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LAND DEGRADATION ASSESSMENT UNDER DIFFERENT USES: IMPLICATIONS ON SOIL PRODUCTIVITY AND FOOD SECURITY

PROCJENA DEGRADACIJE TLA RAZLIČITO KORIŠTENA: DJELOVANJE NA PROIZVODNOST TLA I SIGURNOST HRANE

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ABSTRACT

Land use type is one of the critical factors affecting land degradation and soil productivity. The extent to which it influences land degradation and productivity has not been fully ascertained. This has been necessary for this study with the aim of assessing the extent to which land use influences crop productivity.

Soil degradation levels were assessed using direct observation. The land use types studied were arable cropping (land use 1), oil palm (land use 2), and building sites (land use 3). Rank ordered correlation was used for the data analyses.

Direct observation showed that physical and biological degradations were more severe than chemical degradation in all the land uses. Degradation processes were more prominent in land uses 1 and 3 than 2. 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 and soil types.

However, since degradation processes were very high in all land uses, there must be careful choice of appropriate use of land in order to reduce degradation and enhance soil productivity.

Key words**:** land degradation, land uses, direct observation, soil productivity and food security

SAŽETAK

Način korištenja tla jedan je od kritičnih faktora što djeluje na degradaciju i proizvodnost tla. Razmjeri na koji oni utječu na degradaciju i proizvodnost tla nisu u potpunosti ustanovljeni. To nas je potaklo za procjenjivanje razmjera u kojem korištenje tla utječe na proizvodnost usjeva. Razine degradacije tla procijenjene su izravnim motrenjem. Promatrani načini korištenja tla bili su: obradivo tlo za usjeve (korištenje tla 1), uljana palma (korištenje tla 2) i gradilišta (korištenje tla 3).

Za analizu podataka primijenjena je korelacija za određivanje namjene (rank order correlation). Izravno motrenje je pokazalo da su fizička i biološka degradacija bile jače od kemijske, kod svih korištenja tla. Procesi degradacije bili su jače izraženi kod korištenja tla 1 i 3 nego kod 2. Prema nalazu korištenje tla bilo je značajno ($P<0.01$) povezano s degradacijom tla ($r=9.47$) na svim položajima. Razina degradacije kretala se od umjerene do velike zbog neodgovarajućeg korištenja zemljišta i tipova tla.

Međutim, budući da su procesi degradacije bili vrlo izraženi kod svih korištenja zemljišta potrebno je pažljivo izabrati odgovarajuće korištenje kako bi se smanjila degradacija i potakla produktivnost tla.

Ključne riječi: degradacija tla, korištenje zemljišta, izravno motrenje, produktivnost tla i sigurnost hrane

INTRODUCTION

Meeting the food and fibre needs of the ever-increasing growing population in this period of global recession has been a major concern to the agriculturists. This has beendifficult to actualize as the farmers are embarking on two or more land use types, which are contrasting in specific details and potentials on similar soils or the same land use types on dissimilar soils.

In practice, particularly in 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 and 2007). Land has been utilized intensively for all purposes at the expense of its suitability thereby resulting in land degradation and altering the natural ecological conservational balances in the landscape. Such imbalances pose great difficulty to soil productivity and food security (Senjobi, 2007).

In the last 50 years alone, 20% of the world's agricultural land has been irreversibly damaged due to human-induced land degradation. Thus, if the process of destruction continues at this pace, agriculture will lose 15-30% of its present productivity (FAO, 1984).

According to UNEP-ISRIC (1990) on human-induced land degradation between 1945 and 1990, about 494 million of hectares in Africa were completely degraded while 22% of the total area of land constitutes the producing biomass. This is so, since land degradation due to inappropriate land use systems severely impairs the productive capacity of the soils.

It has been observed that every kind of land use partly destroys soil structure and reduces soil fertility (Vink, 1975). Therefore, long-term land use must be accompanied by measures to conserve the soils of the land. Although many works have been done on implications of different land uses on soil properties and fertility, yet little or nothing is done on land degradation and its assessment through direct approach. (Adejuwon and Ekanade, 1988; Ogunkunle and Eghaghara, 1992; Abubaka, 1997; Ameyan and Ogidiola, 1989; Choker and Odemertio, 1994; Essiet, 1990; Graefard Stahr, 2000, Lal, 1996; and Mainguet, 1993). This has initiated necessitated this research work with the view of assessing the extent of land degradation as influenced by different land uses so as to guide the farmers on the land use planning.

MATERIALS AND METHODS

Description of the Study Area

The study was located at Olabisi Onabanjo University Campus, Ago-Iwoye. The area is located between latitudes $6^0$55' and $7^0$00'N and between longitudes $3^0$45' and $4^0$05'E. The area falls within the rain forest region of South Western Nigeria with an annual rainfall of about 1150mm and mean annual temperature of about 27^0C. Mean relative humidity of the area is generally high (about 80%) with the peak between May and October. The natural vegetation of the area consists mainly of secondary forest. Cultivated land and bush re-growth accounted for less than 10% of the land area especially where Apomu, Egbeda, Olorunda soil series dominate. The site is generally undulating with a few gentle to steep slopes.

The soils investigation of the site shows that most of the soils derived from coarse grained rocks generally characterized by their varying amounts of quartz and/or ironstone gravel with some occasional stones in the top one meter of the profile. Varying quantities of gravel and stones may be found on the surface of these soils. The major land use types in the study are arable crop production, cash crop production and non-agricultural uses such as residential, commercial and roads construction.

Field Work

Three land use types: Arable cropping (land use1), oil palm (land use 2) and building sites (land use 3) were studied. At each of the chosen land use type, an area of 50hectares was identified with the aid of tape measure. This was divided into 10 units of 5ha each. In each of the 5hectares unit, land degradation types, land type and soil type were recorded. Within each 5ha area, soil samples were augered using grid survey approach at 100m equidistance points. Bulk samples consisting of ten (10) surface (0-15cm) and subsurface (15-30cm) core samples were collected separately for physical, chemical and biological analyses.

Profile pits (2m x 1m x2m) were dug at the three predominant different land type or slope segments encountered. These were crest, middle slope, and valley-bottom. The general site description such as climate, vegetation, land use, gradient of slope, drainage type, soil surface form, type and degree of erosion, field texture, micro-relief and depths to ground water table were recorded. The pits were described, sampled and the samples analyzed according to Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology (1986). The pedons were classified according to soil taxonomy (Soil Survey Staff, 2003), the FAO/UNESCO (FAO, 2006), Higgins (1964) and Smyth and Montgomery (1962) systems of classification. A total of 9 profile pits were dug (3 at each land use) and a total of 110 soil samples (consisting 28 profile samples and 82 core samples from the soil surface) were collected for laboratory analysis.

Laboratory Analysis

The soil samples were air-dried and sieved with a 2mm-mesh sieve. Some portion of the sieved samples was further passed through 0.5mm-mesh sieve for organic matter and total N determination. Soil samples were analysed for the following parameters: Soil pH was determined in both water and 0.01M potassium chloride solution (1:1) using glass electrode pH meter (Mclean, 1965). Total nitrogen was determined by the macro-kjeldahl digestion method of Jackson (1962), available P was extracted using Bray-1 extract followed by molybdenum blue colorimetry. Exchangeable cations were extracted with IM NH_4OAC (pH 7.0), potassium, calcium and sodium were determined using flame photometer and exchangeable Mg by atomic absorption spectro-photometer (Sparks, 1996). Exchangeable acidity was determined by the Kcl extraction method (Mclean, 1965), organic carbon was determined using dichromate wet oxidation method (Walkley and Black, 1934). Organic matter was got by multiplying the percent age of organic carbon by 1.72. Cation exchange capacity (CEC) was calculated from the sum of all exchangeable cations. Available micro-nutrients were determined by Atomic Absorption Spectrophotometer (AAS) method after leaching on NH_4Cl (Water and Sammer, 1948). Saturated hydraulic conductivity was determined using a constant head method, 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). Particle size analysis was done by the Bouyoucos hydrometer (1951) method using calgon as dispersing agent.

Land Degradation Assessment by Direct Approach

Pedons at each land use site were placed in degradation classes by matching soil characteristics with the land degradation indicators (Tables 1-3). A broad classification of the seriousness of degradation was made to determine the degree of degradation. Land degradation was classified following approach of FAO (1979) and Snakin et.al (1996). The estimation of the degree of degradation was based on physical, chemical and biological parameters of land use types.

Table 1: Indicators and criteria of physical degradation of soil

Tablica 1 : Pokazatelji i kriteriji fizičke degradacije tla

	***Degree of degradation** (%)				
Indicator	**Initial level**	**1**	**2**	**3**	**4**
Soil bulk density (g/cm^3)	1.25 – 1.4	< 1.5	1.5 – 2.5	2.5 – 5	> 5
Permeability (cm/hr)	5 – 10	< 1.25	1.25 – 5	5 – 10	> 20

Sources: FAO (1979), Snaking *et al*. (1996).

*Where 1= None to slight degraded soils
2= Moderately degraded soils
3= Highly degraded soils
4= Very highly degraded soils.

Table 2: Indicators and criteria of chemical degradation of soil

Tablica 2: Pokazatelji i kriteriji kemijske degradacije tla

Indicator	***Degree of degradation (%)**			
	1	**2**	**3**	**4**
Content of Nitrogen Element (Multiple decrease) N (%)	>0.13	0.10 – 0.13	0.08 – 0.10	< 0.08
Content of Phosphorus Element (mgkg^{-1})	> 8	7 – 8	6 – 7	<6
Content of Potassium Element (cmolkg^{-1})	> 0.16	0.14 – 0.16	0.12 – 0.14	< 0.12
Content of Readily Soluble Salts (Increase by %)	< 0.20	0.20 – 0.40	0.40 – 0.80	> 0.8%
Content of ESP (Increase by % of CEC)	< 10	10 – 25	25 – 50	> 50
Content of Base Saturation (Decrease of Saturation if more than 50%)	< 2.5%	2.5 – 5%	5 – 10%	> 10%
Excess Salts (Salinization) (Increase in conductivity) mmho/cm/yr	< 2	2 – 3	3 – 5	> 5

Source: FAO (1979), Snaking *et al.* (1996).

*Where 1= None to slight degraded soils
2= Moderately degraded soils
3= Highly degraded soils
4= Very highly degraded soils.

Table 3: Indicators and criteria of biological degradation of soil

Tablica 3: Pokazatelji i kriteriji biološke degradacije tla

	*Degree of degradation (%)			
Indicator	**1**	**2**	**3**	**4**
Content of organic matter in soil (%)	> 2.5	2 – 2.5	1.0 – 2	< 1.0

Source: FAO 1979

*Where 1 = None to slight degraded soils
2 = Moderately degraded soils
3 = Highly degraded soils
4 = Very highly degraded soils.

Table 4: Land qualities/Soil properties for land degradation assessments of Cassava/Maize/ Plantain /Banana Land Use Types

Tablica 4: Kakvoća zemljišta/svojstva tla za procjenu degradacije zemljišta tipa korištenja za plantažu kasave/kukuruza/banana

		Physical		Chemical					Biological
Land Use 1	**Depth (cm)**	**B.D (g/cm^3)**	**Permeability (cm/hr)**	**B. Sat. (%)**	**N (%)**	**P (mg.kg^{-1})**	**K cmol.kg^{-1}**	**ESP (%)**	**Organic matter (%)**
A1	0 – 15	1.36	13.6	97.38	0.10	14.27	0.12	10.48	0.44
B1	15 – 30	1.60	4.92	96.21	0.08	10.82	0.16	5.86	0.77
A2	0 – 15	1.30	7.48	97.55	0.19	4.50	0.81	3.68	2.35
B2	15 – 30	1.25	6.52	97.11	0.19	4.00	0.43	7.02	2.18
A3	0 – 15	1.34	7.38	95.45	0.14	6.00	0.10	4.92	1.48
B3	15 – 30	1.20	7.01	97.49	0.11	4.00	0.14	4.08	1.19
A4	0 – 15	1.50	5.70	96.17	0.19	6.50	0.27	5.36	2.51
B4	15 – 30	1.39	5.48	98.04	0.13	11.32	0.39	7.84	1.20
A5	0 – 15	1.22	4.12	98.11	0.13	3.51	0.24	3.14	1.34
B5	15 – 30	1.19	4.08	96.89	0.11	4.50	0.32	5.19	1.17
A6	0 – 15	1.57	6.78	95.35	0.29	7.20	0.31	6.59	3.63
B6	15 – 30	1.48	6.25	94.55	0.12	9.35	0.14	5.45	1.33
A7	0 – 15	1.28	8.46	94.39	0.06	12.80	0.14	4.67	0.72
B7	15 – 30	1.24	8.04	97.28	0.14	7.87	0.30	4.71	1.55
A8	0 – 15	1.32	5.88	97.42	0.24	5.50	0.18	3.72	2.49
B8	15 – 30	1.36	6.02	97.18	0.10	2.00	0.18	4.58	0.99
A9	0 – 15	1.16	4.96	97.74	0.10	9.35	0.91	5.01	1.04
B9	15 – 30	1.20	5.84	96.68	0.04	8.86	0.34	5.65	0.34
A10	0 – 15	1.12	5.70	96.98	0.06	4.00	0.14	4.02	0.56
B10	15 – 30	1.57	5.48	98.15	0.39	7.50	1.29	7.39	4.29

Table 5: Land qualities / soil properties for land degradation assessments of oil palm plantation land use type

Tablica 5: Kakvoća zemljišta /svojstva tla za procjenu degradacije zemljišta tipa korištenja za plantažu uljane palme

		Physical		Chemical					Biological
Land Use 2	Depth (cm)	B.D (g/cm^3)	Permeability (cm/hr)	B. Sat. (%)	N (%)	P (mg.kg^{-1})	K cmol.kg^{-1}	ESP (%)	Organic matter (%)
A_1	0 -15	1.60	18.48	96. 93	0.13	3.50	0.17	4.29	1.34
B_1	15 – 30	1.30	5.92	96.88	0.12	6.89	0.23	4.86	1.16
A_2	0 – 15	1.55	10.86	95.93	0.07	9.35	0.20	7.72	0.69
B_2	15 – 30	1.23	4.85	98.18	0.13	5.50	0.30	4.01	1.42
A_3	0 – 15	1.61	8.16	96.23	0.01	6.40	0.14	4.79	0.15
B_3	15 – 30	1.58	7.92	96.92	0.10	3.00	0.19	3.38	1.19
A_4	0 – 15	1.56	6.78	96.19	0.10	5.00	0.13	4.24	1.14
B_4	15 – 30	1.49	6.20	96.44	0.19	1.14	0.15	8.54	2.04
A_5	0 – 15	1.29	3.54	96.42	0.10	3.00	0.14	4.50	1.03
B_5	15 – 30	1.30	3.68	96.85	0.05	3.44	0.28	6.69	0.46
A_6	0 – 15	1.44	10.32	96.59	0.13	0.94	0.25	11.36	1.28
B_6	15 – 30	1.12	9.82	95.31	0.04	0.20	0.09	4.69	0.42
A_7	0 – 15	1.72	12.24	95.97	0.10	3.00	0.24	4.03	1.08
B_7	15 – 30	1.85	14.40	94.42	0.04	12.79	0.19	4.65	0.59
A_8	0 – 15	1.62	10.35	96.51	0.01	9.35	0.17	6.59	0.10
B_8	15 – 30	1.53	9.82	96.63	0.07	6.89	0.21	7.12	0.66
A_9	0 – 15	1.46	8.63	96.95	0.10	6.51	0.20	5.08	1.01
B_9	15 – 30	1.20	7.52	97.40	0.04	6.89	0.15	7.47	0.50
A_{10}	0 – 15	1.61	10.54	98.34	0.10	14.54	0.16	14.24	1.03
B_{10}	15 – 30	1.58	10.44	98.24	0.02	3.00	0.06	7.75	0.16

Statistical Analysis

Land use types and degree of degradation were ranked and the association between them was estimated by the use of rank correlation coefficient.

Table 6: Land qualities / soil properties for land degradation assessment of building sites land use type

Tablica 6: Kakvoća zemljišta/ svojstva tla za procjenu degradacije zemljišta tipa korištenja za gradilišta

Land Use 3	Depth (cm)	Physical		Chemical					Biological
		B.D (g/cm^3)	Permeability (cm/hr)	B. Sat. (%)	N (%)	P ($mg.kg^{-1}$)	K $cmol.kg^{-1}$	ESP (%)	Organic matter (%)
A_1	0-15	1.07	3.46	95.74	0.10	5.90	0.11	6.20	0.94
B_1	15-30	1.39	1.38	95.36	0.03	3.51	0.10	4.93	0.22
A_2	0-15	1.21	3.57	96.43	0.19	3.50	0.16	5.52	2.12
B_2	15-30	1.24	3.47	96.06	0.03	6.40	0.09	6.30	0.27
A_3	0-15	1.57	3.66	97.38	0.19	13.78	0.15	7.33	1.97
B_3	15-30	1.42	4.05	96.94	0.03	3.51	0.10	3.19	0.22
A_4	0-15	1.33	7.32	97.63	0.09	10.33	0.20	8.47	0.88
B_4	15-30	1.46	5.72	97.56	0.05	10.33	0.16	6.97	0.59
A_5	0-15	1.18	7.08	97.73	0.19	3.29	0.38	10.06	2.68
B_5	15-30	1.23	6.78	98.24	0.03	1.50	0.09	3.52	0.25
A_6	0-15	1.14	2.94	97.87	0.09	6.89	0.21	5.67	0.85
B_6	15-30	1.16	3.01	97.81	0.05	8.86	0.11	8.13	0.46
A_7	0-15	1.35	5.08	98.68	0.01	8.86	0.19	3.95	0.09
B_7	15-30	1.24	4.88	97.89	0.19	3.00	0.23	4.15	2.33
A_8	0-15	1.49	4.68	97.44	0.15	9.84	0.45	9.90	1.58
B_8	15-30	1.38	4.24	97.94	0.12	2.35	0.23	10.31	1.31
A_9	0-15	1.66	5.92	97.98	0.11	12.80	0.18	8.75	1.05
B_9	15-30	1.52	5.26	95.31	0.07	1.51	0.38	5.16	0.71
A_{10}	0-15	1.50	4.16	96.51	0.19	1.41	0.13	10.47	2.04
B_{10}	15-30	1.57	3.89	99.07	0.29	7.02	1.07	3.71	3.60

RESULTS AND DISCUSSION

The land/soil requirement (indicators and criteria i.e. land qualities/soil properties) for grouping lands into different degradation classes are given in Tables 4-6. The matching of soil properties (Tables 4-6) with the soil indicators and criteria (Tables 1-3) produced the various degradation classes for all the locations at the land use types in Tables 7-9.

Land Use Types

Tables 7-9 present aggregate scores for the degree of degradation classification in all study sites.

Table 7: Scores for physical, chemical and biological degradation of land Use 1 (Cassava /Maize)

Tablica 7: Bodovi za fizičku, kemijsku i biološku degradaciju zemljišta korištenja 1 (kasava /kukuruz)

Land Use 1	Depth (cm)	B. D. (g/cm^3)	Permeability (cm/hr)	B. Sat. (%)	N	K	P	ESP	Organic matter (%)
					(cmol.kg^{-1})		(mg.kg^{-1})	%	
		Physical		Chemical					Biological
1	0 – 15	1	3	3	2	3	1	-2	4
	15 – 30	2	2	3	3	2	1	1	4
2	0 – 15	1	3	3	1	1	4	1	2
	15 – 30	1	3	3	1	1	4	1	2
3	0 – 15	1	3	3	1	4	3	1	3
	15 – 30	1	3	3	2	3	4	1	3
4	0 – 15	2	3	3	1	1	3	1	1
	15 – 30	1	3	3	2	1	1	1	3
5	0 – 15	1	2	3	2	1	4	1	3
	15 – 30	1	2	3	2	1	4	1	3
6	0 – 15	2	3	3	1	1	2	1	1
	15 – 30	1	3	3	2	2	1	1	3
7	0 – 15	1	3	3	4	2	1	1	4
	15 – 30	1	3	3	1	1	2	1	3
8	0 – 15	1	3	3	1	1	4	1	2
	15 – 30	1	3	3	2	1	4	1	4
9	0 – 15	1	2	3	2	1	1	1	3
	15 – 30	1	3	3	4	1	1	1	4
10	0 – 15	1	3	3	4	2	4	1	4
	15 – 30	2	3	3	1	3	2	1	1

KEY:
None to slight=1
Moderate=2
High=3
Very high=4

Table 8: Scores for physical, chemical and biological degradation of land use 2 (Oil Palm)

Tablica 8: Bodovi za fizičku, kemijsku i biološku degradaciju zemljišta korištenja tipa 2 (uljana palma)

Land Use 2	Depth (cm)	B. D. (g/cm^3)	Permeability (cm/hr)	B. Sat. (%)	N	K	P	ESP	Organic matter (%)
					(cmol.kg^{-1})		(mg.kg^{-1})	%	
		Physical		Chemical					Biological
1	0 – 15	2	3	3	2	1	4	1	3
	15 – 30	1	3	3	2	1	3	1	3
2	0 – 15	2	3	3	4	1	1	1	4
	15 – 30	1	2	3	2	1	4	1	3
3	0 – 15	2	3	3	4	2	3	1	4
	15 – 30	2	3	3	2	1	4	1	3
4	0 – 15	2	3	3	2	2	4	1	3
	15 – 30	1	3	3	1	2	4	1	2
5	0 – 15	1	2	3	2	2	4	1	3
	15 – 30	1	2	3	4	1	4	1	4
6	0 – 15	1	3	3	2	1	4	2	3
	15 – 30	1	3	3	4	4	4	1	4
7	0 – 15	2	3	3	3	1	4	1	3
	15 – 30	2	3	3	4	1	1	1	4
8	0 – 15	2	3	3	4	1	1	1	4
	15 – 30	2	3	3	4	1	3	1	4
9	0 – 15	1	3	3	3	1	3	1	3
	15 – 30	1	3	3	4	2	3	1	4
10	0 – 15	2	3	3	3	2	1	2	3
	15 – 30	2	3	3	4	4	4	1	4

KEY:
None to slight=1
Moderate=2
High=3
Very high=4

Physical Degradation

At land use 1, about 80% of the soils was none to slightly degraded and 20% moderately degraded with respect to bulk density. About 20% were moderately degraded and 80% highly degraded in terms of permeability. At land use 2, about 45% of the soils were none to slightly and 55% moderately degraded in terms of bulk density. 15% of the soils were moderately degraded and 85% highly degraded with respect to permeability.

Table 9: Scores for physical, chemical and biological degradation of land use 3 (Building Sites)

Tablica 9: Bodovi za fizičku, kemijsku i biološku degradaciju zemljišta korištenja tipa 3 (gradilišta)

Land Use 5	Depth (cm)	B. D. (g/cm^3)	Permeability (cm/hr)	B. Sat. (%)	N (cmol.kg^{-1})	K	P (mg.kg^{-1})	ESP %	Organic matter (%)
		Physical		Chemical					Biological
1	0-15	1	2	3	3	4	4	1	4
	15-30	1	2	3	4	4	4	1	4
2	0-15	1	2	3	1	2	4	1	2
	15-30	1	2	3	4	4	3	1	4
3	0-15	2	2	3	1	2	1	1	3
	15-30	1	2	3	4	4	4	1	4
4	0-15	1	3	3	4	1	1	1	4
	15-30	1	3	3	4	2	1	1	4
5	0-15	1	3	3	1	1	4	2	1
	15-30	1	3	3	4	4	4	1	4
6	0-15	1	2	3	4	1	3	1	4
	15-30	1	2	3	4	4	1	1	4
7	0-15	1	3	3	4	1	1	1	4
	15-30	1	2	3	1	1	4	1	2
8	0-15	1	2	3	1	1	1	2	3
	15-30	1	2	3	2	1	4	1	3
9	0-15	2	3	3	2	1	1	1	3
	15-30	2	3	3	4	1	4	1	4
10	0-15	2	2	3	1	3	4	2	2
	15-30	2	2	3	1	1	2	1	1

KEY:
None to slight=1
Moderate=2
High=3
Very high=4

At land use 3, about 75% of the soils were none to slightly degraded, while 25% were moderately degraded with respect to bulk density. With respect to permeability about 65% were moderately degraded and 35% highly degraded in land use 3.

Chemical Degradation

At all locations in all the land use types, all the soils were moderately degraded with respect to base saturation. At land use 1, 40% of the soils were none to slightly degraded, 40% moderately degraded, 5% highly degraded and 15% very highly degraded with respect to nitrogen. About 50% of soils were highly to very highly degraded, 60% none to slightly degraded and only 10% were moderately degraded with respect to phosphorus, potassium and exchangeable sodium percentage (ESP) respectively. At land use 2, about 60% of soils were highly (15%) to very highly (45%) degraded in terms of nitrogen, 20% none to slightly degraded, 25% highly degraded and 55% very highly degraded with respect to phosphorus. In the case of potassium, 60% were none to slightly, 30% highly and 10% very highly degraded and only 10% were very highly degraded in terms of exchangeable sodium percentage (ESP) with the remaining 90% none to slightly degraded.

In the case of land use 3 soils, about 35% and 50% were none to slightly and very highly degraded respectively in terms of nitrogen and phosphorus. About 10% were moderately and 5% highly degraded with respect to nitrogen. About 5% of soils were moderately and 10% highly degraded in terms of phosphorus. For potassium, 50% of soils were none to slightly degraded, 15% moderately, 5% highly and 30% very highly degraded. Only about 15% were moderately degraded and the remaining 85% were none to slightly degraded with respect to exchangeable sodium percentage (ESP).

Biological Degradation

At land use 1, the soils were 15% none to slightly degraded, 15% moderately, 40% highly and 30% very highly degraded with respect to humus content, while at land use 2, only 5% of the soils were moderately, 50% highly and 45% very highly degraded. Only about 55% were very highly degraded with 20% highly, 15% moderately and 10% none to slightly degraded at land use 5.

The result of the rank correlation between the land use type and land degradation (Table 10-12) showed that correlation co-efficient was negative but

Table 10: Rank correlation coefficients between land use types, land type, land suitability and land degradation in land use type 1 (Cassava/Maize)

Tablica 10: Koeficijenti korelacije reda između tipova korištenja zemljišta, tipa zemljišta, prikladnosti zemljišta i degradacije zemljišta tipa korištenja 1 (kasava /kukuruz)

	LUT	Oil palm	Plantain	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	-	-0.218	a	-0.509*	a	-0.250	0.250	a	-0.179	0.391	-0.311	-0.688**	-0.378
Oil palm			a	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 11: Rank correlation coefficients between land use types, land type, land suitability and land degradation in land use type 2 (Oil Palm)

Tablica 11. Koeficijenti korelacije reda između tipova korištenja zemljišta, tipa zemljišta, prikladnosti zemljišta i degradacije zemljišta tipa korištenja 2 (uljana palma)

	LUT	Oil palm	Plantain	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
Oil palm			a	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 12: Rank correlation coefficients between land use types, land type, land suitability and land degradation in land use type 3 (Building Sites)

Tablica 12: Koeficijenti korelacije reda između tipova korištenja zemljišta, tipa zemljišta, prikladnosti zemljišta i degradacije zemljišta tipa korištenja 3 (gradilišta)

	LUT	Oil palm	Plantain	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
Oil palm			a	a	a	a	a	a	a	a	a	a	a
Plantain				a	a	a	a	a	a	a	a	a	a
Cassava					a	0.471*	-0.471*	a	-0.325	0.223	0.171	0.057	-0.139
Maize						a	a	a	a	a	a	a	a
B.D							0.061	a	-0.376	-0.147	-0.242	0.081	-0.336
Permeability								a	0.311	-0.248	-0.323	-0.015	0.163
B. Sat									a	a	a	a	a
N										-0.066	0.410	-0.415	0.886**
P											0.298	0.382	-0.177
K												-0.154	0.421
Esp													-0.490*
Organic matter content													-

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

statistically significant ($P < 0.01$) only in exchangeable sodium percentage and positive but not significant for some physical and chemical indicators. 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 type and degree of degradation found on the land are major factors to be considered in determining the appropriate approach to soil rehabilitation or improvement for agricultural uses. Chemical and biological degradation are a result of soil fertility depletion and organic matter decline through exploitative cropping which could be ameliorated through improved nutrient management (Eswaran and Dumanksi, 1998).

Physical degradation involves soil deterioration in-situ, which is a result of improper management practices and requires a long time to ameliorate (Hulugalle, 1994). Compacted or hard setting soils may be rehabilitated by appropriate tillage practices (Mullins et. al., 1990). Bush fallowing mechanisms go a long way to replenish organic matter and nutrient status of the soils (Johnson and Bradshaw, 1979).

It was observed that the land use types employed in 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 predisposing 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. These include plausible land use approach, multiple cropping, 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 capacity and constraints.

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