576-1583.

Received on October 27th, 2017 Accepted on July 31st, 2018

FIRST/CORRESPONDING AUTHOR

Dr. Adebayo Oluwole Eludoyin is a Senior Lecturer in Ecohydrology at the Department of Geography, Obafemi Awolowo University, Ile-Ife. Nigeria. His doctoral research was on hydrological pathways at farm-scale at the Rothamsted Research North Wyke was awarded by the University of Exeter, Devon, United Kingdom in 2014. He possesses degrees in the areas of Geography, Geographic Information Systems as well as in Environmental Control and Management. His researches are generally into the interdisciplinary field studying the interactions between water and ecosystems, including the effects of such interactions on streams, atmosphere and land.