Nigerian Journal of Soil Science 23 (2013) 66 – 75

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

ASSESSMENT OF SOME SOIL QUALITY INDICATORS IN BENUE STATE

A.O. Adaikwu[1], and A. Ali[2]
Department of Soil Science, University of Agriculture,
P.M.B 2373, Makurdi, Benue State, Nigeria.
odigbo2011@yahoo.com

ABSTRACT

A study was carried out in 2009 to assess some soil quality indicators. These indicators include the soil pH, organic matter (OM) content, total nitrogen, available phosphorus, exchangeable cations, cation exchange capacity (CEC), saturated hydraulic conductivity and base saturation. The areas included SIWES farm, University of Agriculture Makurdi, Obarike in Oju, National Root Crops Research Institute (NRCRI) out station, Otobi, NYSC Farm, Guma, Adum in Obi Local Government Area and Odoba–Otukpa in Ogbadibo Local Government Area. The physical and chemical properties of these soils were evaluated in the laboratory and the results obtained were compared with their respective standard (Obi 2004). The textural composition of the soil ranged from loamy sand to sandy loam to clay loam. Saturated Hydraulic conductivity ranged from 0.31 to 0.74 cmh^{-1} corresponding to slowly and moderately permeable. The pH ranged from slightly to moderately acidic condition in some locations and strongly acidic in the eroded parts. The organic matter was very low in all the study areas. Available phosphorus was low in all the locations. Total nitrogen was predominantly very low in most of the cultivated areas to low in the fallow soils. Cation Exchange capacity (CEC) also ranged from very low to low. It is recommended that soil conservation practice should be intensified in these areas. The practice should include the use of organic manure such as cow dung and poultry droppings for the fertilization of the fragile low fertility soils. There should also be a programme for monitoring the fertility status of the soil at least every five years from the time the soil is first cultivated.

INTRODUCTION

A significant decline in soil quality has occurred worldwide through adverse changes in its physical, chemical and biological properties and contamination by inorganic and organic chemicals, therefore maintenance of soil quality is critical to environmental sustainability. Knowledge and assessment of changes (positive or negative) in the status of the soil is needed with time to evaluate the impact of different management practices.

Many definitions of soil quality have been proposed in the last 10 years (Arshad and Coen, 1992; Doran and Parkin, 1994; Karlen *et al.*, 1997) with similar elements. The most recent, proposed by Karlen and a committee for the Soil Science Society of America is as follows: “the fitness of a specific kind of soil, to function within its capacity and within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation”.

Selections of key indicators and their critical limits (threshold values), which must be maintained for normal functioning of the soil, are required to monitor changes and determine trends in improvement or deterioration in soil quality for various agro-ecological zones for use. Although, selection of soil indicators will vary with societal goals, the followings seem to be suitable indicators for crop production in most cases: soil pH, organic matter (OM) content, total nitrogen, available phosphorus, exchangeable cations, cation exchange capacity (CEC), saturated hydraulic conductivity and base saturation. In this study, these indicators were evaluated in the laboratory and the results interpreted using the interpretation guide for evaluating analytical data.

Objectives of the Study

The main objective was to assess the status of some soil quality indicators in selected areas of Benue State; it has the following specific objectives:

1. To conduct a reconnaissance survey of the selected study areas in Benue State so as to identify appropriate study sites.
2. To assess the status of these soil quality indicators in the study areas through laboratory evaluation.
3. To compare the results with interpretation guide for evaluating analytical data with a view to making modest recommendations on the rehabilitation and proper management of degraded soils.

MATERIALS AND METHODS

The Study Area

The study areas are in Benue state. Benue falls within latitudes $6^{o}20N$ to $7^{o}55N$ and longitudes $7^{o}30E$ and $9^{o}40E$. It shares boundaries with six other states of Nigeria, these include, Nassarawa to the north, Taraba and Cross River to the south, Enugu and Ebonyi to the South East and Kogi to the West. It has a land area of about 30,955 square kilometers. The state is bounded on the north by 280km of River Benue and traversed by 202km of River Katsina-Ala in the Inland areas.

Study Sites

The followings areas were selected for the assessment:

i. NYSC Farm Nyiev Udei village in Guma LGA of the State;
ii. SIWES Farm University of Agricultural Makurdi;
iii. National Root Crop Research Institute NRCRI, outpost Otobi;
iv. Adum-Ito in Obi local Government Area;
v. Odoba–Otukpa near Audu Ogbe's Cashew plantation Ogbadibo Local Government Area;
vi. Obarike in Oju Local Government

Field Methods

At each of the study sites, an area of two hectares of land was chosen and bulk samples were collected and properly labeled. Also at each of these study sites, soil samples were collected from an adjacent soil at a distance of about 100m away. Samples were labeled as A and B respectively for such location. Samples labeled 'A' were from the cultivated areas while sample 'B' represented soils under fallow condition. The sampling covered 0 – 15 cm depths for the surface and 15-30 cm for the subsurface. Also a core sampler was used to collect soil samples for bulk density determination.

Laboratory Analysis

Particle Size Distribution was determined by the Bouyoucos hydrometer method, while the soil textures were determined using the USDA textural triangle. Bulk Density was determined using the core method. Saturated Hydraulic Conductivity was determined by the constant head method. The soil pH in water (1:1) and in KCl (1:1) were determined by electrometric method.

The wet oxidation method was used to determine the organic carbon content of the soil samples. Total Nitrogen was determined by the Macro-Kjeldahl digestion method. Cation Exchange Capacity (CEC) was determined by neutral, 1N Ammonium acetate method.

Bray-1 method was used to determine the extractable phosphorus. Calcium and Magnesium were determined by EDTA titration method . The EDTA extracts of Na and K were determined with flame photometer. Base Saturation was calculated by dividing the sum of exchangeable bases by CEC and multiplying by 100.

Results interpretation

The results of this study were interpreted using the interpretation guide for evaluating analytical data.

Table 1: Interpretation Guide for Evaluating Analytical Data

(a) Exchangeable Cations

Ca^{2+}	Mg^{2+}	K^{+}	Na^{+} (cmol/kg)	Class
< 2	< 0.3	< 0.2	<0.1	Very low
2 – 5	0.3 – 1	0.2 – 0.3	0.1 – 0.3	Low
5 – 10	1 – 3	0.3 – 0.6	0.3 – 0.7	Moderate
10 – 20	3 – 8	0.6 – 1.2	0.7 – 2	High
> 20	> 8	1.2 – 2	> 2	Very high

(b) Cation exchange capacity (CEC) (cmol/kg)

Range	Class
< 6	Very low
6 – 12	Low
12 – 25	Moderate
25 – 40	High
> 40	Very high

(c) Percentage base saturation (%)

Range %	Class
0 – 20	Very low
20 – 40	Low
40 – 60	Moderate
60 – 80	High
> 80	Very high

(d) Hydroulic conductivity (USDA SCS 1974)

Range (cm/hr)	Class
< 0.13	Very low
0.13 – 0.51	Slow
0.51 – 2.0	Moderate slow
2.0 – 6.3	Moderate
6.3 – 12.7	Moderately rapid
12.7 – 25.4	Rapid
> 25.4	Very rapid

(e) Organic matter rating and interpretation
Rating by Metson (1961)

Range (%)	Class
< 2	Very low
2 – 4	Low
4 – 10	Medium
10 – 20	High
> 20	Very high

(f) Soil pH Range	Rating
< 4.5	Extremely acid
4.5 – 5.0	Very strongly acid
5.1 – 5.5	Strongly acid
5.6 – 6.0	Moderately acid
6.1 – 6.5	Slightly acid
6.6 – 7.5	Neutral
7.4 – 7.8	Slightly alkaline
7.9 – 8.4	Moderately alkaline
8.5 – 9.0	Strongly alkaline
> 9.0	Very strongly alkaline

(g) Total Nigrogen
Rating by Metson (1961)

Range (%)	Class
< 0.1	Very low
0.1 – 0.2	Low
0.2 – 0.5	Medium
0.5 – 1.0	High
> 1.0	Very high

(h) Organic carbon

Range (%)	Class
< 0.4	Very low
0.4 – 1.0	Low
1.0 – 1.5	Moderate
1.5 – 2.0	High
> 2.0	Very high

(i) Available phosphorus
Rating by Enwezor *et al.* (1989)

Bray 1		Bray 2	
Range (ppm)	Class	Range (ppm)	Class
< 8	Low	15	Low
8 – 20	Medium	15 – 25	Medium
> 20	High	> 25	High

Source: Special Programme for Food Security, Fed. Ministry of Agric. and Rural Devpt. (SPFS FMARD) FAO (2004).

RESULTS AND DISCUSSION

Physical Properties of the Soils in the Study Areas

The physical properties of the soils in the six study areas are shown in Table 1. The textural composition of the SIWES Farm indicates loamy sand in the cultivated area (A) and sandy loam for the fallow soil (B). The soil bulk density (BD) ranges from 1.44–1.46 gcm^{-3} for the surface and subsurface at A and 1.52-1.56 gcm^{-3} at B. The higher BD in the fallow soil compared with the cultivated soil agrees with the findings of, Ike (1986) who reported higher BD under untilled soil compared with the cultivated soil. The saturated hydraulic conductivity Ksat indicated moderately slow permeability having values between 0.62–0.65 $cmhr^{-1}$ at A and 0.53 – 0.57 cmhr-1 at B.

In Oju, the textural compositions indicate clay loam texture in the cultivated part (A) and loam in the fallow (B). The bulk density (BD) averaged 1.97 gcm^{-3} at A and 1.72 gcm^{-3} in the fallow soil B. Ksat was between 0.31 – 0.33 $cmhr^{-1}$ at A and 0.51- 0.53 $cmhr^{-1}$ at B indicating slow and moderately slow permeability at A and at B, respectively.

Table 1: Physical properties of the soils of the study areas

Location	Depth (cm)	Bulk Density (gcm^{-3})	Total Porosity (%)	Sat. Hydr Condc. (cmhr)	Sand (%)	Silt (%)	Clay (%)	Textural Class
SIWES	0-15A	1.44	46	0.62	88	10	2	Loamysand
Farm	15-30A	1.46	45	0.65	86	12	2	Loamysand
	0-15B	1.52	43	0.53	80	12	8	Sandyloam
	15-30B	1.56	41	0.57	78	14	8	Sandyloam
Oju	0-15A	1.85	30	0.31	46	18	36	Clayloam
	15-30A	1.97	26	0.33	44	18	38	Clayloam
	0-15B	1.69	36	0.51	58	20	22	Loam
	15-30B	1.74	36	0.53	58	20	22	Loam
Otobi	0-15A	1.54	42	0.58	78	15	7	Sandyloam
	15-30A	1.49	44	0.58	76	13	11	Sandyloam
	0-15B	1.64	38	0.58	61	19	20	Sandyloam
	15-30B	1.64	38	0.57	60	16	24	Loam
NYSC	0-15A	1.36	49	0.59	61	21	18	Loam
	15-30A	1.36	48	0.55	57	21	22	Loam
	0-15B	1.48	44	0.55	57	16	27	Loam
	15-30B	1.5	43	0.57	55	16	29	Loam
Adum	0-15A	1.28	52	0.79	85	12	3	Loamysand
	15-30A	1.33	50	0.74	85	8	7	Loamysand
	0-15B	1.54	42	0.65	69	14	17	Sandyloam
	15-30B	1.51	38	0.60	65	14	21	Sandyloam
Otukpa	0-15A	1.45	46	0.74	85	12	3	Loamysand
	15-30A	1.46	45	0.69	85	12	3	Loamysand
	0-15B	1.58	40	0.58	69	18	12	Sandyloam
	15-30B	1.60	40	0.55	67	20	13	Sandyloam

Soil pH

The results in Table 2 compared with the standard in Table 2 f indicate that all the soils were in the pH range of 5.06 in topsoils at Otobi to 6.50 in subsurface layers at SIWES farm. The soils in SIWES farm were slightly acidic at both the cultivated and uncultivated areas. At Oju, the pH range indicates strongly acidic to moderately acid condition for the soils of the cultivated (A) and fallow sites (B), respectively. At Otobi the soils were strongly acidic to moderately acidic in the cultivated and the fallow soils. In NYSC farm, the cultivated soil was moderately acidic while the uncultivated indicated slightly acidic condition. At Adum-Ito the soils were strongly acidic and slightly acidic for soils at A and at B respectively. At Otukpa, the range was from strongly to slightly acid condition. The strongly acid condition as found in the eroded part of Adum–Ito and Otukpa may be attributed to the loss of exchangeable cations (Ca^{2+} K^{+}, Mg^{2+} and Na^{+}), through surface run off and leaching. Soil acidity is known to affect most soil nutrients especially P,N,S and other micronutrients (Agbede, 2009).

Soil organic matter (OM) content

The results of organic matter content in table 3 in all the locations were very low. The very low organic matter contents are indicative of very high biological degradation of all the soils of the study areas, that is, both the cultivated and the fallow soils. Also, the low OM content is a phenomenon associated with the savanna soils, which could be due to high temperatures that rapidly break down OM and inhibit nitrogen fixation by rhizo-bacteria, (Harpstead, 1973). Agbede (2009) recommended that incorporated crop residue must be of high quality, that is, must have C/N ratio of below 20/1. Leguminous plants provide such high quality residues.

Table 2: pH Rating of the Soils of the Study Sites

S/N	Locations		pH Value (H_20)	*pH Range	*Rating
1.	SIWES Farm	A	6.08 – 6.13	6.1 – 6.5	Slightly acid
		B	6.20 – 6.50	6.1 – 6.5	Slightly acid
2.	Obarike	A	5.23 – 5.43	5.1 – 5.5	Strongly acid
	Oju	B	5.54 – 5.60	5.6-6.0	Moderately acid
3.	Otobi	A	5.06 - 5.65	5.1 – 5.65	Strongly- moderate acid
		B	5.37 – 5.77	5.1 – 5.77	Strongly- moderately acid
4	NYSC farm	A	5.6-5.78	5.60-6.0	moderately acid
		B	6.0 – 6.20	6.1 – 6.50	slightly acid
5.	Adum	A	5.30 – 5.50	5.1 – 5.5	Strongly acidic
	Ito	B	6.29 – 6.44	6.1 – 6.5	Slightly acidic
6.	Otukpa	A	5.10 – 5.30	5.1 – 5.5	Strongly acid
		B	6.20 – 6.44	6.1 – 6.5	Slightly acid

***(**USDA-SCS 1974**)**

A-cultivated soils, B-fallow soils

Table 3: Organic Matter rating of the soils of the study sites: Total Nitrogen Rating of. the Soil of Study

Locations		O.M Value (%)	*range	*rating	N value (%)	*ratings	*Class
SIWES Farm	A	0.67	<2	very low	0.08	<0.1	Very low
	B	1.15	<2	very low	0.13	0.1-0.2	Low
ObarikeA		1.31	<2	very low	0.12	0.1-0.2	Low
Oju	B	1.47	<2	very low	0.13	0.1-0.2	Low
Otobi	A	0.91	<2	very low	0.08	<0.1	Very low
	B	1.74	<2	very low	0.13	0.1-0.2	Low
NYSC Farm	A	1.19	<2	very low	0.08	<0.1	Very low
	B	1.72	<2	very low	0.13	0.3-0.2	Low
Adum	A	0.80	<2	very low	0.10	0.1-0.2	Low
Ito	B	1.53	<2	very low	0.14	0.1-0.2	Low
Otukpa	A	0.71	<2	very low	0.09	<0.1	Very low
	B	1.52	<2	very low	0.13	0.1-0.2	Low

*(Obi, 2004)
A – Cultivated soil, B – Fallow soils
OM – Organic Matter

Soil total nitrogen content

The result in Table 3 indicated that nitrogen rated very low in the cultivated soil and low in the uncultivated soil of the SIWES farm. At Obarike- Oju both the uncultivated and the cultivated soils were rated low. At Otobi the nitrogen content of the surface and sub-surface depth zones of the cultivated soils rated very low while for the fallow soil they were low. The soils in NYSC farm and Otukpa showed a similar trend of nitrogen content. The Adum-Ito soils had low nitrogen content at both the cultivated and the uncultivated sites. Nitrogen as a soil quality indicator is one of the key nutrients in plant growth. Agbede (2009) listed nitrogen as the most important of all the 16 essential plant elements needed for plant growth, development and reproduction and also the most easily limiting or deficient throughout the world especially in the tropics. Nitrogen as a mobile element can easily be lost.

Cation exchange capacity (CEC) of the soils

The ratings for the cation exchange capacity (CEC) in all the locations are shown in Table 5. CEC was low at both the SIWES farm and Obarike-Oju site. In Otobi, the cultivated site was very low while the uncultivated area was considered low. The NYSC farm, Adum-Ito and Otukpa both indicated very low to low CEC in the cultivated/eroded as well as the fallow soils. The low CEC may be highly related to the low organic matter (OM) content.

Available phosphorous

Table 5 shows the rating of available phosphorus in all the study areas as compared with the standard (Table 1i). The soils were all low. The values obtained were below 8 ppm.

Exchangeable cations

The exchangeable cations are presented in Table 6. Calcium was low in both the cultivated and uncultivated sites of the SIWES farm (A and B). The magnesium content ranged from low to moderate. The potassium content was low and sodium ranged from low to moderate. In Obarike-Oju calcium was low and magnesium was low to moderate, Potassium was low and sodium was moderate to high. The soils at Otobi showed low calcium content, low to moderate magnesium, very low to low potassium and moderate sodium content. For the NYSC farm calcium was low whereas mean magnesium content was moderate. Potassium contents were very

low to low and sodium values were low to moderate. At Adum-Ito the calcium level was very low to low

The magnesium content was rated low to moderate whereas potassium and sodium were very low to low and low to moderate respectively.

Base saturation

The base saturation rated moderately low to high from the fallow to the cultivated sites in SIWES farm, moderate in Oju and moderate to high at Otobi. Also the NYSC farm indicated high base saturation at both sites A and B, while it was moderate to high for cultivated (A) and fallow (B) soils in Adum-Ito. The Otukpa soils indicated high base saturation at the both sites (Table 7).

Saturated hydraulic conductivity (Ksat.)

Table 7 shows the K_{sat} values. The soils of the study sites showed moderately slow permeabilities. The soils of Oju had slow permeability.

Table 5: Cation Exchange capacity Phosphorus (CEC) Rating of The study sites

Available Phosphorus Rating of the soils of study sites

Locations		CEC Value	*rating	*class	Value (ppm)	*range (ppm)	*Class
SIWES Farm	A	6.24-6.92	6-12	low	4.4-4.8	<8	Low
	B	7.76-7.92	6-12	low	4.46-4.56	<8	Low
Obarike	A	8.56-9.20	6-12	low	4.50-4.58	<8	Low
Oju	B	8.32-9.52	6-12	low	4.30-5.56	<8	Low
Otobi	A	5.20-5.80	<6	very low	4.46-4.48	<8	Low
	B	7.60-8.16	6-12	low	4.48-4.52	<8	Low
NYSC Farm	A	6.00-6.12	6-12	low	4.00-4.48	<8	Low
	B	7.76-8.12	6-12	low	4.52-4.56	<8	Low
Adum	A	4.20-5.00	<6	very low	4.00-4.48	<8	Low
Ito	B	8.20-9.20	6-12	low	4.42-4.48	<8	Low
Otukpa	A	4.00-4.15	<6	very low	4.46-4.48	<8	Low
	B	7.49-7.60	6-12	low	4.50-4.52	<8	Low

*(Obi, 2004)

A – Cultivated soil, B – Fallow soils

Table 6: Exchangeable cation rating for the soils of the study sites

Loc/Range			Ca	Mg	K	Na
1.*	Range		2-5	0.3 – 1.32	<0.2	0.1 – 0.4
	SIWES Farm	A	2-8 – 2.96	0.74 – 0.96	0.1 – 0.13	0.35 – 0.40
		B	3.00 – 3.18	0.98 – 1.32	0.16 – 0.17	0.23 – 0.28
Class* A & B	**Low**		**Low – mod.**	**A & B low**	**Low-mod.**	
2.*	Range		2-5	0.3 – 1.04	0.2 – 0.3	0.7 – 0.84
	Obarike A		2.98 – 3.20	0.82 – 1.00	0.21 – 0.23	0.84 – 0.88
	Oju	B	3.04 – 3.36	0.86 – 1.04	0.24 – 0.27	0.71 – 0.73
Class*	**Low**		**Low – mod.**	**Low**	**Mod.-High**	
3.*	Range		2-5	0.3 – 1.44	0.2 – 0.3	0.3 – 0.7
	Otobi	A	2.66 – 3.00	1.20 – 1.44	0.22 – 0.23	0.40 – 0.48
		B	1.84 – 2.12	0.48 – 0.62	0.05 – 0.09	0.36 – 0.38
Class*	**Low**		**Low – mod.**	**V. Low-low**	**Mod.**	
4.*	Range		2-5	1 – 3	0.1 – 0.22	0.1 – 0.3
	NYSC farm	A	2.50 – 2.88	1.18 – 1.44	0.08 – 0.10	0.22 – 0.26
		B	3.52 – 3.74	1.18 – 1.44	0.22 – 0.24	0.19 – 0.30
Class*			**Low**	**Mod**	**V. low-low**	**Low-mod**
5.*	Range		2-5	0.3 – 3	0.06 – 2.0	0.23 – 0.42
	Adum	A	1.48 – 1.64	0.4 – 0.5	0.06 – 0.09	0.36 – 0.42
	Ito	B	3.58 – 3.60	1.08 – 1.62	0.19 – 0.20	0.23 – 0.28
Class*			**V. Low-low**	**Low-mod**	**Very low-low**	**Low-mod**
6.*	Range		1 – 5	0.52 – 1.2	0.1 – 0.3	0.2 – 0.7
	Otukpa	A	1.60 – 1.86	0.52 – 0.6	0.10 – 0.11	0.26 – 0.32
		B	3.30 – 3.38	0.98 – 1.20	8 – 0.61	0.20 – 0.25
Class*			**V. Low-low**	**Low-mod**	**Very low-low**	**Low-mod**

***Source:** (Obi, 2004). **A**-cultivated soils, B-fallow soils

Table 7: Base Saturation Rating of the soils of the study sites

Hydraulic Conductivity (K_{SAT}) Soils of the Study Sites

Locations		Bs value (%)	* range	* class	K_{sat} Value	*range	*class
1. SIWES farm	A	64	60 – 80	High	0.62-0.65	0.51-2.0	Mod. slow
	B	56 – 63	40 – 60	Moderate	0.53-0.57	0.51-2.0	Mod. slow
2. Obarike	A	57 – 58	40 – 60	Moderate	0.31-0.33	0.13-0.51	Slow
Oju	B	56 – 59	40 – 60	Moderate	0.51-0.53	0.13-0.51	Mod. slow
3. Otobi A		59 – 63	50 – 63	Mod-high	0.57-0.58	0.51-2.0	Mod. slow
	B	52 – 53	40 – 60	Moderate	0.58-0.58	0.51-2.0	Mod. slow
4. NYSC farm	A	70 – 77	60 – 80	High	0.55-0.59	0.51-2.0	Mod. slow
	B	66 – 70	60 – 80	High	0.55-0.57	0.51-2.0	Mod. low
5. Adum A		53 – 55	40 – 60	Moderate	0.74-0.79	0.51-2.0	Mod. slow
Ito	B	62	60 - 80	High	0.60-0.65	0.51-2.0	Mod. slow
6. Otukpa	A	67 – 70	60 – 80	High	0.69-0.74	0.51-2.0	Mod. slow
	B	68 - 70	60 – 80	High	0.55-0.58	0.51-2.0	Mod. slow

*(Obi, 2004)

A-cultivated soils, B-fallow soils, Bs-Base saturation.

CONCLUSIONS

An investigation was conducted in 2009 to assess some soil quality indicators for crop production. These indicators include soil pH, Organic matter, total Nitrogen, CEC, exchangeable cations, available phosphorus, hydraulic conductivity and base saturation. The main objective was to assess the status of these soil quality indicators through laboratory evaluation and to compare the result with interpretation guide for evaluating analytical data.

Most of these indicators were found to range from very low to low, while others ranged from low to moderate. In the cultivated part of the study areas, most of the indicators were below the thresh hold limit for crop production. This is an indication that the soils in such areas have been over used.

RECOMMENDATIONS

Base on the findings of this study the following recommendations are made;

1. The application of mineral fertilizer nutrients especially nitrogen, phosphorus, and potassium is necessary.
2. The use of organic manure such as cow dung and poultry dropping is recommended to improve the productivity of these degraded soils. Also farmers are encouraged to leave crop residue on their farms and incorporate same during tillage rather than burning them.
3. The Portions of the SIWES farm, NYSC farm and the site at Otobi that had been used continuously for cultivation for quite some time should be allowed to fallow, as the higher degree of degradation observed may be due to their prolonged use.
4. There should be a programme for monitoring the fertility status of the soils at regular intervals.

REFERENCE

Agbede, O.O. (2009). Understanding Soil and Plant Nutrition. 1st Edition, Keffi-Nasarawa State, Salman Press & Co. Nigeria Ltd. 260pp.

Arshad, M.A., Coen, G.M., 1992. Characterization of soil quality: physical and chemical criteria. Am. J. Alternative Agric. 7,12–16.

Doran, J.W., Parkin, T.B., 1994. Defining and assessing soil quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B. A.(Eds.), Defining Soil Quality for a Sustainable Environment, Madison, WI. Soil Sci. Soc. Am. 35, 3–21(special publication).

Harpstead, M.T. (1973). The classification of some Nigerian soils. Soil Science. 116:437 – 442.

Ike, I.F. (1986). Soil and crop responses to different tillage practices in a ferruginous soils in the Nigeria savanna. Soil and Tillage Res. 6:261 – 272.

Karlen, D.L., Mausbach, M.J., Doran, J.W., Kline, R.G., Harris, R.F., Schuman, G.E., 1997. Soil quality: a concept, definition ,and framework for evaluation. Soil Sci. Soc. Am. J. 61, 4–10.