



Assessment of land degradation status of three forest reserves under teak and gmelina plantation in South-West Nigeria

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ABSTRACT

This study assessed the degradation status of the three forest reserves along a toposequence under exotics plantation of *Gmelina arborea* and *Tectona grandis* with the aim of evaluating the deterioration level of the soil productivity in respect to human disturbance. Surface samples at depths of 0 - 15 cm and 15 - 30 cm were collected and soil laboratory analysis carried out to determine the soil properties of each site. Direct approach method was used to assess soil degradation status of these soils. The direct approach method showed that the soils at the three locations, both under teak and Gmelina plantation were seriously degraded physically, chemically and biologically. Onigambari were more degraded physically, chemically and biologically than other two locations with higher degradation in the upper slope segment. The type and degree of degradation observed on the two land use types across the locations are major factors to be considered in determining the suitable approach to soil improvement for sustainable management and production of timbers and non-wood products in our plantations.

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1.0. Introduction

Land degradation indicates temporary or permanent long-term decline in the function and productive capacity of an ecosystem. It is refer to the weakening or deterioration in health of terrestrial ecosystems, thus affecting the associated biodiversity, natural ecological processes and ecosystem pliability or resilience. It also considers the reduction or loss of biological, economic productivity and complexity of croplands, pasture, woodland, forest, etc. Across the world, over 20% of cultivated areas, 30% of forests and 10% of grasslands are suffering from degradation, affecting about 1.5 billion people. (Aruleba, 2004; Senjobi, 2007).

Understanding the changes and magnitude of the deterioration of the soil under exotic tree species plantation resulting from exploitation may provide a template for the sustainable management of the resource base of the eco-

system (Eswaran *et al.*, 2001).

Turner *et al.* (1990) observed that the demand for forest resources will continue to increase as long as they remain the basis for development with severe consequence on environment resources and development. Development of sustainable agricultural systems such as alley farming is an attempt to reduce degradation of natural resources caused by deforestation and to find environmentally compatible ways of increasing and promoting agricultural production and development. This has not been given topmost priority especially in Southern Nigeria.

This study was therefore designed to assess the changes and the status of degradation in the soil characteristics under teak and Gmelina plantations in three forest areas in a tropical environment of South-West Nigeria.

2.0. Materials and Methods

This study was carried out at the forest Reserves in Ogun, Osun and Oyo States. The forest reserves include: Omo Forest Reserve (Area J4), Osun sacred grove and Onigambari Forest Reserves, all in the South-West Nigeria. Osun Sacred Grove is located approximately between latitudes 7°44'50.0" - 7°46'00.0" N and longitudes 4°32'40"-4°33'40" E. Onigambari Forest Reserve is located between latitude 7°26'N and longitude 3°51'E. Omo Forest Reserve situate between latitudes 6° 35' to 7° 05' N and 4° 19' to 4° 40' E (Figure 1). The rainfall regime is double – peak, and the mean annual rainfall of the three locations falls between the ranges 1250 mm and 1,600 mm per annum. The mean annual temperature ranges between 21°C and 28°C. They are formed from basement complex rock, although different parent material (Alabi et al., 2017).

2.1. Field Survey

Field sampling was conducted between October, 2013 and March, 2014 using rigid-grid sampling to cover the forest reserves, this was done in order to cover the major soil series in the three studied areas using Smyth and Montgomery (1962). At each study site (Osun sacred grove, Onigambari and Omo forest reserves). Three profile pits (2 m × 1.5 m × 2 m) were dug on each land use (Teak and Gmelina plantation) totalling eighteen profiles in all locations following the establishment of the model soil profile pits for each soil unit. The profile pits have varying depth and were described using the guidelines of FAO (2006). Sampling of each profile was carried out according to the pedogenic horizons. Twenty-four (24) surface soil samples (comprising of 0-15 cm surface and 15-30 cm sub-surface soil samples) and core surface and sub-surface samples were also sampled for laboratory analysis.

2.2. Laboratory Analysis

Collected soil samples were air dried, sieved using 2mm sieve. The sieved soil samples were used for the laboratory determination of the soil properties. The Bulk density was determined using the core method (Anderson and Ingram, 1993). The total porosity of the soils was estimated from the bulk density (BD) of the soil by assuming that the particle density (PD) of the soil was 2.65 gcm⁻³. Saturated hydraulic conductivity was determined by constant head method as described by Reynolds (2002). Particle size analysis was determined using the hydrometer method (Bouyoucos, 1962). Soil pH determined electrometrically in 1:1 soil water suspension (IITA, 1982) and in 1N KCl solution. Total soil organic carbon was determined using acid dichromate wet-oxidation procedure of Walkley and Black method (1934). Total Nitrogen was determined using Kjeldahl digestion method as described by Bremner (1982). The effective cation Exchange capacity (ECEC) was determined by the summation of the exchangeable bases (Ca, Mg, Na and K) and exchangeable acidity. Micro nutrients were determined by Atomic Absorption Spectrophotometer (AAS).

2.3. Land Degradation Assessment

The assessment of the degradation status of the soils of each study area was done using direct Approach method according to FAO (1979) and Snakin *et al.*, (1996). In this method, the surface samples were taken at depth 0 – 15 cm and 15 – 30 cm at two points across the toposequence with the samples subjected to analyses and the result were placed in degradation classes by matching soil characteristics with land degradation indicators. This is used to estimate the degree of degradation that must have taken place on the land with emphasis on the identified physical, chemical and biological parameters (Tables 1, 2 and 3) (Lal, 2001).

Table 1: Indicators and Criteria of Physical degradation of Soil

	*Degree of degradation (%)				
	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), Snakin *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

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 (cmolk ⁻¹)	>0.16	0.14 -0.16	0.12 – 0.14	<0.12
Content of Readily soluble Salt (Increase by %)	<0.20	0.20 – 0.40	0.40 – 0.80	4
Content of ESP (Increase by % of CEO)	<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)	<2	2 – 3	3 – 5	>5
mmho/cm /yr				

Sources: FAO (1979), Snakin *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: Indicator and Criteria of Biological Degradation of Soil

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

Sources: FAO (1979).

Where 1= none to slight degraded soils

2= moderately degraded soils

3= highly degraded soils

4= Very highly degraded soils

Results and Discussion

3.1. Direct Method of Land Degradation Assessment

The physical properties of surface samples collected (Table 4 - 6) and the chemical properties of the surface samples collected from each location of study areas (Table 7 - 9) were used for grouping of lands into different degradation classes were given in Table 10-12, while the matching of soil properties therein with the soil indicator and criteria (Table 1-3) produced the various degradation classes for the three locations under study. The aggregate scores for the degree of degradation classification at Osun sacred grove, Onigambari and Omo forest reserves were given in Table 10-12.

3.2. Physical Degradation

Across the toposequence, at the upper slope, middle slope, and lower slope, under teak plantation at Osun sacred grove, 33.3% of soils was none to slight degraded and 66.6% were moderately degraded in terms of bulk density and hydraulic conductivity follows the same trend while under Gmelina, in terms of bulk density, 66.67% of soils were none to slight degraded while 33.33% were moderately degraded. In terms of hydraulic conductivity, 66.67% of soils were none to slight degraded and 33.33% are moderately degraded.

Meanwhile, at Onigambari forest reserve, under teak plantation, 50% soils were moderately degraded in terms of

bulk density while in terms of hydraulic conductivity (Ksat), 41.67% were none to slight degraded and 58.33% were moderately degraded and under Gmelina 16.7% of soils were none to slight degraded and 83.3% are moderately degraded in terms of bulk density and in terms of Ksat, 8.33% were none to slight degraded and 91.67% were moderately degraded.

However, at Omo forest reserve, Area J4, under teak plantation, 25% of the soils were none to slight degraded and 75% were moderately degraded with respect to bulk density whereas, in term of hydraulic conductivity, 16.67% of the soils were none to slight degraded and 83.33% were moderately degraded. Meanwhile, under Gmelina plantation 66.67% of the soils were none to slight degraded and 33.33% were moderately degraded in terms of bulk density with hydraulic conductivity follows the same trend.

3.3. Chemical Degradation

Chemical degradation using direct approach showed that at Osun sacred grove, under teak plantation, 16.67% were none to slight to slight, 50% moderately, 25% highly degraded, 8.33% were very highly degraded with respect to Nitrogen. About 16.67% soils were none to slight degraded while 83.33% moderately degraded with regards to available phosphorus. While under Gmelina, about 16.67% soils were none to slight degraded, 25% moderately degraded, 8.33% highly degraded and 50% soils were

Table 4: Physical properties of surface sample at Osun sacred grove

Sample	Point	Depth (cm)	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Gravel (g/kg)	Bulk density g/cm ³	Total porosity (%)	EC (dS/m)
UPTOGR	1	0-15	710	148	142	SL	2935	1.50	43.58	2
UPTOGR	1	15-30	770	88	142	SL	5085	1.51	43.21	1
UPTOGR	2	0-15	830	08	162	SL	4715	1.32	50.38	2
UPTOGR	2	15-30	750	108	142	SL	3666	1.50	43.58	1
UPGOGR	1	0-15	770	88	142	SL	650	1.61	39.43	1
UPGOGR	1	15-30	750	68	182	SL	952	1.17	56.04	1
UPGOGR	2	0-15	770	88	142	SL	475	1.51	43.21	2
UPGOGR	2	15-30	730	68	202	SCL	1570	1.06	60	1
MDTOGR	1	0-15	770	128	102	SL	590	2.16	18.68	2
MDTOGR	1	15-30	730	68	202	SCL	1914	1.06	60.00	5
MDTOGR	2	0-15	750	128	122	SL	940	1.77	33.21	1
MDTOGR	2	15-30	750	68	182	SL	1289	1.17	56.04	1
MDGOGR	1	0-15	750	88	162	SL	797	1.31	50.56	2
MDGOGR	1	15-30	750	88	162	SL	804	1.31	50.56	1
MDGOGR	2	0-15	770	48	182	SL	1188	1.17	56.04	1
MDGOGR	2	15-30	710	108	182	SL	865	1.17	56.04	1
LSTOGR	1	0-15	790	88	122	SL	550	1.78	32.83	1
LSTOGR	1	15-30	730	88	182	SL	615	1.17	56.04	1
LSTOGR	2	0-15	810	48	142	SL	690	1.52	42.83	4
LSTOGR	2	15-30	730	128	142	SL	440	1.50	43.58	1
LSGOGR	1	0-15	670	188	142	SL	2601	1.50	43.58	1
LSGOGR	1	15-30	750	68	182	SL	2725	1.17	56.04	1
LSGOGR	2	0-15	790	68	142	SL	1870	1.51	43.21	1
LSGOGR	2	15-30	790	48	162	SL	2989	1.31	50.75	1

Table 5: Physical properties of surface sample at Onigambari forest reserve

Sample	Point	Depth (cm)	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Gravel (g/kg)	Bulk density g/cm ³	Total porosity (%)	EC (dS/m)
UPTOGB	1	0-15	790	68	142	SL	1684	1.51	43.21	4
UPTOGB	1	15-30	730	88	182	SL	3583	1.17	56.03	4
UPTOGB	2	0-15	790	58	152	SL	1665	1.4	47.17	1
UPTOGB	2	15-30	830	08	162	SL	1605	1.32	50.38	1
UPGOGB	1	0-15	790	68	142	SL	4215	1.51	43.21	2
UPGOGB	1	15-30	730	128	142	SL	7005	1.50	43.58	2
UPGOGB	2	0-15	730	148	122	SL	2317	1.76	33.58	2
UPGOGB	2	15-30	810	38	152	SL	5645	1.41	46.98	2
MDTOGB	1	0-15	750	68	182	SL	2795	1.17	59.04	3
MDTOGB	1	15-30	750	88	162	SL	4527.5	1.31	50.57	2
MDTOGB	2	0-15	850	18	132	SL	883	1.66	37.55	2
MDTOGB	2	15-30	790	68	142	SL	1415	1.51	43.21	4
MDGOGB	1	0-15	770	108	122	SL	2225	1.78	33.02	2
MDGOGB	1	15-30	790	88	122	SL	3175	1.78	32.83	2
MDGOGB	2	0-15	850	18	132	LS	396	1.66	37.55	2
MDGOGB	2	15-30	750	88	162	SL	518	1.31	50.57	2
LSTOGB	1	0-15	810	68	122	SL	2620	1.79	32.26	1
LSTOGB	1	15-30	790	88	122	SL	2540	1.17	56.04	2
LSTOGB	2	0-15	850	18	132	SL	583	1.78	32.83	2
LSTOGB	2	15-30	750	88	162	SL	410	1.51	43.21	1
LSGOGB	1	0-15	810	48	142	SL	3120	1.52	42.83	3
LSGOGB	1	15-30	730	148	122	SL	5370	1.76	33.58	3
LSGOGB	2	0-15	830	68	102	LS	2265	2.22	16.23	2
LSGOGB	2	15-30	770	88	142	SL	2325	1.51	43.21	2

Table 6: Physical properties of surface sample at Omo forest reserve, area J4

Sample	Point	Depth (cm)	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Gravel (g/kg)	Bulk density g/cm ³	Total porosity (%)	EC (dS/m)
UPTOFR	1	0-15	830	48	122	LS	4141	1.81	31.89	4
UPTOFR	1	15-30	710	88	202	SCL	4615	1.07	59.81	2
UPTOFR	2	0-15	830	48	122	LS	3760	1.81	31.89	8
UPTOFR	2	15-30	730	108	162	SCL	5077	1.31	50.75	4
UPGOFR	1	0-15	850	08	142	LS	2940	1.53	42.45	2
UPGOFR	1	15-30	710	88	202	SCL	4828	1.07	59.81	2
UPGOFR	2	0-15	810	68	122	SL	3691	1.80	32.26	2
UPGOFR	2	15-30	790	68	142	SL	5763	1.51	43.21	1
MDTOFR	1	0-15	830	38	132	SL	2780	1.65	37.84	2
MDTOFR	1	15-30	750	108	142	SL	5974	1.50	43.58	1
MDTOFR	2	0-15	850	08	142	LS	3525	1.53	42.45	2
MDTOFR	2	15-30	890	08	102	LS	6040	2.30	13.21	2
MDGOFR	1	0-15	810	48	142	SL	2745	1.52	42.83	2
MDGOFR	1	15-30	730	88	182	SL	3450	1.17	56.04	2
MDGOFR	2	0-15	750	88	162	SL	3335	1.31	50.57	2
MDGOFR	2	15-30	750	88	162	SL	4265	1.31	50.57	1
LSTOFR	1	0-15	830	68	102	LS	2419.5	2.22	16.23	2
LSTOFR	1	15-30	810	68	122	SL	3673	1.80	32.26	2
LSTOFR	2	0-15	830	38	132	SL	2078	1.65	37.74	2
LSTOFR	2	15-30	770	78	152	SL	4316	1.40	47.17	2
LSGOFR	1	0-15	710	108	182	SL	2145	1.17	56.04	2
LSGOFR	1	15-30	690	68	242	SCL	2235	0.93	65.09	2
LSGOFR	2	0-15	770	68	162	SL	2860	1.31	50.57	2
LSGOFR	2	15-30	790	28	182	SL	3590	1.17	56.04	3

Table 7: Chemical properties of soil samples at Osun sacred grove

Sample	Point	Depth (cm)	pH (H ₂ O)	pH (Kcl)	OM %	OC %	N %	P mg/kg	K ⁺ (cmol/kg)	Ca 2 ⁺ (cmol/kg)	Mg 2 ⁺ (cmol/kg)	Na ⁺ (cmol/kg)	CDR	Silica %	H ⁺ (cmol/kg)	EC _{EC} (cmol/kg)	B.S %	B (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)
UPTOGR	1	0-15	7.5	5.38	2.41	1.40	0.15	14.79	0.53	3.31	3.89	0.61	5.79	63.79	0.80	9.14	98.8	0.53	86.01	30.22	34.99
UPTOGR	1	15-30	6.9	5.29	2.04	1.19	0.13	12.55	0.43	2.80	4.84	0.52	4.90	63.79	0.85	9.44	98.15	0.45	73.01	24.58	43.21
UPTOGR	2	0-15	7.2	5.41	1.96	1.14	0.12	12.02	0.41	2.69	3.57	0.49	5.79	54.99	0.10	7.26	98.15	0.43	69.92	31.03	43.10
UPTOGR	2	15-30	6.9	4.39	1.19	0.69	0.07	7.3	0.25	1.63	3.05	0.3	6.48	57.3	0.10	5.33	96.05	0.26	42.43	27.84	30.89
UPGOGR	1	0-15	7	4.27	0.77	0.45	0.05	4.75	0.17	1.06	2.34	0.2	6.87	59.39	0.12	3.89	94.49	0.17	27.62	24.47	17.39
UPGOGR	1	15-30	6	4.50	2.25	1.31	0.14	13.85	0.48	3.09	2.25	0.57	5.79	55.87	0.10	6.49	98.26	0.5	80.55	26.67	25.90
UPGOGR	2	0-15	6.4	4.61	2.30	1.34	0.14	14.14	0.48	3.16	4.55	0.58	7.50	62.91	0.11	8.88	98.12	0.5	82.23	26.23	20.46
UPGOGR	2	15-30	6.9	4.72	2.13	1.24	0.13	13.1	0.45	2.93	6.94	0.54	5.79	62.03	0.12	10.98	97.94	0.47	76.17	26.54	17.94
MDTOG _R	1	0-15	6.2	5.07	1.42	0.83	0.09	8.71	0.30	1.95	3.88	0.36	6.43	62.91	0.11	6.6	97.04	0.31	50.64	24.48	15.27
MDTOG _R	1	15-30	6.6	5.16	2.12	1.23	0.13	13.03	0.45	2.91	7.00	0.54	5.79	59.39	0.11	11.01	98.09	0.47	75.78	23.92	16.36
MDTOG _R	2	0-15	6.2	4.34	2.20	1.28	0.14	13.48	0.46	3.01	3.20	0.55	7.34	59.39	0.12	7.34	97.98	0.48	78.37	27.6	19.59
MDTOG _R	2	15-30	5.4	4.56	2.04	1.19	0.12	12.56	0.43	2.81	5.11	0.51	5.76	57.63	0.12	8.98	97.8	0.45	73.04	22.29	20.41
MDGOG _R	1	0-15	5.6	4.19	1.13	0.66	0.07	6.94	0.24	1.55	3.24	0.28	5.56	58.75	0.15	5.46	94.23	0.25	40.33	25.59	16.67
MDGOG _R	1	15-30	5.3	5.12	1.70	0.99	0.11	10.44	0.36	2.33	2.99	0.43	4.40	51.71	0.11	6.23	96.45	0.38	60.71	22.79	13.24
MDGOG _R	2	0-15	6.2	4.08	1.13	0.66	0.07	6.94	0.24	1.55	1.80	0.29	5.46	61.4	0.15	4.02	95.15	0.25	40.33	28.22	19.61
MDGOG _R	2	15-30	5.9	4.21	1.37	0.80	0.08	8.42	0.29	1.88	1.64	0.35	4.71	58.75	0.15	4.31	95.9	0.3	48.95	23.68	13.4
LSTOGR	1	0-15	6.8	4.25	1.88	0.10	0.11	11.58	0.40	2.60	3.32	0.48	7.9	64.9	0.14	6.94	97.18	0.42	67.34	32.58	23.42
LSTOGR	1	15-30	6.8	4.36	1.24	0.72	0.08	7.61	0.26	1.70	1.93	0.32	6.01	53.47	0.13	4.34	95.62	0.27	44.25	26.88	15.92
LSTOGR	2	0-15	6.9	4.34	1.53	0.89	0.09	9.38	0.32	2.09	2.89	0.39	7.73	61.39	0.14	5.82	96.93	0.34	54.54	29.62	21.82
LSTOGR	2	15-30	6.6	4.19	1.56	0.90	0.10	9.54	0.33	2.13	2.19	0.39	7.73	64.02	0.15	5.18	96.24	0.34	55.47	31.08	20.21
LSGOGR	1	0-15	5	4.53	2.02	1.18	0.12	12.39	0.43	2.77	1.97	0.51	6.41	56.11	0.12	5.82	97.41	0.44	72.07	32.58	21.23
LSGOGR	1	15-30	6.4	4.39	1.02	0.60	0.06	6.26	0.22	1.40	1.87	0.26	5.46	56.11	0.13	3.89	94.94	0.23	36.43	30.12	14.8
LSGOGR	2	0-15	7.2	5.10	1.12	0.66	0.07	6.88	0.24	1.54	1.92	0.28	8.85	57.87	0.11	4.1	96.23	0.25	40.03	29.62	18.36
LSGOGR	2	15-30	5.6	4.74	0.71	0.42	0.05	4.35	0.15	0.97	1.09	0.18	5.12	56.1	0.14	2.53	92.85	0.16	25.27	31.08	15.59

Table 8: Chemical properties of surface samples at Onigambari forest reserve

Sample	Point	Depth (cm)	pH (H ₂ O)	pH (Kcl)	OM %	OC %	N %	P mg/kg	K+ (cmol/kg)	Ca 2+ (cmol/kg)	Mg 2+ (cmol/kg)	Na+ (cmol/kg)	CDR	Silica %	H+ (cmol/kg)	EC _{EC} (cmol/kg)	B.S %	B (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)
UPTOGB	1	0-15	5.6	5.72	2.84	1.65	0.17	17.44	0.6	3.89	8.81	0.71	9.59	50.83	0.09	14.1	98.78	0.62	101.4	19.75	25.7
UPTOGB	1	15-30	6.2	5.61	2.34	1.36	0.14	14.34	0.49	3.2	6.13	0.59	8.47	52.59	0.09	10.5	98.49	0.51	83.4	23.56	23.01
UPTOGB	2	0-15	6.2	5.3	1.46	0.85	0.09	8.93	0.31	1.99	6.23	0.37	7.15	56.99	0.07	8.97	98.05	0.32	51.95	31.62	21.19
UPTOGB	2	15-30	6.6	5.71	1.52	0.88	0.09	9.32	0.32	2.08	4.32	0.38	7.28	53.23	0.08	7.18	97.81	0.33	54.19	34.64	22.6
UPGOGB	1	0-15	5.8	5.32	1.77	1.03	0.11	10.86	0.37	2.43	3.32	0.45	7.28	55.87	0.08	6.65	98.03	0.39	63.17	25.87	20.63
UPGOGB	1	15-30	5.6	5.38	1.24	0.72	0.08	7.6	0.26	1.7	2.62	0.31	7.48	54.99	0.08	4.97	97.14	0.27	44.19	17.49	14.39
UPGOGB	2	0-15	6	5.42	1.94	1.13	0.12	11.91	0.41	2.66	5.36	0.49	6.59	60.27	0.07	8.99	98.52	0.43	69.24	32.49	28.9
UPGOGB	2	15-30	5.4	5.46	2.23	1.3	0.14	13.73	0.47	3.06	5.07	0.56	6.04	58.51	0.09	9.25	98.54	0.49	79.84	31.9	22.79
MDTOG	1	0-15	6	5.42	1.94	1.13	0.12	11.88	0.41	2.65	2.82	0.49	6.64	48.83	0.09	6.46	98.24	0.43	69.09	25.85	20.39
MDTOG	1	15-30	6.8	5.81	1.33	0.77	0.08	8.15	0.28	1.82	2.7	0.34	7.48	56.75	0.10	5.24	97.37	0.29	47.41	29.89	17.15
MDTOG	2	0-15	6.6	5.4	2.56	1.49	0.15	15.71	0.54	3.51	5.51	0.64	7.48	52.35	0.08	10.3	98.78	0.56	91.34	35.38	21.21
MDTOG	2	15-30	6.2	5.45	2.12	1.23	0.13	13.01	0.45	2.9	6.83	0.53	8.04	50.59	0.07	10.8	98.79	0.47	75.65	35.23	18.89
MDGOG	1	0-15	6.7	5.38	1.73	1.01	0.11	10.62	0.36	2.37	3.1	0.44	7.35	57.63	0.08	6.35	98.33	0.38	61.75	36.08	13.31
MDGOG	1	15-30	5.7	5.39	1.95	1.13	0.12	11.96	0.41	2.67	3.72	0.49	8.8	51.48	0.08	7.37	98.36	0.43	69.57	40.2	14.29
MDGOG	2	0-15	6.2	5.3	2.38	1.38	0.14	14.65	0.5	3.27	3.51	0.6	6.14	51.47	0.09	7.97	98.63	0.52	85.19	41.76	19.01
MDGOG	2	15-30	5.7	5.49	1.58	0.92	0.10	9.73	0.35	2.17	2.46	0.4	8.8	50.59	0.07	5.45	98.26	0.35	56.57	30.64	14.81
LSTOGB	1	0-15	5.6	6.6	2.2	1.28	0.13	13.53	0.46	3.02	3.35	0.56	8.8	56.75	0.06	7.45	98.79	0.48	78.66	33.29	16.99
LSTOGB	1	15-30	6.2	5.81	2.54	1.48	0.16	15.63	0.54	3.49	3.08	0.64	8.03	57.63	0.06	7.81	99.09	0.55	90.94	34.45	18.14
LSTOGB	2	0-15	6.4	5.48	2.41	1.4	0.15	14.81	0.51	3.31	9.18	0.61	7.96	55.57	0.05	13.7	99.07	0.53	86.14	34.44	17.86
LSTOGB	2	15-30	6.1	5.4	2.34	1.36	0.14	14.35	0.49	3.2	5.85	0.59	6.04	54.11	0.08	10.2	98.79	0.51	83.49	38.33	20.49
LSGOGB	1	0-15	5.1	5.6	1.94	1.13	0.12	11.9	0.41	2.66	4.33	0.49	6.04	55.87	0.09	7.98	98.15	0.43	69.19	32.78	18.57
LSGOGB	1	15-30	4.9	4.62	1.65	0.96	0.09	10.13	0.35	2.26	2.51	0.42	6.65	51.47	0.12	5.66	96.92	0.36	58.89	27.94	16.41
LSGOGB	2	0-15	4.7	5.5	1.98	1.15	0.12	12.18	0.42	2.72	2.14	0.5	6.59	56.75	0.11	5.89	97.89	0.44	70.81	29.15	15.23
LSGOGB	2	15-30	3.8	4.5	1.15	0.67	0.07	7.05	0.24	1.57	1.88	0.29	6.65	59.39	0.12	4.1	93.73	0.25	40.97	25.55	17.33

Table 9: Chemical properties of surface samples at Omo forest reserve, Area J4

Sample	Point	Depth (cm)	pH (H ₂ O)	pH (Kcl)	OM %	OC %	N %	P mg/kg	K+ (cmol/kg)	Ca 2+ (cmol/kg)	Mg 2+ (cmol/kg)	Na+ (cmol/kg)	CDR	Silica %	H+ (cmol/kg)	ECEC (cmol/kg)	B.S %	B (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)
UPTOFR	1	0-15	6.9	4.7	2.79	1.63	0.17	17.15	0.59	3.83	4.62	0.7	6.33	60.51	0.11	9.85	98.39	0.61	99.70	30.67	24.54
UPTOFR	1	15-30	6.8	4.6	2.68	1.56	0.16	16.45	0.57	3.67	2.68	0.67	5.01	52.59	0.12	7.71	98.26	0.59	95.61	26.44	21.67
UPTOFR	2	0-15	6.2	4.5	1.52	0.88	0.09	9.30	0.32	2.08	2.58	0.38	8.11	50.83	0.13	5.49	95.97	0.33	54.10	30.18	20.41
UPTOFR	2	15-30	7.4	4.3	1.68	0.98	0.10	10.13	0.35	2.3	2.49	0.43	7.30	53.23	0.14	5.71	96.90	0.57	59.95	30.64	25.77
UPGOFR	1	0-15	5.0	4.5	2.22	1.29	0.14	13.65	0.47	3.05	2.26	0.56	6.36	60.51	0.14	6.48	97.48	0.49	79.35	39.45	25.0
UPGOFR	1	15-30	6.0	5.7	2.72	1.59	0.17	16.73	0.58	3.74	2.67	0.69	3.76	55.23	0.12	7.8	98.28	0.67	97.28	32.02	22.40
UPGOFR	2	0-15	6.6	4.3	2.37	1.38	0.15	14.58	0.5	3.25	3.12	0.6	6.62	54.35	0.1	7.57	98.31	0.52	84.82	27.78	29.94
UPGOFR	2	15-30	4.8	5.6	1.66	0.07	0.10	10.20	0.35	2.28	2.01	0.42	5.40	57.89	0.07	5.13	98.31	0.36	59.32	22.98	13.42
MDTOFR	1	0-15	5.2	5.4	2.22	1.29	0.13	13.64	0.47	3.05	3.09	0.56	4.17	56.75	0.09	7.26	98.38	0.49	79.29	40.02	32.28
MDTOFR	1	15-30	5.5	5.4	2.64	1.54	0.16	16.22	0.56	3.63	3.35	0.67	7.14	53.47	0.1	8.31	98.54	0.58	94.35	31.70	27.73
MDTOFR	2	0-15	7.6	5.3	2.48	1.44	0.15	15.23	0.52	3.4	3.28	0.62	9.47	54.11	0.12	7.94	98.50	0.54	88.57	35.61	16.34
MDTOFR	2	15-30	6.8	5.6	1.95	1.14	0.12	11.96	0.41	2.67	2.85	0.49	6.41	62.28	0.09	6.51	98.21	0.43	69.56	32.86	19.63
MDGOFR	1	0-15	6.0	5.5	2.52	1.47	0.15	15.47	0.53	3.45	3.37	0.64	4.11	59.39	0.1	8.09	98.50	0.56	89.99	29.75	15.30
MDGOFR	1	15-30	7.1	5.3	2.46	1.43	0.15	15.10	0.52	3.38	3.85	0.62	10.1	49.95	0.1	8.47	98.48	0.54	87.85	31.09	28.59
MDGOFR	2	0-15	7.4	5.6	2.17	1.26	0.13	13.29	0.46	2.97	2.36	0.54	7.35	52.35	0.11	6.44	98.31	0.48	77.26	26.99	20.80
MDGOFR	2	15-30	6.9	5.1	2.30	1.34	0.14	14.10	0.49	3.15	4.75	0.58	5.25	52.59	0.12	9.09	98.16	0.50	82.02	31.84	20.59
LSTOFR	1	0-15	6.2	4.8	1.67	0.97	0.10	10.26	0.36	2.29	2.3	0.42	6.21	50.83	0.12	5.49	97.25	0.37	59.68	29.44	13.82
LSTOFR	1	15-30	5.8	4.6	1.54	0.90	0.09	9.48	0.33	2.12	2.42	0.39	3.99	53.47	0.15	5.41	96.54	0.34	55.15	24.02	17.66
LSTOFR	2	0-15	5.8	4.4	1.75	1.02	0.11	10.73	0.37	2.4	2.69	0.44	5.01	49.08	0.12	6.02	97.23	0.39	62.59	31.44	17.55
LSTOFR	2	15-30	4.8	4.3	1.41	0.82	0.09	8.68	0.3	1.94	3.63	0.36	6.91	66.43	0.14	6.37	96.56	0.31	50.49	29.26	15.31
LSGOFR	1	0-15	5.8	5.8	2.86	1.66	0.17	9.70	0.26	1.91	1.50	0.64	4.26	57.87	0.09	4.39	98.06	0.39	69.90	24.65	20.19
LSGOFR	1	15-30	5.8	6.2	1.53	0.89	0.09	10.68	0.34	1.91	1.71	0.49	3.76	61.39	0.08	4.53	98.24	0.43	69.61	19.05	19.15
LSGOFR	2	0-15	6.8	5.6	1.65	0.96	0.10	9.80	0.31	1.78	1.39	0.45	6.99	49.95	0.09	4.01	97.88	0.33	58.65	29.96	21.34
LSGOFR	2	15-30	6.8	5.8	1.18	0.69	0.07	10.30	0.40	2.15	1.67	0.54	6.22	53.47	0.08	4.82	98.45	0.35	48.97	18.32	18.15

Table 10: Scores for the Physical, Chemical and Biological degradation of Osun Sacred Grove

Sample	Surface (0 - 15 cm)								Surface (0 - 15 cm)								
	BD (g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/ Kg)	K (cmol/Kg)	B.S (%)	EC (dS/ m)	OM (%)	Sample	BD(g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/ Kg)	K (cmol/Kg)	B.S (%)	EC (dS/m)	OM (%)
UPTOGR A	2	2	1	1	1	4	2	2	UPTOGR	2	2	2	1	1	4	1	2
B	1	1	2	1	1	4	2	3	A	2	2	4	2	1	4	1	3
UPGOGR A	2	2	4	4	1	4	1	4	UPGOGR	1	1	1	1	1	4	1	2
B	1	2	1	1	1	4	2	2	A	1	1	2	1	1	4	1	2
MDTOGR A	2	2	3	1	1	4	2	3	MDTOGR	1	1	2	1	1	4	3	2
B	2	2	1	1	1	4	1	2	A	1	1	2	1	1	4	1	2
MDGOGR	1	1	4	3	1	4	2	3	MDGOGR	1	1	2	1	1	4	1	3
A	1	1	4	3	1	4	1	3	A	1	1	3	1	1	4	1	3
B	1	1	4	3	1	4	1	3	B	1	1	3	1	1	4	1	3
LSTOGR A	2	2	2	1	1	4	1	3	LSTOGR	1	1	3	2	1	4	1	3
B	2	2	3	1	1	4	3	3	A	2	2	2	1	1	4	1	3
LSGOGR A	2	2	2	1	1	4	1	2	B	2	1	4	3	1	4	1	3
B	2	2	4	3	1	4	1	3	LSGOGR	2	1	4	3	1	4	1	3
B	2	2	4	3	1	4	1	3	A	1	1	4	4	2	4	1	4

UPTOGR= upper slope under teak plantation at Osun Grove, UPGOGR= upper slope under Gmelina at Osun Grove, MDTOGR= middle slope under Teak plantation at Osun Grove, MDGOGR= middle slope under Gmelina at Osun Grove, LSTOGR= Lower slope under Teak at Osun Grove, LSGOGR= Lower slope under Gmelina at Osun Grove, A= Point 1, B= Point 2, BD= Bulk density, Ksat= Hydraulic conductivity, EC= Electrical conductivity, OM= Organic matter, BS= Base saturation, N= Nitrogen, K= Potassium, Av.P= Available phosphorus

Table 11: Scores for the Physical, Chemical and Biological degradation of Onigambari Forest reserve

Sample	Surface (0 - 15 cm)					Surface (0 - 15 cm)					Sample	BD(g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/Kg)	K (cmol/Kg)	B.S (%)	EC (dS/m)	OM (%)
	BD (g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/Kg)	K (cmol/Kg)	B.S (%)	EC (dS/m)	OM (%)											
UPTOGB A	2	2	1	1	1	4	3	1	UPTOGB	1	1	1	1	1	1	4	3	2	
B	1	2	3	1	1	4	1	3	A	1	1	3	1	1	4	1	3		
UPGOGB A	2	2	2	1	1	4	2	3	UPGOGB	2	2	3	2	1	4	2	3		
B	2	2	2	1	1	4	2	3	A	1	2	1	1	1	4	2	2		
MDTOGB A	1	1	2	1	1	4	3	3	MDTOGB	1	1	3	1	1	4	2	3		
B	2	2	1	1	1	4	2	1	A	2	2	2	1	1	4	3	2		
MDGOGB A	2	2	2	1	1	4	2	3	MDGOGB	2	2	2	1	1	4	2	3		
B	2	2	1	1	1	4	2	2	A	1	1	2	1	1	4	2	3		
LSTOGB A	2	2	2	1	1	4	1	2	LSTOGB	1	1	1	1	1	4	2	2		
B	2	2	1	1	1	4	2	2	A	2	2	1	1	1	4	1	2		
LSGOG A	2	2	2	1	1	4	3	3	LSGOG A	2	2	3	1	1	4	3	3		
B	2	2	2	1	1	4	2	3	B	2	2	4	2	1	4	2	3		

UPTOGB= upper slope under teak plantation at Onigambari, UPGOGB= upper slope under Gmelina at Onigambari, MDTOGB= middle slope under Teak plantation at Onigambari, MDGOGB= middle slope under Gmelina at Onigambari, LSTOGB= Lower slope under Teak at Onigambari, LSGOGB= Lower slope under Gmelina at Onigambari, A= Point 1, B= Point 2, BD= Bulk density, Ksat= Hydraulic conductivity, EC= Electrical conductivity, OM= Organic matter, BS= Base saturation, N= Nitrogen, K= Potassium, Av.P= Available phosphorus.

Table 12: Scores for the Physical, Chemical and Biological degradation of Omo Forest Reserve (Area J4)

Sample	Surface (0 - 15 cm)								Surface (0 - 15 cm)								
	BD (g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/ Kg)	K (cmol/Kg)	B.S (%)	EC(dS/ m)	OM (%)	Sample	BD(g/cm ³)	Ksat (cm/hr)	N (%)	Av P(mg/ Kg)	K (cmol/Kg)	B.S (%)	EC (dS/m)	OM (%)
UPTOGR A	2	2	1	1	1	4	2	2	UPTOGR	2	2	2	1	1	4	1	2
B	1	1	2	1	1	4	2	3	A								
UPGOGR A	2	2	4	4	1	4	1	4	UPGOGR	1	1	1	1	1	4	1	2
B	1	2	1	1	1	4	2	2	A								
MDTOGR A	2	2	3	1	1	4	2	3	MDTOGR	1	1	2	1	1	4	3	2
B	2	2	1	1	1	4	1	2	A								
MDGOGR	1	1	4	3	1	4	2	3	MDGOGR	1	1	2	1	1	4	1	3
B	1	1	4	3	1	4	1	3	A								
LSTOGR A	2	2	2	1	1	4	1	3	LSTOGR	1	1	3	2	1	4	1	3
B	2	2	3	1	1	4	3	3	A								
LSGOGR A	2	2	2	1	1	4	1	2	LSGOGR	2	1	4	3	1	4	1	3
B	2	2	4	3	1	4	1	3	A								

UPTOGR= upper slope under teak plantation at Area J4, UPGOFR= upper slope under Gmelina at Area J4, MDTOFR= middle slope under Teak plantation at Area J4, MDGOFR= middle slope under Gmelina at Area J4, LSTOFR= Lower slope under Teak at Area J4, LSGOFR= Lower slope under Gmelina at Area J4, A= Point 1, B= Point 2, BD= Bulk density, Ksat= Hydraulic conductivity, EC= Electrical conductivity, OM= Organic matter, N= Nitrogen, K= Potassium, Av.P= Available

very highly degraded with respect to Nitrogen. With respect to available phosphorus, 50% soils were none to slight degraded, 33% highly degraded with only 16.67% very highly degraded.

Whereas, at Onigambari forest reserve, about 50% soils were none to slight degraded, 25% soils were moderately degraded and 25% were highly degraded with respect to Nitrogen. The soils were not deficient in phosphorus at all because 100% soils were none to slight degraded, the same trend goes for potassium but under Gmelina about 16.67% soils were highly degraded, 58.3% were moderately degraded and 16.67% soils were none to slight degraded with regards to Nitrogen. About 83% soils were none to slight degraded and 17% were moderately degraded with respect to phosphorus whereas 100% soils were none to slight degraded with respect to potassium.

Meanwhile, under teak plantation at Area J4, 33.33% soils were highly degraded, 33.33% moderately degraded and 33.33% were none to slight degraded with respect to nitrogen. Soils had right proportion of phosphorus and potassium with 100% also 100% soils were very highly degraded in terms of base saturation. Moreover, under Gmelina about 66.7% soils were none to slight degraded, 16.67% were moderately degraded, 8.33% were highly degraded and 8.33% soils were very highly degraded with respect to Nitrogen. The phosphorus and potassium content follows the same trend of teak plantation.

3.4. Biological Degradation

Direct approach method result revealed that at Osun sacred grove, under teak plantation, about 58.33% soils were highly degraded and 41.67% soils were moderately degraded in terms of organic matter content whereas under Gmelina plantation, 16.67 soils were very highly degraded, 50% soils were highly degraded with only 33.33% soils moderately degraded. At Onigambari forest reserve, under teak, 8.33% soil were none to slight degraded, 50% soils were moderately degraded and 41.67% were highly degraded. Meanwhile, under Gmelina plantation 83.33% soils were highly degraded with only 16.67% soils that were moderately degraded with respect to organic matter content. Moreover, at Area J4, under teak plantation, 58.33% soils were highly degraded, 16.67% moderately degraded and 25% soils were none to slight degraded while under Gmelina plantation, only 16.67% soils were none to slight degraded, 50% moderately degraded with only 33.33% soils highly degraded in terms of organic matter content in the soil.

The percentage of none to slight to moderate degradation are high and common with upper and lower slope, under teak plantation while the high to very high degradation are common with middle slope especially under Gmelina plantation.

4.0. Discussion

In all the three locations, both under teak and Gmelina plantation, the soils were highly degraded with respect to Nitrogen and very highly degraded in terms of base saturation which could be attributed to leaching loss in the soil and low cation exchange capacity of the soil that were generally low. At location 2, Onigambari, where half of the soils were highly degraded, with respect to bulk density could be deduced that the soil had suffered much anthropogenic activities like logging, picking of leaves for domestic use, Taungya farming e.t.c. similar result was reported by Awotoye et al., 2009.

Biologically, it is expected that soil organic matter would

be high in the forested areas but the reverse was the case here in all the study sites, the soils were degraded seriously in terms of organic matter which could be attributed to sites exposure to fire during weed control and litter that would have been converted into organic matter on decomposition is destroyed by fire. It would be necessary to allow plant litter to decompose in situ by eliminating the practice of burning during weed control (Aborisade and Aweto). The more pronounced biological degradation was also observed by Ewetola et al., 2015.

Chemically, available phosphorus and potassium were none to slight degraded in all the soils across the toposequence and locations which could be attributed to one of the characteristics of tropical environment while the levels of total Nitrogen ranged from moderately to very highly degrade in all locations across the toposequence. The high available phosphorus with no build-up of organic matter presumably suggests that the build-up of phosphorus under plantations was mainly in the form of inorganic phosphorus (Aweto, 2003).

Onigambari were more degraded physically, chemically and biologically than other two locations with higher degradation in the upper slope segments due to erosion, much anthropogenic activities etc. The type and degree of degradation observed on the two land use types across the locations are major factors to be considered in determining the appropriate approach to soil rehabilitation for sustainable management and production of timbers and other products in our plantations.

5.0. Recommendation

Re-afforestation, regeneration and improved fallow system are hereby recommended to improve soil immensely in terms of organic matter formation. Also Government of each State should revisit the enforcement of Law on the use of the forest Reserves so as to restrain illegal logging by both local and foreign timber merchants in conjunction with corrupt forestry officers.

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