Effect of Land Use on Soil Degradation and Soil Productivity Decline on Alfisols and Ultisols in Ogun State in South Western, Nigeria

Bolarinwa Ayoola SENJOBI [1](✉)
Olayiwola Ayoade OGUNKUNLE [2]

Summary

One of the critical factors influencing land degradation is land use. However, the extent to which land use influences land degradation has not been fully ascertained in the southwestern part of Nigeria (i.e. particularly in Ogun State). Thus, this study was designed to assess the extent to which land use influences crop productivity in Ogun State. Two major soil types identified at the site were Alfisols and Ultisols. Within these, three land use types (LUT) were identified: arable crop - Land Use 1, cash crop production - Land Use 2, and non-agricultural use – Land Use 3. These were evaluated for three commonly cultivated crops in the area, namely: maize, cassava and oil palm, using the FAO framework for Land Sustainability Evaluation (LSE). Soil degradation levels were assessed under three LUTs using parametric approach. Descriptive statistics and rank ordered correlation were used for the data analysis.

The results of the LSE showed that all the pedons were marginally suitable (S3) for maize, 60 % were of moderate (S 2) and 40 % of marginal (S 3) suitability for cassava respectively. However, for oil palm, 47 % of the lands were classified as being marginally suitable (S 3) while 53 % were not suitable (N). The major limitations identified were sub-optimal, poor soil (i.e. texture(s) and fertility), poor drainage/wetness (w), steep topography (t), and sub-optimal climate (c) (i.e. annual rainfall, mean annual temperature and length of growing season). Parametric assessment revealed that chemical degradation was moderate within LUT 2, but ranged between slight to none in LUTs 1 and 3 respectively. Land uses 2 and 3 were slightly degraded physically, while 1 was moderate. Land use was found to be significantly ($P < 0.01$) correlated with land degradation ($r = 0.47^{**}$) at all sites. The degradation level ranked from moderate to high due to inappropriate land uses. Thus, it is recommended that in all LUTs must be a careful choice of appropriate use of land in order to reduce degradation.

Key words

land, degradation, land evaluation, land use, land productivity, Nigeria

[1] Department of Soil Science and Farm Mechanization, College of Agricultural Sciences, Olabisi Onabanjo University, PMB 2002, Ago-Iwoye, Ogun State, Nigeria
✉ e-mail: bolasenjobi@yahoo.com
[2] Department of Agronomy, University of Ibadan, Nigeria

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Introduction

One of the most serious problems currently affecting agricultural productivity in developing countries of the tropics, including Nigeria, is land degradation. The intensification of cultivation resulting in the opening up of new lands exposes the top soil to the elements of degradation and alters the natural ecological conservatory balances in the landscape. Such imbalances pose great difficulty for productivity increase to meet the food and fibre needs of a rapidly growing population in the region, thus endangering food security (Lal, 2007; Senjobi, 2007).

An estimate by Food and Agricultural Organisation (FAO) in 1984 indicated that 5 to 7 million hectares of land a year are lost globally to agricultural production as a result of erosion and related forms of land degradation, including siltation of water ways and dams. Tropical soils, which are generally less stable than those of the temperate climates, are particularly severely threatened, due to their fragile properties and the very aggressive climatic conditions. However, since the primary step towards effective land conservation is appropriate allocation of land to uses for which they are most suitable, land use should be in accordance to land potential capacity, so as to optimize and sustain agricultural productivity. However, in practice, particularly is south western Nigeria, the use to which land is put is not often related to the land potential capacity for the use type (Senjobi, 2001). This is largely because the decision on land use rests virtually with land owners/users, who are mostly peasant farmers and not on the outcome of professional land evaluation (Ogunkunle and Eghaghara, 1992). This had rendered some of the previously agriculturally rich lands, progressively unfit for agricultural production especially where two or more land use types, contrasting in specific details and potentials occur on similar soils or the same land use types on dissimilar soils.

In many urban areas in South Western Nigeria, for example, encroachment on agricultural lands for other uses without due regard for their qualities is rampant. In Ago-Iwoye, Ogun State, the establishment of a University resulted in stiff competition for use of land for agriculture and non-agricultural use (e.g. residential and road construction). Unfortunately, land use types, encroachment, misuse and consequences are least researched and poorly documented in these areas. Furthermore, beyond the South Western Nigeria microcosm, fears are ripe that the present pace of encroachment on agricultural lands may eventually lead to the loss of substantial parts of prime agricultural lands in many countries to other land uses to the extent that they may become food importers (Fasina, 1996).

There is therefore need to have reliable information on the influence of different land uses on land degradation and agricultural productivity in Ogun State, Nigeria. Information is also required on the extent to which the land has been misused in this area. This will not only guide the land users (or owners) in relating land degradation type to land use, but help in the choice of selection of the appropriate approach to land use. This is the essence of this study. Specifically, the study aims to evaluate three land use types (LUT) using the FAO method of land evaluation and then examine the kinds and degree of land degradation on these major LUTs in South Western Nigeria, as well as their implications on agricultural productivity.

Materials and methods

Description of the study site. The study area is the Olabisi Onabanjo University Campus site, Ago-Iwoye, Ogun State located at point latitudes 6°55' and 7°00'N and between longitudes 3°45' and 4°05'. It covers about 3141 ha of land. The area has bimodal rainfall, with peaks between June - July and September - October. This is followed by a short period of dry season that is usually between November and February. It has an annual rainfall of about 1150 mm and it is located in the rain forest belt. Mean relative humidity of the area is generally high (about 80 %) with the peak between May and October and the annual mean temperature is 27°C. Tree species found in the study area include: *Pentaclethra macrophylla*, *Basqueia angloansis*, *Piptadeniastrum africanam*, *Antiaris toxicaria* var. *Africana*, *Cola gigantea*, *Milicia excelsa, Guarea* spp. and *Mimusop* spp., and there is also the wide spread of *Elaeis guineensis* and these were dominated by the presence of *Chlomolaena odorata*; a perennial weed found in fallow lands in south western Nigeria. This perennial weed reduces the amount of litter regeneration and the rate of re-growth of other weedy species in the study area. The major land use types in the study area were: (i) arable crop (LUT 1), (ii) cash crop production (LUT 2) and (iii) non-agricultural uses (i.e. such as residential, commercial, and roads construction) (LUT 3). The major food crops in the area include cassava (*Manihot spp)*, maize (*Zea mays)*, cocoyam (*Colocasia esculentum*), yams (*Dioscorea* spp.), melon (*Colocynthis* spp), and variety of vegetables such as *Celosia argentea*, *Amaranthus* spp., okra (*Abelmoschus esculentum*) etc. The major cash crops are cocoa, oil palm, kolanut and citrus while the commonest cropping pattern is early maize + cassava, yam + maize + melons. Three land use types (LUT) were used for the purpose of this study: arable cropping, oil palm and building sites. It was observed that the land under arable cropping has been under continuous cropping for about sixteen years while the oil palm plantation has been established for over thirty years for commercial purpose with little or no input.

Field work. These three LUTs viz: arable cropping (LUT 1), oil palm (LUT 2) and building sites (LUT 3) were studied and within each of the chosen LUTs, an area of 50 hectares was demarcated and subsequently divided into 10 blocks/units of 5 ha each. Within these blocks i.e. each of the 5 ha area, soil samples were collected using grid methods and transects were cut at 100 m x 100 m. In and around each of these intersections, bulk samples consisting of ten surface (0-15 cm) and subsurface (15-30 cm) samples were collected separately for physical, chemical and biological analyses. Subsequently, within each of these LUTs, profile pits (2.0 m deep) were dug at the crest/upper slope, middle- slope, and valley-bottom respectively. The general site description was described after the FAO guidelines for site and profile descriptions (FAO, 2006). Attributes described were the climate, vegetation, land use, gradient of slope, drainage type, soil surface form, type and degree of erosion, microrelief and depths to ground water table (GWT) were recorded. The profile pits were also described morphologically after FAO (2006), sampled, placed them in labeled bags and transported to the laboratory for air-drying. A total of nine profiles pits were dug (three within each LUTs) and were subsequently classified after Soil Taxonomy (Soil Survey Staff, 2003).

After being air-dried for 72 hours, the samples were crushed and sieved using a 2 mm screens. Soil samples were analyzed for the following parameters: soil pH in both water and 0.01 M potassium chloride solution (1:1) using glass electrodes pH meter (Mclean, 1965). Total nitrogen was determined by the macro-kjeldahl digestion method of Jackson (1962), available P was after (Bray and Kurtz, 1945) extraction using Bray-l extract followed by molybdenum blue colorimetry. Exchangeable cations were extracted with 1M NH_4OAC (pH 7.0), K, Ca and Na were determined using flame photometer and exchangeable Mg by atomic absorption spectrophotometer (Sparks, 1996). Exchangeable acidity was determined by the KCl extraction method (Mclean, 1965) and organic carbon was after dichromate wet oxidation method (Walkley and Black, 1934). The organic matter content was got by multiplying a factor of percent organic carbon by 11.72. Cation exchange capacity (CEC) was calculated from the sum of all exchangeable cations. Available micronutrients were extracted with 1N NH_4Cl solutions and determined by Atomic Absorption Spectrophotometer (AAS) (Water and Sammer, 1948 cited from Aruleba, 2004). Particle size analysis was done by the Bouyoucos (1951) method. Saturated hydraulic conductivity was determined using a constant head method and bulk density by core method. Soil porosity was estimated from the bulk density data at an assumed particle density of 2650 kgm-3. Water retention at 15 bar was determined in order to calculate available water holding capacities of the soil profile horizons (Mbagwu, 1985).

Land evaluation. The suitability of the soils was assessed for three crops (oil-palm, maize and cassava) that are commonly and currently grown in the study area following the method of Sys (1985). The detailed land and soil requirement for each of the crop are presented in Tables 1–3. Pedons were placed in suitability classes by matching their characteristics (Table 4) with the requirements of various crops (Tables 1-3). The suitability class of a pedon is that indicated by its most limiting characteristics for the conventional approach (FAO, 1976).

For the parametric method, each limiting characteristic was rated as in Tables 1-3. The index of productivity (actual and potential) was calculated using the following equation (Sys, 1985).

$$IP = A * \sqrt{\underset{(c)}{\frac{B}{100}} * \underset{(f)}{\frac{C}{100}} * \underset{(w)}{\frac{D}{100}} * \underset{(s)}{\frac{E}{100}} * \underset{(f)}{\frac{F}{100}}}$$

Where IP = Index of Productivity; A = overall fertility limiting and B, C … F are the lowest characteristic ratings of each land quality group. Five land quality groups climate (c), topography (t), soil physical properties (s), wetness (w) and fertility (f) were used in this method of evaluation. Only one member in each group was used for calculation purpose because there are usually strong correlations among members of the same group (e.g. texture and structure). For actual productivity index, all the lowest characteristics ratings for each land qualities group were substituted into the index of productivity equation above. However, in the case of potential productivity index, it was assumed that the corrective fertility measure will no longer have fertility constraints. Suitability classes S1, S2, S3 and N are equivalent to IP values of 100 – 75, 74 – 50, 49 – 25 and 24 – 0 respectively as shown in Table 5.

Table 1. Land and Soil Requirements for Maize (Modified from Sys, 1985)

Land Qualities	100 S11	95 S12	85 S2	60 S3	40 N1	25 N2
Climate (c):						
Annual rainfall (mm)	850-1250	850-750 1250-1600	750-600 1600-1800	600-500 >1800	550-500	>500
Length of growing Season (days)	150-220	220-270 130-150	270-325 110-130	325-335 90-110	335-345 90-100	>345 <90
Mean annual temp. (^{0}C)	22-26	22-18 26-32	18-16 32+	16-14	14	<14
Relative humidity Developmental stage (%)	50-80	50-42	42-36	36-32	32-30	>30
Topography (t):						
Slope (%)	0-2	2-4 4-8	4-8 8-16	8-16 16-30	30-50	>16 >50
Wetness: (w)						
Drainage	good somewhat poorly drained	moderate moderate	somewhat poorly drained good	poor aeric	poor drainage	poor and very poor not drainable
Soil physical properties (s):						
Texture	Cs, SiCs, CL	Cs, SC, L, SCL	SL, Lfs, LS	LCS, Fs	Cm, CL	Cm, CS
Soil depth (cm)	<100	75-100	50-75	30-50	20-30	<20
Fertility (f):						
CEC (cmol. kg^{r1} clay)	>24	16-24	<16 (-)	<16 (+)	<10	<10
Base saturation (%)	>50	35-50	20-35	15-20	<15	<15
Organic matter (%C)	>2	1.2-2	1.0-1.2	0.8-1.0	0.6-0.8	<0.6
(0-15cm)	>1.5 >0.8	0.8-1.2 0.6-0.8	0.6-0.8 0.5-0.6	0.5-0.6 0.4-0.5	<0.5 <0.4	<0.5 <0.4

Symbols used for soil texture and structures are defined as follows: Cs: structure clay; Cm: massive clay; SiCs: silty clay, blocky clay; SiCL: silty clay loam; CL: clay loam; Si: silt; SiL: silty loam; SC: sandy clay; L: loam; SCL: sandy clay loam; SL: sandy loam; Lfs: loamy fine sand; LS: loam sand; LCS: loam coarse sand; Fs: fine sand; S: sand; CS: coarse sand.

Table 2. Land and Soil Requirements for Cassava (Modified from Sys, 1985)

Land Qualities	100 S11	95 S12	85 S2	60 S3	40 N1	25 N2
Climatic (C):						
Annual rainfall (mm)	1400-1800	1000-1400 1800-2400	750-600 >2400	600-550	550-500	<500
Length of growing season (months)	3-4	4-5 1-3	5-6 <1	6-7	7	<7
Mean temp. (^{0}C)	26-20	26-30 20-18	>30 18-16	16-14	14-12	<12
Topography (t):						
Slope (%)	0-4	4-8	8-16	16-30	30-50	>50
Wetness (w):						
Drainage	good	good	moderate	somewhat poorly drained	poor drainable	poor, very poor not drainable
Soil physical properties (s):						
Texture	L, SCL	CS, SiCs, SiCL, CL, SCL, SC	Cs, Lfs, LS, LCS, Fs	Cs, S, CS	SC, Cm	Cm, Si
Soil depth (cm)	>125	>100	>75	>50	>55	<50
Fertility (f):						
CEC (cmol/kg^{-1}Clay)	>16	Any	<10	<10	<5	<5
Base saturation (%)	>35	35-20	20-15	15-10	<10	<10
Organic matter (%C) (0-15cm)	>1.5	0.8-1.5	<0.8	<0.5	<0.3	<0.2

Symbols used for soil texture and structures are defined as follows: Cs: structure clay; Cm: massive clay; SiCs: silty clay, blocky clay; SiCL: silty clay loam; CL: clay loam; Si: silt; SIL: silty loam; SC: sandy clay; L: loam; SCL: sandy clay loam; Lfs: loamy fine sand; LS: loam sand; LCS: loam coarse sand; Fs: fine sand; S: sand; CS: coarse sand.

Table 3. Land and Soil Requirements for Oil Palm (Modified from Sys, 1985)

Land Qualities	100 S11	95 S12	85 S2	60 S3	40 N1	25 N2
Climatic (C):						
Annual rainfall (mm)	>2000	1700-2000	1450-1700	1300-1450	1300-1250	<1250
Length of growing season (months)	<1	1-2	2-3	3-4	3-4	<4
Mean annual temp. (^{0}C)	>25	22-25	20-22	18-20	16-18	<16
Relative humidity (%)	>75	70-75	65-70	62-65	60-62	<60
Topography (t):						
Slope (%)	0-4	4-8	8-16	16-30	>30	>30
Wetness (w):						
Flooding	Fo	Fo	F1	F2	F2	F3
Drainage	somewhat poorly drained	mod. well	mod. well	Poor aeric	Poor, drainable	Poor, very poor, not drainable
Soil physical properties (s):						
Texture	CL, SCL, L	CL, SCL, L	SCL	SCL-Lfs,	Any	C, Cs, any
Structure	Blocky	Blocky				
Soil depth (cm)	>125	>100	>75	>50	>55	<50
Fertility (f):						
CEC (cmol/kg^{-1}Clay)	>16	Any	<10	<10	<5	<5
Base saturation (%)	>35	35-20	20-15	15-10	<10	<10
Organic matter (%C) (0-15cm)	>1.5	0.8-1.5	<0.8	<0.5	<0.3	<0.2

Symbols used for soil texture, structure and flooding are defined as follows: Cs: structure clay; Cm: massive clay; SiCs: silty clay, blocky clay; SiCL: silty clay loam; CL: clay loam; Si: silt; SiL: silty loam; SC: sandy clay; L: loam; SCL: sandy clay loam; Lfs: loamy fine stand; LS: loam sand; Lcs: loam coarse sand; Fs: fine sand S: sand; CS: coarse sand. F0 = No flooding, F1 =1 – 2 flooding months in > 10 years, F2 = not more than 2 – 3 months in 5 years out of 10 years, F3 = 2 months almost every year, F4 = 2 – 3 months every year.

Land degradation assessment by parametric approach. For each degradation process, the index of degradation was calculated using the equation:

D = f (C, S, T, V, L, M) (FAO, 1979)

Where D = Index of Soil degradation, C = Climatic aggressivity factor, S = Soil factor, T = Topographic factor, V = Natural vegetable factor, L = Land use factor, and M = Management factor. The degradation risk for each process was also calculated using the general formula (FAO, 1979).

D = f (C, S, T, K)

Where K = the constant, representing the standard condition of V, L, and M.

The land qualities / characteristics for grouping land into degradation classes are given in the Table 6. The rating and determination of the land qualities / characteristics of the land produced the various degradation classes for the soils given in Table 10.

Statistical Analyses. The following statistical analyses were carried out:

– **Rank correlation.** Land use types, land suitability type and degree of degradation were ranked and the association between them was estimated by the use of rank correlation co-efficient.

– **Multiple linear step-wise regression analysis (forward elimination method).** This was employed to determine the relative contribution of each factor (land use types and suitability) to land degradation for each site. To achieve this objective, a step-down model that adds one variable to the regression equation at a time was used (SAS Inst., 1990). As each variable was entered, the model incorporated a check on the variance test. The process of adding variables in turn continued until the contribution of the most recently entered variable was not significant at ($P < 0.05$) by the partial F-value. Any variable that provided a non-significant contribution was removed from the model.

Results and discussions

Land quality assessment

Land Suitability Evaluation (LSE)

The matching of the land qualities / characteristics of the pedons (Table 4) with the land requirements of the crops (Tables 1 – 3) produced the various suitability classes for the various crops given in Tables 7 – 9.

Maize

All the pedons are marginally suitable (S3) for both parametric and non-parametric approaches in all the land use types for maize production (Table 7). The major limitations are soil texture and structure, which directly affect water-holding capacity, permeability of the soil and other physical properties. Other limiting factors are drainage and soil fertility, measured by CEC, organic matter and total nitrogen content.

Cassava

Table 8 shows the suitability of the soils for cassava production. At land use 1, about 66.7 % are moderately suitable (S2) and 33.3 % of the soils are not suitable (N1) using non-parametric method. At land use 2, about 33.3 % of the soils are permanently not suitable (N2) while the remaining 66.7 % are marginally suitable (S3). About 66.7 % of soils in land use 3 are permanently not suitable (N2), while the remaining soils are moderately suitable (S2) with non-parametric approach. The limitations found are poor soil structure and texture. This affects the aggregate and water-holding capacity of the soil. Other constraints include drainage and soil fertility.

Oil Palm

For oil palm production, the suitability of the soils is shown in Table 9. About 66.7% of the soils of land use 1 are currently not suitable (N1) and 33.3 % of the soils are marginally suitable (S3), while all the soils of land use types 2 and 3 are currently not suitable (N1). The dominant limitations are climate (inadequate rainfall and length of dry season), soil texture and structure as well as drainage and soil fertility (CEC, organic matter + Total N).

Land degradation assessment by parametric method

Physical Degradation

The assessment of the present physical degradation for all the studied land use types determined from climate aggressivity factor, soil factor, topography, vegetation, land use and manage-

Table 4. Land Qualities / Characteristics of the Selected Site for Suitability Classification

Profile No.	Annual rainfall (mm)	Length of dry season (months)	Mean temp. (^{o}C)	Relative humidity (%)	Slope (%)	Soil depth (cm)	Texture	Exch. K ($cmol.kg^{-1}$)	Org. carbon (%)	Org. matter (%)	Exch. Mg ($cmol.Kg^{-1}$)	ECEC Soil ($cmol.Kg^{-1}$)	Base saturation (%)	pH KCl
P_1	1337.0	4 – 5	28	80	10	>126	SCL – SC	0.19 – 0.30	0.29 – 0.38	0.49 – 0.65	1.60 – 2.06	3.12 – 3.70	98.40 – 98.65	4.75 – 5.65
P_2	1337.0	4 – 5	28	80	5	>118	SCL – SC	0.24 – 0.43	0.29 – 1.54	0.49 – 2.62	1.21 – 1.87	2.95 – 3.76	96.27 – 98.51	5.10 – 6.15
P_3	1337.0	4 – 5	28	80	1	>112	SCL – CL	0.14 – 0.41	0.40 – 1.66	0.68 – 2.83	1.19 – 2.00	2.94 – 3.96	96.26 – 97.73	4.95 – 5.20
P_4	1337.0	4 – 5	28	80	6	>110	SL – SCL	0.21 – 0.29	0.43 – 1.57	0.73 – 2.67	1.56 – 1.83	3.12 – 3.82	97.91 – 98.40	5.05 – 6.15
P_5	1337.0	4 – 5	28	80	3	>137	S – LS	0.10 – 0.14	0.16 – 1.31	0.27 – 2.23	1.38 – 1.89	2.92 – 3.22	97.26 – 98.14	5.65 – 5.90
P_6	1337.0	4 – 5	28	80	0.5	>112	S – SC	0.13 – 0.30	0.48 – 0.99	0.82 – 1.68	1.19 – 1.79	2.66 – 3.44	97.37 – 98.84	5.90 – 6.20
P_7	1337.0	4 – 5	28	80	7	>149	SL – SCL	0.11 – 0.18	0.64 – 2.12	1.09 – 3.61	1.40 – 1.95	2.93 – 3.61	97.16 – 97.78	5.05 – 5.85
P_8	1337.0	4 – 5	28	80	2	>168	LS – SL	0.18 – 0.28	0.20 – 1.55	0.34 – 2.64	1.46 – 2.06	3.03 – 3.78	98.35 – 98.90	5.80 – 6.10
P_9	1337.0	4 – 5	28	80	4	>167	S – SCL	0.16 – 0.28	0.21 – 0.62	0.36 – 1.05	1.56 – 1.81	2.87 – 3.48	97.85 – 98.85	5.70 – 6.50

Table 5. Productivity index and corresponding suitability classes

Index of productivity values	Suitability classes
100-75	S1
75-50	S2
49-25	S3
24-0	N

Table 6. Land Qualities/Characteristics for Parametric Assessment of the Land Use Type Sites

Land Quality	*Land Use Type		
	1	2	3
Rainfall annual (mm)	1337.0	1337.0	1337.0
Rainfall mean monthly (mm)	111.4	111.4	111.4
Potential evapotranspiraton (PET) annual mean (mm)	1080.2	1080.2	1080.2
PET monthly mean (mm)	90.0	90.0	90.0
Air temp (^{0}C)	28	28	28
Erodibility class	III	II	I
Silt	3.8	3.9	2.13
% clay	9.5	10.6	5.9
% O. M	1.58	0.87	1.28
Soil factor (physical)	0.75 X 2	0.1 X 1	0.01 X 0.5
Soil factor (chemical)	0.25 X 3	1 X 2	1 X 1
Soil factor (sodication)	0.1	0.1	1
Soil texture class	1	1	1
Clay type	1	1	1
Topography	0.5	1	1
Vegetation	1	0.6	0.7
Land use	0.8	0.4	0.6
Management	1	1	1

* Land Use Type1=Cassava/Maize; 2=Oil Palm; 3=Building Site

ment were as follows: 3.12 % (LUT 1); 0.12 % (LUT 2) and 5.2 % (LUT 3), hence the present physical degradation was none to slight for the land use type 2 and moderate for LUTs 1 and 3. While the risk of physical degradation was moderate for LUT 1 (3.90 %), and very high for LUT 3 (10.4 %), it was none to slight for LUT 2 with the risk of degradation of 0.52 %.

Chemical Degradation

The assessment of the present chemical degradation determined from climatic aggressivity factor, soil factor, topography, vegetation, land use and management for all the land use types was as follows 0.78 % (LUT 1) that is none to slight, 1.25 % (LUT 2) that is moderate and 2.6 % for LUT 3 that is high.

However, the risk of chemical degradation determined was very high for LUTs 2 and 3 (i.e. 5.2 %) and none to slight for LUT 1 (0.98 %).

Sodication

The assessment of the present sodication determined from climatic aggressivity factor, soil factor, topography, vegetation, land use and management is none to slight for all the land use types with range between 0.0003 and 0.004 ESP/year. Hence, the risk of sodications for all the land use types is none to slight.

The results of the land degradation assessment by parametric method show that the land degradation ranged between none to slight and high for physical and chemical degradation. The assessment of land degradation for oil palm based crop for physical

Table 7. Suitability Class Scores and Aggregate Suitability Classification of the Representative Pedons for Maize

Profile No	Soil series	Annual rainfall (mm)	Mean annual temp. (^{0}C)	Length growth season (months)	Dev. Stage RH %	Topography slope (%)	Net (w) drainage	Soil physical characteristic texture / structure	Soil depth (cm)	B. sat %	Soil ECEC Cmol.Kg^{-1}	Non – parametric		Parametric	
												Actual	Potential	Actual	Potential
		Land Use 1: Cassava / Maize / Plantain / Banana													
P_1	Jago	S1(95)	S1(95)	S1(95)	S1(100)	S2(85)	S3(60)	S1(95)	S1(100)	S1(100)	S3(60)	S3wf	S3w	S3(32)	S2(54)
P_2	Ibadan	S1(95)	S1(95)	S1(95)	S1(100)	S2(95)	S1(100)	S1(95)	S1(100)	S1(100)	S3(60)	S3tf	S2t	S3(43)	S2(72)
P_3	Egbeda	S1(95)	S1(95)	S1(95)	S1(100)	S1(100)	S1(100)	S1(95)	S1(100)	S1(100)	S3(60)	S3f	S1	S3(44)	S2(74)
		Land Use 2: Oil Palm Plantation													
P_4	Jago	S1(95)	S1(95)	S1(95)	S1(100)	S1(95)	S1(100)	S2(85)	S1(100)	S1(100)	S3(60)	S3sf	S2s	S3(41)	S2(68)
P_5	Apomu	S1(95)	S1(95)	S1(95)	S1(100)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S3(60)	S3sf	S3s	S3(35)	S2(58)
P_6	Egbeda	S1(95)	S1(95)	S1(95)	S1(100)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S3(60)	S3sf	S3s	S3(35)	S2(58)
		Land Use 3: Fallow													
P_7	Jago	S1(95)	S1(95)	S1(95)	S1(100)	S1(95)	S1(100)	S2(85)	S1(100)	S1(100)	S3(60)	S3tf	S2t	S3(41)	S2(68)
P_8	Apomu	S1(95)	S1(95)	S1(95)	S1(100)	S1(100)	S1(100)	S2(85)	S1(100)	S1(100)	S3(60)	S3tf	S2t	S3(42)	S2(70)
P_9	Egbeda	S1(95)	S1(95)	S1(95)	S1(100)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S3(60)	S3sf	S3s	S3(35)	S2(58)

Aggregate suitability class scores: 100 – 75 = S1; 74 – 50 = S2; 49 – 25 = S3; 0 – 24 = N1

Table 8. Suitability Class Scores and Aggregate Suitability Classification of the Representative Pedons for Cassava

Profile No	Soil series	Annual rainfall (mm)	Mean annual temp. (^{0}C)	Length growth season (months)	Dev. stage RH %	Topography slope (%)	Net (w) drainage	Soil physical characteristic texture / structure	Soil depth (cm)	B. sat %	Soil ECEC Cmol.Kg^{-1}	Non – parametric		Parametric	
												Actual	Potential	Actual	Potential
		Land Use 1: Cassava / Maize /Plantain/Banana													
P_1	Jago	S1(95)	S1(95)	S1(95)		S2(85)	N1(40)	S1(95)	S1(100)	S1(100)	S2(85)	N1wtf	N1wt	S3(43)	S2(51)
P_2	Ibadan	S1(95)	S1(95)	S1(95)		S1(95)	S1(100)	S1(95)	S1(95)	S1(100)	S2(85)	S2f	S1	S2(73)	S1(85)
P_3	Egbeda	S1(95)	S1(95)	S1(95)		S1(100)	S1(100)	S1(100)	S1(95)	S1(100)	S2(85)	S2f	S1	S2(74)	S1(88)
		Land Use 2: Oil Palm Plantation													
P_4	Jago	S1(95)	S1(95)	S1(95)		S1(95)	S1(100)	N2(25)	S1(100)	S1(100)	S2(85)	N2sf	N2s	S3(37)	S3(44)
P_5	Apomu	S1(95)	S1(95)	S1(95)		S1(100)	S1(100)	S3(60)	S1(95)	S1(100)	S2(85)	S3sf	S3s	S2(59)	S2(70)
P_6	Egbeda	S1(95)	S1(95)	S1(95)		S2(100)	S1(100)	S3(60)	S1(95)	S1(100)	S2(85)	S3sf	S3s	S2(59)	S2(70)
		Land Use 3: Fallow													
P_7	Jago	S1(95)	S1(95)	S1(95)		S1(95)	S1(100)	N2(25)	S1(100)	S1(100)	S2(85)	N2sf	N2s	S3(37)	S3(44)
P_8	Apomu	S1(95)	S1(95)	S1(95)		S1(100)	S1(100)	S2(85)	S1(100)	S1(100)	S2(85)	S2sf	S2s	S2(70)	S1(83)
P_9	Egbeda	S1(95)	S1(95)	S1(95)		S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S2(85)	S3sf	S3s	S2(59)	S2(70)

Aggregate suitability class scores: 100 – 75 = S1; 74 – 50 = S2; 49 – 25 = S3; 0 – 24 = N1

Table 9. Suitability Class Scores and Aggregate Suitability Classification of the Representative Pedons for Oil Palm

Profile No	Soil series	Annual rainfall (mm)	Mean annual temp. (^{0}C)	Length growth season (months)	Dev. stage RH %	Topography slope (%)	Net (w) drainage	Soil physical characteristic texture/structure	Soil depth (cm)	B. sat %	Soil ECEC Cmol.Kg^{-1}	Org. arbon %	Non-parametric		Parametric	
													Actual	Potential	Actual	Potential
		Land Use 1: Cassava / Maize /Plantain /Banana														
P_1	Jago	S3(60)	S1(100)	S3(60)	S1(100)	S2(85)	S3(60)	N1(40)	S1(100)	S1(100)	S3(60)	N1(40)	N1cwtf	N1t	N1(11)	S3(27)
P_2	Ibadan	S3(60)	S1(100)	S3(60)	S1(100)	S1(95)	S1(95)	N1(40)	S1(100)	S1(100)	S3(60)	N1(40)	N1csf	N1s	N(12)	S3(29)
P_3	Egbeda	S3(60)	S1(100)	S3(60)	S1(100)	S1(100)	S1(95)	S1(100)	S1(100)	S1(100)	S3(60)	S3(60)	S3cf	S3s	S3(35)	S2(58)
		Land Use 2: Oil Palm Plantation														
P_4	Jago	S3(60)	S1(100)	S3(60)	S1(100)	S1(95)	S1(95)	S3(60)	S1(100)	S1(100)	S3(60)	N1(40)	N1csf	S3cs	N(14)	S3(36)
P_5	Apomu	S3(60)	S1(100)	S3(60)	S1(100)	S1(100)	S1(95)	N1(40)	S1(100)	S1(100)	S3(60)	S3(60)	N1csf	N1cs	N(22)	S3(37)
P_6	Egbeda	S3(60)	S1(100)	S3(60)	S1(100)	S1(100)	S1(95)	N1(40)	S1(100)	S1(100)	S3(60)	S3(60)	N1csf	N1cs	N(22)	S3(37)
		Land Use 3: Fallow														
P_7	Jago	S3(60)	S1(100)	S3(60)	S1(100)	S1(95)	S1(95)	S3(60)	S1(100)	S1(100)	S3(60)	S2(85)	S3csf	S3cs	S3(26)	S3(44)
P_8	Apomu	S3(60)	S1(100)	S3(60)	S1(100)	S1(100)	S1(95)	S3(60)	S1(100)	S1(100)	S3(60)	N1(40)	N1csf	S3cs	N(15)	S3(37)
P_9	Egbeda	S3(60)	S1(100)	S3(60)	S1(100)	S1(100)	S1(95)	N1(40)	S1(100)	S1(100)	S3(60)	N1(40)	N1csf	N1cs	N(12)	S3(30)

Aggregate suitability class scores: 100 – 75 = S1; 74 – 50 = S2; 49 – 25 = S3; 0 – 24 = N1

Table 10. Degradation Class Scores by Parametric Method for the Land Use Type Sites

	*Land Use Type 1			*Land Use Type 2			*Land Use Type 3		
	Physical degradation	Chemical degradation	Sodication	Physical degradation	Chemical degradation	Sodication	Physical degradation	Chemical degradation	Sodication
Climatic aggressivity factor	5.2	2.6	0.08	5.2	2.6	0.08	5.2	2.6	0.08
Soil factor	0.75 X 2	0.25 X 3	0.1	0.1 X 1	1` X 2	0.1	0.01 X .05	1 X 1	1
Topography	0.5	0.5	0.5	1	1	1	1	1	1
Vegetation	1	1	1	0.6	0.6	0.6	0.7	0.7	0.7
Land use	0.8	0.8	0.8	0.4	0.4	0.4	0.6	0.6	0.6
Management	1	1	1	1	1	1	1	1	1
Present	3.12%	0.78%	0.003 ESP/yr	0.12%	1.25%	0.002 ESP/yr	0.01%	1.09%	0.03 ESP/yr
Degradation	Moderate	None to slight	None to slight	None to slight	Moderate	None to slight	None to slight	None to slight	None to slight
Risk of	3.90%	0.98%	0.004 ESP/yr	0.52%	5.2%	0.008 ESP/yr	0.03%	2.6%	0.08 ESP/yr
Degradation	Moderate	None to slight	None to slight	None to slight	Very high	None to slight	None o slight	High	None to slight

* Land Use Type1=Cassava/Maize; 2=Oil Palm; 3=Fallow

Table 11. Rank Correlation Coefficients between Land Use Types, Land Type, Land Suitability and Land Degradation in Land Use Type 1 (Cassava/Maize)

	LUT	LT	Oil palm	Cassava	Maize	B.D (g/cm^3)	Permeability (cm/hr)	B. sat (%)	N ($cmol.kg^{-1}$)	P (mg/kg^{-1})	K ($cmol.kg^{-1}$)	ESP (%)	Organic matter content (%)
LUT	-	-0.365	-0.218	-0.509*	a	-0.250	0.250	a	-0.179	0.391	-0.311	-0.688**	-0.378
LT		-	0.937**	0.717**	a	0.021	-0.021	a	-0.259	0.010	0.273	0.251	-0.037
Oil palm				0.429	a	0.055	-0.055	a	-0.245	-0.058	0.108	0.150	-0.097
Plantain				a	a	A	a	a	A	a	a	a	a
Cassava					a	-0.055	0.055	a	-0.181	0.140	0.492*	0.350	0.097
Maize						A	a	a	A	a	a	a	a
B.D							-0.063	a	-0.220	-0.208	0.055	-0.115	-0.543*
Permeability								a	-0.147	0.019	0.220	0.115	-0.197
B. Sat									A	a	a	a	a
N										-0.312	0.035	0.011	0.764**
P											-0.131	-0.269	-0.237
K												0.340	0.160
Esp													0.260
Organic matter content													

* = significant at 5%; ** =significant at 1%; a = cannot be computed because at least one of the variables is constant.

Table 12. Rank Correlation Coefficients between Land Use Types, Land Type, Land Suitability and Land Degradation in Land Use Type 2 (Oil Palm)

	LUT	LT	Oil palm	Cassava	Maize	B.D (g/cm^3)	Permeability (cm/hr)	B. sat (%)	N (cmol.kg^{-1})	P (mg/kg^{-1})	K (cmol.kg^{-1})	ESP (%)	Organic matter content (%)
LUT	-	a	a	a	a	a	a	a	A	a	a	a	a
LT		-	a	0.717**	a	-0.059	-0.012	a	-0.421	0.289	-0.248	-0.197	-0.260
Oil palm				a	a	a	a	a	A	a	a	a	a
Plantain				-1.000**	a	-0.154	-0.055	a	0.218	-0.009	0.310	0.218	0.075
Cassava					a	-0.154	0.055	a	-0.218	0.009	-0.310	-0.218	-0.075
Maize						a	a	a	A	a	a	a	a
B.D							0.553*	a	0.302	-0.406	-0.066	-0.034	0.276
Permeability								a	0.125	-0.260	0.191	0.167	0.129
B. sat									A	a	a	a	a
N										-0.477*	0.218	-0.167	0.943**
P											0.246	-0.188	-0.387
K												-0.036	0.206
Esp													-0.229
Organic matter content													-

* = significant at 5%; ** =significant at 1%; a = cannot be computed because at least one of the variables is constant.

Table 13. Rank Correlation Coefficients between Land Use Types, Land Type, Land Suitability and Land Degradation in Land Use Type 3 (Building Site)

	LUT	LT	Oil palm	Cassava	Maize	B.D (g/cm^3)	Permeability (cm/hr)	B. sat (%)	N (cmol.kg^{-1})	P (mg/kg^{-1})	K (cmol.kg^{-1})	ESP (%)	Organic matter content (%)
LUT	-	A	a	a	a	A	a	a	A	a	a	a	A
LT			-0.717**	0.445*	a	0.349	-0.547*	a	0.137	0.105	0.040	a	-0.093
Oil palm				-0.943**	a	-0.524*	0.764**	a	-0.290	-0.039	-0.275	a	0.027
Plantain				-0.105	a	-0.190	0.327	a	-0.032	-0.116	-0.085	a	0.107
Cassava					a	0.507*	-0.721**	a	0.307	0.000	0.334	a	0.010
Maize						A	a	a	A	a	a	a	A
B.D							-0.218	a	0.531*	-0.116	0.559*	a	0.510*
Permeability								a	-0.037	-0.266	-0.065	a	0.277
B. Sat									a	a	a	a	A
N										0.026	0.134	a	0.472*
P											-0.192	a	-0.218
K												a	0.192
Esp													A
Organic matter content													-

* = significant at 5%; ** =significant at 1%; a = cannot be computed because at least one of the variables is constant.

showed none to slight degradation. Degradation was moderate for arable based crops. It was moderate for present degradation and high for risk of degradations for building site with respect to physical parameters.

The present degradation and risk of degradation were high and very high chemically for building site and it was moderate and very high respectively for oil palm based crop. However, the present and risk of degradation for chemical were both none-slight for arable-based crops. With the parametric method of assessment, all characteristics of the soil, climate, environment and management factors are considered in the assessment while in the case of direct method, the soil quality decides the degradation class, apart from this the parametric method is multiplicative and more stricter on the soil factor and climate than other method. The risk of land degradation was assessed first, using the data on the physical aspects of the environment. Subsequently the present rate of degradation was derived from the risk by introducing the human factors of land use and soil management (FAO, 1979).

It was observed form the LSE results that soil texture was the major soil constraint to optimum performance of both arable and the cash crops production in the experimental area. This is because soil texture is very vital in relation to the soil nutrient status and soil moisture retention (Senjobi, 2007). However, most of the pedons were found to be marginally suitable for all the commonly grown crops despite the appreciable content of organic matter in the soils. This is because the sandy texture of the soils as well as high concentration of the gravel in the soil must have encouraged the leaching of the available soil nutrients thereby limiting the suitability of the planted crops (Senjobi, 2007). However, good soil management practices that encourage the use of organic manure, cultivation of cover crops, zero tillage as well as correct usage of the land for the use it is meant for are required before substantial improvement and sustainable production can be achieved.

The result of the rank correlation between the land use type and land degradation showed that correlation co-efficient was negative but statistically significant ($P < 0.01$) only for ESP and positive but not significant for some physical and chemical indicators (i.e. permeability and phosphorus). This shows that inappropriate land use type and management encourage the dispersion of soil and nutrients consequently leading to sub-optimal production of the planted crops. The result of rank correlation between land suitability and land degradation (Tables 11 – 13) showed that correlation co-efficient was statistically highly significant ($P < 0.01$) for some physical properties (i.e. permeability, bulk density), chemical properties (total N, K and nitrogen) and biological properties (organic matter content) and significant ($P < 0.05$) for some physical (bulk density) and chemical (potassium) in most of the land use sites. This is an indication that crops that were planted on the land are not suitable and appropriate for the potential capacity of the soil. This suggests that when lands are not used according to their suitabilities classification, they tend to have much effect on the soil physical properties. The effect of suitability on the chemical degradation may be undoubtedly due to excessive crop uptake coupled with nutrient loss through leaching. This result of rank correlation between land use type and land suitability showed that correlation was statistically non-significant at all the land use sites and this indicate unappreciable relationship between them.

The result of the multiple linear stepwise regression analysis (Table 14) showed that factors contributing to different forms of degradation differ from one land use type to another and suggests that virtually most of the degradation forms are contributed to by suitability in all the land use types. This could be attributed to the exploitative nature of the crops which are mainly cassava/maize and oil palm as well as exposure of land by the arable crops.

Building site and arable-based crops land use types showed greater decline in physical and chemical properties following the exposure of the soils to erosion menace and over-exploitation of the nutrients by soil depleting crops. The differences observed in physical and chemical properties of the soils under these land use types could probably be explained mainly on the basis of nutrient cycling and farm management practices (Adejuwon and Ekanade, 1988; Senjobi, 2007). In the oil palm based land use, the sandy texture of the soils, which does not only result in the excessive drainage and retention of little moisture, encourages the leaching of essential nutrients especially exchangeable K that is needed for high yield in oil palm production (as reported by Tinker, 1963; and Ataga et. al., 1981). Ogunkunle (1993) and Senjobi (2001) also noted that loss of potassium through leaching in an oil palm plantation leads to decrease in the optimum yield.

It is important to note that inappropriate allocation of land for any use hinder the optimization of agricultural and land management practices coupled with the choice of the crops (which are soil depleting crops) and absence of residue management practices on the part of the farmers must have probably amplified these changes (Senjobi, 2007). Also, the sandy texture of the soils make them highly vulnerable to one form of erosion or the

Table 14. Stepwise Multiple Linear Regression Analysis of Land Use Types, Land Types, Land Suitability and Land Degradation

Degradation Indicator	Independent Variable	Land use 1		Land use 2		Land use 3	
		Contribution	Cumulative	Contribution	Cumulative	Contribution	Cumulative
B.D.	Suitability (Oil Palm) (S)	0-	0-	0-	0-	27.4	27.4
Permeability	Land type	0-	0-	0-	0-	-	-
	Suitability (Oil palm) (S)	0-	0-	0-	0-	58.3	58.3
N	Land type	0-	0-	0-	0-	0-	-
	Suitability (Cassava/Maize) (S)	0-	0-	0-	0-	-	-
K	Suitability (Cassava/Maize) (S)	24.2	24.2	-0	-0	0-	-
Organic matter content	Suitability (Cassava/Maize) (S)	-0	-0	-0	-0	0-	-

Model for Land degradation: Land use 1 - Potassium, $Y = 0.38 + 0.49S_1 – 0.08LUT - 0.16LT – 0.13S_2$; Land use 3 - Permeability, $Y=2.93 – 0.15S_1 – 0.28LT$; Potassium, $Y=0.53 + 0.30SY + 0.60LT$; LUT – Land use type, LT – Land type, S_1 – Cassava/Maize, S_2 – Oil palm other upon exposure and consequently increase the degradation processes. The observed decline in NPK could be attributed to reduction of organic matter content during tillage and management practices and nitrate – nitrogen (NO_3 –N) loss by leaching and crop mining through uptake (Agboola, 1987).

Application of inorganic fertilizers, organic manures, cultivation of cover crops, and correct usage of the land for the purpose it is best suited for will go a long way to reduce the degradation level of the soils.

Prevention of surface wash and its consequences through mulching of the soils throughout the year (Lal, 1975) will help in reducing the energy impact of both rain drops and leaf drops and will prevent serious run off and erosion of the topsoil. In view of the competition between agricultural land use and non-agricultural uses for limited land space, steps should be taken to stop the loss of good agricultural lands to non-agricultural uses (Senjobi, 2001). This will go a long way to combat degradation processes.

Conclusions

The degradation processes were very prominent under building site and cassava and maize based cropping systems and very high under oil palm based crop.

Land suitability contributed greatly to land degradation in all land use sites. Land use type significantly correlated with land degradation, that is, it influenced significantly land degradation chemically. Physical degradation accounted for most of the degraded soils in all the land use types.

In view of the above, land use type and land suitability need to be considered in taking appropriate approach to soil degradation, rehabilitation or improvement for agricultural uses in the sites under study.

It was observed that the land use types employed on the study sites were not very compatible with the characteristics of the soil. This inappropriate allocation of land to uses coupled with the inadequate agricultural techniques enhanced the exposure of farm lands and predisposed the soils to both water and wind erosion.

To take adequate care of these deficiencies, and minimize land degradation in the study sites, the following measures are recommended: plausible land use approach, multiple cropping, uses of organic mulching, contour ridge and cultivation of cover crops.

In addition to the above measures, there is the need to understand the soil adequately through detailed soil survey and land evaluation. When this is carefully done, the soil can then be put to appropriate land use i.e. cultivate the crops that are most suitable for the land having known its capability and constraints.

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