Australian Journal of Science and Technology

ISSN Number (2208-6404)
Volume 5; Issue 2; June 2021

Original Article

Effects of 13 years vegetation cover of *Albizia lebbeck* on some soil physicobiochemical properties

Stephen Meyiwa Chomini[1], Victoria Ibukun Joshua[1], Emilia Akunna Chomini[2], Walter Chinaka John[3], Micah Kalu Peter[1], Abisola Oluwafunmilayo Ayodele[1], Victor Fatoke[4], Katherine Ikwe Barri[1]

[1]Forestry Technology Department, Federal College of Forestry, Jos - Plateau, Nigeria, [2]Science Laboratory Technology Department, Federal College of Forestry, Jos - Plateau, Nigeria, [3]Pest Management Technology Department, Federal College of Forestry, Jos - Plateau, Nigeria, [4]Agricultural Technology Department, Federal College of Forestry, Jos - Plateau, Nigeria

ABSTRACT

Forest vegetation cover engenders enhanced soil fertility and microbial community structure based on litter diversity change, which significantly affect metabolic quotient. Soil quality assessment is essential to monitor forest ecosystem stability. Thus, the effects of *Albizia lebbeck* plantation on some soil physicobiochemical properties after 13 years of planting were assessed in the Federal College of Forestry Jos. A 2 × 2 factorial experiment in a randomized complete block design (RCBD) was employed consisting of four treatments combinations in three replicates. There were significant % increases ranging from 26.7 to 51.4% (sand), 24% to 70% (cation exchangeable capacity), 31.90% to 61.25% (pH [H_2O], and 44.70% to 62.45% (pH(KCl). Highest % increase of Na (285.7%), P (122.8%), and K (121.0%) was obtained from T_1D_1, T_1D_1, and T_1D_0, with variations in physicobiochemical properties (silt, clay, sand, bulk density, textural class, and porosity), chemical (Na, P, K, OC, and OM), heavy metal (Cr, Cu, and Mn). There were significant effects on soil enzymes (urease, phosphatase, and dehydrogenase), over the control (adjacent non-vegetated plot) at the investigated depths. Soil indices indicated moderate contamination of Cu, Mn, and Cr with no ecological threats under *A. lebbeck* cover, although Cr might pose a potential health risk. These findings revealed the nitrogen-fixing and bio-remediating capacities of the tree species, which could be exploited for agro-forestry system as green nitrogen source, while ensuring hazard-free and sustainable environment.

Keywords: Vegetation cover, heavy metals, physical properties, mineral elements, enzymes, *Albizia lebbeck*

Submitted: 26-05-2021, **Accepted:** 01-06-2021, **Published:** 30-06-2021

INTRODUCTION

In general, anthropogenic factors constitute the major drivers of forest degradation in the tropical forest.[1] These activities affect the distribution and supply of soil nutrients as well as effecting biological transformations,[2] leading to a decrease in the productivity capacity and alterations in the ecological function of the soil with a consequence of an increased biochemical activity.[3] Forest soils are subject to fewer agricultural practices, yet forest vegetation impact on soil, and especially the impact of trees, differs in many ways. The impact of tree species on soil fertility and microbial community structure differs significantly with the type as well as metabolic requirements. In the tropical forest ecosystem, high soil acidity engendered by increased rainfall and temperature resulted in high microbial degradation of organics and nutrient leach usually leads to high C and Al, and lowered Ca and Mg.[4] These coupled with the quantity and quality of litter composition can affect soil carbon availability and microbial utilization efficiency.[5] Change in litter diversity proportionately affects metabolic quotient significantly.

The assessment of soil quality is essential to monitor forest ecosystem stability. Soil properties that change slowly overtime may not be useful tools for soil quality assessment, especially under drastic environment fluctuations. Consequently, soil properties that respond rapidly to environmental stress could be deployed for soil quality evaluation. Biological and biochemical soil properties have been found useful for their prompt responses to changes in the environment. These

Address for correspondence: Stephen Meyiwa Chomini, Department of Forestry Technology, Federal College of Forestry, Jos, P.M.B. 2019, Bauchi Road, Jos, Plateau State, Nigeria. E-mail: stevemchoms@gmail.com

properties directly relate to population and activity of soil microbes and their enzymes as well as soil organic biomass.[6] Soil or land cover, was described by the Organization for Economic Cooperation and Development, as the proportion of the total arable cropland under vegetative cover throughout the year, observed as one of a series of useful indicators for assessment the environmental performance of agriculture overtime.[7] It was developed to report on the state of and trends in the impact of agriculture on the environment.[8] As a forest soil management practices, forest vegetation or canopy cover confers partial protection and are less susceptible to degradation processes such as erosion, organic matter depletion, structural degradation and loss of fertility.

Some of the primary factors affecting soil quality are the management practices which include cultivation practices, length of time of fallowing, agroforestry practices, type of species and their planting densities, litter quality and quantity, etc. These have strong influence on forest soil fertility. This paper, therefore, focuses on the effect of 13 years of *Albizia lebbeck* plantation on some soil physicobiochemical properties in the federal college of forestry, Jos.

Experimental Site and Collection of Soil Samples

The study was carried out in Federal College of Jos Plateau state. The area lies between the southern limit of guinea savanna ecological zone. The soil is sandy, light to dark in color, the soil is well drained and well aerated. It lies between latitude 7°–11° N and longitude 7–25 E with an annual rainfall of about 1460 mm–4800 mm. Temperature ranges from 10 to 32°C with an altitude of 1200 mm above sea level.[9,10] The experimental site was a 13-year fallowed post-agroforestry system of alley cropping of Irish potato (*Solanum tuberosum* L.) within *A. lebbeck* plantation. The site was divided into two transects of 200 m^2 (i.e. 10 m × 20 m) each. The transects were subdivided into five plots of 4 m × 10 m each. Triplicate soil samples were collected at two different depths: 0–30 cm and 30–60 cm from each plot per transect. The replicate samples for each depth were made into composite, air dried, crushed, passed through a 2 mm sieve, and analyzed using standard procedure. Similarly, triplicate samples were collected from the adjacent non-forested plot (200 m^2) of 5 m away from forest stands. The experiment was a 3 × 2 factorial, which comprised three fallowed transects (two forested and an adjacent plot, as control: T_O, T_1, and T_2) and soil depths (0–30 cm and 30–60 cm: D_O and D_1) making up six treatment combinations (T_OD_O, T_OD_1, T_1D_O, T_1D_1, T_2D_O, and T_2D_1), applied in five replicate plots, executed using RCBD.

Determination of Soil Physical PROPERTIES

The soil physical parameters were assessed based on standard procedures as described in Table 1.

Table 1: Soil parameters and their methods of assessment

S/n	Soil parameter	Procedure
1	Bulk density	Core methods[11]
2	Soil textural	Bouyoucos hydrometric method[12]
3	pore size (porosity)	Water retention method[13]
4	pH (H^2O and kCL)	Method of[14]
5	% OC	Walkley-Black titration method[15]
6	%OM	Loss on ignition method according to[16]
7	% Na	Flame photometer[14]
8	Total n (%)	Micro-Kjeldahl methods[17]
9	Available *P* (%)	Spectrophotometer[17]
10	%K	Flame photometer[17]
11	Cu	Atomic absorption spectrophotometer[18]
12	Mn	Atomic absorption spectrophotometer[18]
13	Cr	USEPA method 3050B[19]
14	CEC	Titration, using 0.1 N NaOH[20]
15	%Base	Described by Asadu *et al*.[21]

Determination of Enzyme Activity of Soil Samples

The enzyme activities of dehydrogenases, urease, and phosphatase were determined using the methods of Alef and Nannipieri.[22] The enzyme activity was measured using PerkinElmer Lambda 25 spectrophotometer. The absorbance for dehydrogenase activity was measured at a wavelength of 485 nm (nanometer). The absorbance for urease and phosphatase was measured at a wavelength of 410 nm, followed by the following calculation:

$$An = \text{As} \times \text{C} \times \text{Vol. of extract} / \text{W} \times \text{Vf} \times 5 / \text{Va}$$

Where: An = absorbance of test sample; As = absorbance of standard solution

C = concentration of standard solution; W = weight of soil used

Vf = total volume of extract; Va = volume of extract analyzed.[23]

Computation of Biochemical Index of Potential Soil Fertility (Mw)

This was obtained from the formula below based on.[24]

$$\text{Mw} = (\text{Phos} + \text{Deh} + \text{Ure} \times 10^{-1}) \times \%\text{C}$$

Where: Phos = phosphatase; Deh = Dehydrogenase; Ure = Urease.

Soil indices determination

The following soil indices were determined.

Contamination factor (CF)

This was obtained from the formula below, according to Sabba.[25]

$$\text{CF} = \frac{\text{Concentration of pollutant}}{\text{Background pre} - \text{contermination concentration}}$$

If contamination is ≥1 which is moderately contaminated.

Hazard quotient (HQ)

This was obtained from the formula below, according to Sabba.[25]

$$\text{HQ} = \frac{\text{Measured concentration}}{\text{Toxicity reference value or selected screening benchmark}}$$

If a HQ >0.2 is obtained, a risk to human health potentially exits.

Environmental risk factor (ERF)

This was obtained from the formula below, according to Efroymson *et al*.[26]

$$\text{ERF} = QV - \frac{\text{CI}}{\text{QV}}$$

Where

QV = Quality value (background/pre-contamination concentration); CI = Heavy metal concentration in the soil fractions; ERF <O = Potential ecological threat; ERF >O = No threat.

Statistical Analysis of Data

Data obtain were subjected to analysis of variance (ANOVA) to determine their significance while significant means were separated using LSD at 5%.

RESULTS AND DISCUSSION

Effects of 13 Years *A. lebbeck* Plantation on the Soil Physical Properties

There were significant variations in the effects of *A. lebbeck* cover after 13 years on the soil textural properties and soil depth. Sand fractions were higher at a depth of 0–30 cm in transect 1 (T_0D_0 [72.20], T_0D_1 [74.00], and C_0D_0 [75.10]) than those of 30–60 cm depth in transect 2 (T_1D_0 [69.10], T_1D_1 [67.20], and C_1D_0 [74.20]), respectively. The contrary was the case for silt and clay, whereby the transect 2 had higher values than transect 1, as shown in Table 1. The effect on bulk density (BD), was in the order of $T_0D_0 > T_0D_1 > T_1D_0 > T_1D_1 > T_2D_0 > T_2D_1$. Furthermore, soils from non-forested site (control) had significant higher porosity values at lower depth than the treatments [Table 2]. These showed that the soil under the vegetation cover was texturally sandy clay, with silt and clay proportions increased with depth, as the sand fraction reduces in all the transects.

Effects of 13 Years *A. lebbeck* Plantation on the Soil Chemical Properties

The forested plots had significant ($P < 0.05$) higher % base than the control adjacent plot, with highest base saturation of 4.22% recorded in 30–60 cm depth of transect 2. The non-forested soil recorded the highest pH (H_2O) of 6.52 at 0–30 cm depth and pH (KCL) of 5.72 (at 30–60 cm depth). All soil samples from forested stands of *A. lebbeck* had a higher cation exchangeable capacity (CEC) values than those of non-forested at both soil depths. However, significant ($P < 0.05$) higher values T_0D_1 (7.45), T_1D_1 (8.37), and T_2D_1 (6.11) were recorded at depth 30–60 cm, than T_0D_0 (6.60), T_1D_0 (6.37), and T_2D_0 (5.55) at 0–30 cm depth [Table 3]. The analysis of variance indicated a significant impact ($P < 0.05$) of the effects of the plantation on these soil parameters.

Effects of 13 Years *A. lebbeck* Plantation on the Soil Mineral Elements and Heavy Metals

The soil samples from 13 years old *A. lebbeck* plantation gave higher values for sodium (Na) and potassium (K) over the non-forested transect, at both depths. However, higher values were recorded for soil depth 30–60 cm than 0–30 cm. Conversely, there were significant higher values obtained for nitrogen (N), phosphorus (P), organic carbon (C), and organic matter (OM) from soil of non-forested plot, with higher values recorded

Table 2: Effects of 13 years *Albizia lebbeck* plantation on the soil physical properties

Variables	DEPTH	Treatment	Sand	Silt	Clay	BD	Porosity
Physical property	30 cm	T_0D_0	72.20^c	12.20^a	15.60^a	6.12^a	31.40^c
		T_1D_0	74.00^b	11.70^{ab}	14.30^b	1.66^a	35.20^b
		C_0D_0	75.10^a	11.10^b	12.80^c	1.58^a	45.30^a
		SE±	0.29	0.28	0.35	2.56	0.21
	60 cm	T_0D_1	69.10^b	13.40^a	17.50^b	1.70^a	27.40^b
		T_1D_1	67.20^c	14.13^a	18.70^a	1.70^a	21.90^c
		C_0D_1	74.20^a	12.30^b	13.50^c	1.58^b	41.60^a
		SE±	0.24	0.22	0.32	0.03	0.19

Means followed by the same superscripts in the same column are not significantly different (P>0.05) BD: Bulk density

Table 3: Effects of 13 years *Albizia lebbeck* plantation on the soil chemical properties

Variables	Depth	Transect/depth	Cation exchange capacity (CEC)	%BASE	pH (H20)	pH (KCL)
Chemical properties	30cm	T_0D_0	6.60[a]	3.55[a]	6.20[b]	5.36[a]
		$T1_1D_0$	6.37[b]	2.51[b]	6.36[ab]	5.38[a]
		C_0D_0	5.55[c]	2.35[b]	6.52[a]	5.52[a]
		SE±	0.05	0.05	0.07	0.08
	60cm	T_0D1_1	7.45[b]	3.91[b]	6.12[b]	5.21[b]
		T_1D1_1	8.37[a]	4.22[a]	6.18[b]	5.25[b]
		C_0D_1	6.11[c]	2.60[c]	6.45[a]	5.72[a]
		SE±	0.06	0.04	0.02	0.02

Mean followed by the same superscripts in the same column are not significantly different (*P*>0.05) from each other

Table 4: Effects of 13 years of plantation of *Albizia lebbeck* on the soil mineral elements

Variables	Depth	Transect/depth (treatment)	% Na	% N	% P	% K	%OC	% O M
Mineral elements	30 cm	T_0D_0	0.67[a]	0.09[a]	3.10b	0.28[a]	0.77[ab]	1.33[b]
		T_1D_0	0.63[a]	0.09[a]	3.90ab	0.27[a]	0.73[b]	1.26[b]
		T_2D_0	0.60[a]	0.07[a]	4.00a	0.25[a]	0.82[a]	1.42[a]
		SE±	0.02	0.02	0.24	0.02	0.02	0.02
	60 cm	T_0D_1	0.71[a]	0.08[a]	2.80a	0.30a[a]	0.70[b]	1.21[b]
		T_1D_1	0.81[a]	0.08[a]	3.60a	0.31[a]	0.61[c]	1.09[c]
		T_2D_1	0.66[a]	0.06[a]	3.60a	0.26[a]	0.79[a]	1.37[a]
		SE±	0.04	0.02	0.29	0.02	0.03	0.03

Mean followed by the same superscripts in the same column are not significantly different (*P*>0.05). Na: Sodium; N: Nitrogen; P: Phosphorus; K: Potassium; OC: Organic carbon; OM: Organic matter

at 0–30 cm depth. There were variations in recorded values of carbon: nitrogen ratios. Nevertheless, higher values were recorded for soil samples at 30–60 cm depth than 0–30 cm depth, except at transect 2 [Table 4]. Analysis of variance (ANOVA) of data obtained on these mineral elements showed significant ($P < 0.05$) effects of vegetation cover and soil depths on these soil parameters, except for N and P ($P > 0.05$) for land use and soil depth, and Na for soil depth 0–30 cm only.

The effects of *A. lebbeck* plantation cover indicated significant higher values Cu, Mn and Cr over the non-forested (control), at both soil depths. However, soil samples from 30 to 60 cm depth had higher concentrations of these heavy metals than those of the 0–30 cm depth. There was a significant difference ($P < 0.05$) of the effects of vegetation cover and soil depth on contents of these heavy metals of the sampled soils [Table 5].

Effects of 13 Years *A. lebbeck* Plantation on the Soil Enzymes

There was a general increase in the activities of dehydrogenase, urease, and phosphatase enzymes of soils under forest cover over those of the non-forested irrespective of the soil depth. The highest dehydrogenase activities T_1D_1 (10.10), T_0D_1 (8.66), and T_2D_1 (7.04) were recorded at 30–60 cm over the values at 0–30 cm depth. The same trend was observed for urease and phosphatase. In general, all the microbial enzyme activities were found to be highest in the sample soils in the order transect 1 > transect 2 > transect 3 at both soil depths. The analysis of variance of data on these parameters indicated significant effect ($P < 0.05$) of the plantation on the soil enzymes. Furthermore, the effects were affected by soil depth [Table 6].

Table 5: Effects of 13 years old plantation of *Albizia lebbeck* on the soil heavy metal contents

Variables	Depth	Transect/ depth	Cu	Mn	Cr
Heavy metals	30 cm	T_0D_0	3.55[a]	2.26[a]	1.50[a]
		T_1D_0	2.51[b]	1.38[b]	1.40[a]
		T_2D_0	2.35[b]	1.30[b]	1.20[b]
		SE±	0.05	0.06	0.05
	60 cm	T_0D_1	3.91[b]	2.47[a]	1.76[a]
		T_1D_1	4.22[a]	2.60[a]	1.88[a]
		T_2D_1	2.60[c]	1.42[b]	1.33[b]
		SE±	0.04	0.04	0.04

Mean followed by the same superscripts in the same column are not significantly different ($P > 0.05$)

Table 6: Effects of 13 years old plantation of *Albizia lebbeck* on the soil enzymes

Variables	Depth	Transect/depth	Dehydrogenase	Urease	Phosphatase
Enzymes	30 cm	T_0D_0	7.93[a]	20.97[b]	3.70[b]
		T_1D_0	8.67[a]	23.19[a]	4.93[a]
		C_0D_0	6.68[a]	17.72[c]	2.69[c]
		SE±	0.58	0.06	0.06
	60 cm	T_0D_1	8.66[b]	21.70[b]	4.19[b]
		T_1D_1	10.10[a]	24.18[a]	5.67[a]
		C_0D_1	7.04[c]	18.33[c]	2.85[c]
		SE±	0.05	0.08	0.09

Mean followed by the same superscripts in the same column are not significantly different (P>0.05)

Table 7: Comparative effects of 13 years *Albizia lebbeck* plantation on physical properties

Items	Properties	Depth (cm)	Initial reading (13 years ago)	Final reading (13 years after)	Transect combination	% Effect	Remark
Physical properties	Sand	30	57.0	72.20	T_0D_0	26.70	Increase
				74.00	T_1D_0	29.80	Increase
				75.10	C_0D_0	31.70	Increase
		60	49.0	69.10	T_1D_1	41.00	Increase
				67.20	T_1D_0	37.10	Increase
				74.20	C_0D_1	51.40	Increase
	Silt	30	20.0	12.20	T_0D_0	39.00	Reduction
				11.70	T_1D_0	41.50	Reduction
				11.10	C_0D_0	45.00	Reduction
		60		13.40	T_1D_1	25.00	Reduction
				14.13	T_1D_0	21.50	Reduction
				12.30	$C0D_1$	31.60	Reduction
	Clay	30	23.0	15.60	T_0D_0	32.00	Reduction
				14.30	T_1D_0	37.00	Reduction
				12.80	C_0D_0	44.00	Reduction
		60	33.0	17.50	T_1D_1	46.00	Reduction
				18.70	T_1D_0	46.00	Reduction
				13.50	C_0D_1	40.00	Reduction

Comparative Effects of 13 Years *A. lebbeck* Plantation on Physical and Biochemical Properties

From Table 6, it was observed that the effects of 13 years of *A. lebbeck* plantation had increased % sand, from 26.7 to 51.4%. There were reductions in %silt (41.5%, [T_1D_0] as the highest % reduction), 46.0% (T_1D_0) for % clay. Cation exchange capacity recorded % reduction (2.40–17.90%) at depth 30 cm and % increases (from 24% to 70%) at depth 60 cm [Table 7]. There were general increases in pH(H_2O) values ranging from 31.90% to 61.25% while a range of 44.70–62.45% was recorded as % increase for pH(KCl) due to 13 years of plantation. There were increases in concentrations of mineral elements such as Na, P, and K, with 285.7% (T_1D_1), 122.8% (T_1D_1), and 121.0% (T_1D_0) as the highest, respectively. The concentration of nitrogen also increased in a range of 2.09–9.09% at depth 0–30 cm and 0.00–14.28% at 30–60 cm depth [Table 8].

Comparative Effects of 13 years *A. lebbeck* Plantation on Some Soil Indices

The CF computed was compared with bench mark (standard) and it indicated that the soil was moderately contaminated with the heavy metals (Cu, Mn, and Cr) in all the transects and at both depths, 0–30 cm and 30–60 cm. All the ERF values calculated were greater than the benchmark for safety (0.0) at both depths, thus, posing no environmental threats. The values of HQ calculated for copper (Cu) and manganese (Mn) were less than the benchmark of 0.2, posing no hazard threat. On the contrary, however, the values for chromium (Cr) were

Table 8: Comparative effects of 13 years *Albizia lebbeck* plantation on chemical properties

Items	Properties	Depth (cm)	Initial reading	Final reading (13 years after)	Transect combination	% effect	Remark
Chemical bases	CEC	30	6.76	6.60	T_0D_0	2.40	Reduction
				6.37	T_1D_0	5.80	Reduction
				5.55	C_0D_0	17.90	Reduction
		60	4.90	7.45	T_1D_1	24.00	Increase
				8.37	T_1D_0	70.00	Increase
				6.11	C_0D_1	24.00	Increase
pH	pH (H_2O)	30	4.7	6.20	T_0D_0	31.90	Increase
				6.36	T_1D_0	35.30	Increase
				6.52	C_0D_0	38.70	Increase
		60	4.0	6.12	T_1D_1	53.00	Increase
				6.18	T_1D_0	54.50	Increase
				6.45	C_0D_1	61.25	Increase
	pH (KCl)	30	3.4	5.36	T_0D_0	54.70	Increase
				5.38	T_1D_0	58.20	Increase
				5.52	C_0D_0	62.40	Increase
		60	3.6	5.21	T_1D_1	44.70	Increase
				5.25	T_1D_0	45.80	Increase
				5.72	C_0D_1	58.90	Increase
Elements	Phosphorus (P)	30	1.75	3.10	T_0D_0	77.10	Increase
				3.90	T_1D_0	122.80	Increase
				4.00	C_0D_0	128.80	Increase
		60	2.40	2.80	T_1D_1	16.70	Increase
				3.60	T_1D_0	50.00	Increase
				3.60	C_0D_1	50.00	Increase
	Potassium (K)	30	0.21	0.28	T_0D_0	33.30	Increase
				0.27	T_1D_0	28.60	Increase
				0.25	C_0D_0	19.00	Increase
		60	0.14	0.30	T_1D_1	114.20	Increase
				0.31	T_1D_0	121.00	Increase
				0.26	C_0D_1	85.70	Increase
Sodium (Na)		30	0.36	0.67	T_0D_0	86.1	Increase
				0.36	T_1D_0	75.0	Increase
				0.63	C_0D_0	66.7	Increase
		60	0.21	0.71	T_1D_1	238.0	Increase
				0.81	T_1D_0	285.7	Increase
				0.66	C_0D_1	214.3	Increase
Nitrogen (N)		30	0.088	0.09	T_0D_0	9.09	Reduction
				0.09	T_1D0	2.27	Increase
				0.09	C_0D0	2.09	No change
		60	0.070	0.08	T_1D_1	0.00	Increase
				0.08	T_1D_0	14.28	Increase
				0.66	C_0D_1	2.10	Increase

>0.2 for all treatments, indicating potential threat to human health [Table 9].

Effect of 13 Years *A. lebbeck* Plantation on Soil Fertility

The effects of 13 years *A. lebbeck* cover were determined on biochemical potential soil fertility. It revealed that the soil under forest cover had higher values and indication better biochemical potential soil fertility (M_W). This propensity for fertility was highest on transect 2 at 0–30 cm depth and was in the order of 2.69(T_1 D_0) > 2.51(T_0D_0) > 2.44(T_1 D_1) > 2.43(T_0 D_1) > 2.23(T_2 D_1) > 2.22(T_2 D_0) [Table 10]. Computation of CF indicated that the soil is moderated with the heavy metals (Cu, Mn, and Cr), with no potential ecological threat. Computed HQ poses no threat to human health, but Cr content indicated potential health risk.

DISCUSSION

The observed soil physical properties corroborated the findings of Habtamu *et al*.[18] that the clay and silts fractions increasing with both land use and soil depth while sand fraction decreased. Furthermore, the BD was highly affected by a combined effect of vegetation cover and soil depth.[18] The textural class was sandy loam Renella *et al*.[27] found that enzyme inhibition was greater in sandy than in fine-textured soils because the clay fraction protects soil enzyme activity. Geiger *et al*.[28] proposed that clay surfaces interact with both enzymes and metals and ultimately reduce the toxicity of metals. Clay and mineral contents have been reported to strongly affect extracellular enzyme activity in soil.[28] According to Bi *et al*.,[29] soils under forest cover could become looser with surface soil BD decreasing, depending on the species, while the porosity increases with the development of underground root systems. All these contributed to improve the soil structure and the ability to hold water, which is of great significance for the subsidence land in the semi-arid and arid regions, as well as for subsequent ecological succession.

The variations in the CEC although depth dependent were similar to the findings of Gonnety *et al*.,[30] obtained, from soil under *Chromolaena odorata*-based fallow which displayed the highest values of exchangeable base contents, CEC, and the lowest C: N ratio, which are characteristics of good quality soil. Soils under plantations of leguminous plant species have the tendency in reducing the soil pH and improving soil electrical conductivity. The pH is considered the main chemical parameter controlling the bioavailability of heavy metals in the soil.[31] This might be due to the accumulation of organic acids secreted or discharged from microorganisms, animals, plant roots, and leaf litters on the surface soil.[29]

Increased mineral contents of the soils under study have been attributed to improved soil electrical conductivity, resulting from the accumulation of K, Na, and Mg ions released from the plant roots. *A. lebbeck* has been regarded as a nitrogen fixer,[32] which can increase soil N and improve soil fertility by N-fixing bacteria in rhizosphere. Bi *et al*.[29] investigated

Table 9: Soil indices determination for heavy metals

Elements	Transect combination	BMC	CF	Remark	ERF	Remark	HQ	Remark
Cu	T_0D_0	0.00	1.51	MC	0.34	No potential ecological threat	0.04	No threat
	T_1D_0		1.07	MC	0.06	No potential ecological threat	0.02	No threat
	T_0D_1		1.50	MC	0.34	No potential ecological threat	0.04	No threat
	T_1D_1		1.62	MC	0.38	No potential ecological threat	0.04	No threat
Mn	T_0D_0	0.00	1.74	MC	0.40	No potential ecological threat	0.005	No threat
	T_1D_0		1.061	MC	0.60	No potential ecological threat	0.003	No threat
	T_0D_1		1.74	MC	0.40	No potential ecological threat	0.005	No threat
	T_1D_1		1.83	MC	0.45	No potential ecological threat	0.005	No threat
Cr	T_0D0_0	0.00	1.25	MC	0.20	No potential ecological threat	1.50	Potential human health risk
	T_1D_0		1.17	MC	0.10	No potential ecological threat	1.40	Potential human health risk
	T_0D_1		1.32	MC	0.20	No potential ecological threat	1.76	Potential human health risk
	T_1D_1		1.41	MC	0.30	Potential ecological threat	1.88	Potential human health risk

BMC: Bench mark for calculation; CF: Contamination factor; ERF: Environmental risk factor; HQ: Hazard quotient; MC : Moderately contaminated

Table 10: Biochemical potential soil fertility index (MW)

Depth (cm)	Transect	Cal.MW
30	T_0	2.51
	T_1	2.69
	C_0	2.22
60	T_0	2.43
	T_1	2.44
	C_0	2.23

the effects of seabuckthorn (*Hippophaer hamnoides*) on soil amelioration, found it useful for the sustainable development of the damaged ecosystem. During growth of plants, mineral elements are absorbed by root systems, stored in the surface soil in the form of organic matters, and then quickly decomposed by microbes.

Heavy metal dynamics in soils are complex and metal bioavailability depends on a variety of factors including the properties of both the metal and soil environment such as the pH, soil organic matter, soil texture, redox potential, and temperature.[33] Season and climatic conditions can also cause an enhanced or reduced mobility. The soil pH is generally the most important factor controlling partitioning behavior of heavy metals in soil. In general, metal sorption to soil is low at low pH (<5.0) and increases as soil pH increases due to the effects of pH on variable-charged sorption sites.[34] Soil pH had significant positive correlation with concentrations of As, Cd, Cr, Cu, Mn, Se, and Zn.[35]

In the current study, it was observed that the heavy metal concentrations had decreased for Cu and Mn after 13 years of establishment. These reductions have been attributed microbial activities. Soil fungi play an important role in reduction of heavy metal concentration in soil.[36] Such variation could also be affected by vegetation succession process and toxic effect of accumulated heavy metal in the plants growing on plantation. According to Mishra *et al*.,[37] despite the fact that these trace elements are fundamentally needed for plant growth, their increased concentrations in soils may pose serious hazards to the plants, as it inhibits the establishment and growth of the plants. Heavy metals inhibit growth of microorganisms in the soil,[38] which play an important role in the decomposition of organic matter and N fixation, thus soil with high concentration of heavy metals are often poor in organic C and N.[39] Addition of organic matter decreases the bioavailability of heavy metals in soil and facilitates establishment of vegetation on such sites. Natural process such as precipitation and steady decrease in heavy metal concentrations with increasing age of plantations (as observed in this study) indicates that either the metals are accumulated in the vegetative parts of different plant species or they could form complexes with other minerals through chemical reaction.[40] In some plant species, heavy metals absorbed by the roots form complexes which are unavailable for translocation and thus sequestered in the plant tissues.[41]

Wyszkowska *et al*.[42] investigated the effects of Cu on soil enzymes (dehydrogenase, urease, acid phosphatase, and alkaline phosphatase) and its interactions with other heavy metals (Mn, Ni, Pb, Cu, and Cr). They found that the activity of dehydrogenase was greater in heavy loamy sand, while the activities of other enzymes were higher in light silt clay. In another words, enzyme inhibition due to heavy metals was greater in heavy loamy sand than in light silt clay (except in the case of dehydrogenase).

The dehydrogenase enzyme activity is commonly used as an indicator of biological activity in soils.[43] This enzyme is considered to exist as an integral part of intact cells but does not accumulate extracellularly in the soil. Dehydrogenase enzyme is known to oxidize soil organic matter by transferring protons and electrons from substrates to acceptors.

Urease activity in soils is influenced by many factors. These include cropping history, organic matter content of the soil, soil depth, soil amendments, heavy metals, and environmental factors such as temperatures.[44] For example, studies have shown that urease was very sensitive to toxic concentrations of heavy metals.[44] In general, urease activity increases with increasing temperature. It is suggested that higher temperatures increase the activity coefficient of this enzyme. Therefore, it is recommended that urea be applied at times of the day when temperatures are low. Since urease plays a key role in the hydrolysis of urea fertilizer, it is important to uncover other unknown factors that may reduce the efficiency of this enzyme in the ecosystem. Studies have shown that food crops cultivated on soils found in the area could be contaminated with heavy metals and therefore could expose consumers of such food to serious health hazards.[45,46] Heavy metals affect many characteristics of soils, including their biological properties Huang and Shindo,[47] Khan *et al*.[48] concluded that heavy metals have an inhibitory influence on soil enzyme.

The present study demonstrated a significant influence of increase soil enzymes activity on the biological soil fertility index [Table 8]. A high biochemical soil fertility index value indicates the possibility of generating high perennial legume cultivation yield and maintaining good soil culture.[49] The enzymes in the soil mainly come from the microbes, excrements (from human and animals) and plant roots, and the increase of their activities reflects improvement in soil qualities such as physical and chemical properties, which are indicative of soil fertility.[50]

CONCLUSION

The study shows that 13 years of *A. lebbeck* cover have significant effects on some soil physicobiochemical properties. The plantation cover effect increases in mineral in N, P, K, org. C, and organic matter, also increased the activities of dehydrogenase, urease, and phosphatase enzymes, which would enhance plant growth and boost soil fertility. The Cu and Mn contents indicated on treats on human and environmental health. However, the concentration of Cr seemed slightly above minimum benchmark, which could pose serious treats to human and environmental health.

REFERENCES

1. Egeru A, Majaliwa JG. Land use/cover change trend in Soroti district in Eastern Uganda. J Appl Sci Environ Manage 2009;13:77-9.
2. Leita L, de Nobili LL, Mondicini M, Muhlbachona G, Contin M. Influence of organic fertilization and soil microbial biomass, metabolic quotient and heavy metal bioavailability. Biol Fertil Soils 1999;28:371-6.
3. Kuzyakov Y, Biryukova OV, Kuznetzova TV, Mölter K, Kandeler E, Stahr K. Carbon partitioning in plant and soil, carbon dioxide fluxes and enzyme activities as affected by cutting ryegrass. Biol Fertil Soils 2002;35:348-58.
4. Huygens D, Boeckx P, Van Cleemput O, Oyarzun CE, Godoy R. Aggregate and soil organic carbon dynamics in south Chilean andisols. Biogeosciences 2005;2:159-74.
5. Chen CR, Xu ZH. Soil carbon and nitrogen pools and microbial properties in a 6-year-old slash pine plantation of subtropical Australia: Impacts of harvest residue management. For Ecol Manage 2005;206:237-47.
6. Trasar-Cepeda C, Leirós MC, Seoane S, Gil-Sotres F. Biochemical properties of soils under crop rotation. Appl Soil Ecol 2008;39:133-43.
7. OECD. Environmental Performance of Agriculture in OECD Countries Since 1990. Paris, France: OECD; 2008. p. 10.
8. Huffman T, Coote D. Soil cover in Canada. In: Eilers W, Mackay R, Graham L, Lefebvre A, editors. Environmental Sustainability of Canadian Agriculture. Ottawa: Agriculture and Agric-Food Canada; 2010. p. 31-5.
9. Labiru MA, Binbol NL. Analysis of Solar Radiation and Sunshine Hours at the University of Jos Meteorological Station, Bauchi Road Campus Jos-Plateau State. In: International Conference proceedings of Nigeria Meteorological Society Held in Sokoto State, Nigeria 23rd-26th Nov; 2015. p. 91-2.
10. Kareem IA. Soil chemical properties as influenced by *Albizia lebbeck* Benth (Rattle Tree) under agri-silvicultural system (alley cropping) with *Solanum tuberosum* Linn. (Potato). Donnish J Hortic Forest 2015;1:1-11.
11. Blake GR, Hartge KH. Bulk density. In: Klute A, editor. Methods of Soil Analysis, Physical and Mineralogical Methods. Madison, WI, USA: ASA; 1986. p. 363-75.
12. Van Reewijk LP. Procedures for Soil Analysis. 3rd ed. Wageningen, Netherlands: International Soil Reference Center (ISRIC); 1992.
13. Brandy NC, Weil RR. Elements of the Nature and Properties of Soils. 3rd ed. Boston: Prentice Hall; 2010.
14. Rhoades JD. Salinity: Electrical conductivity and total dissolved solids. In: Sparks DL, editor. Methods of Soil Analysis: Chemical Methods. Part 3. Madison, WI: Soil Science Society of America; 1996.
15. Burt S. Essential oils: Their antibacterial properties and potential applications in foods-a review. Int J Food Microbiol 2004;94:223-53.
16. Ball DF. Loss on ignition as an estimate of organic matter and organic carbon in non-calcareous soils. J Soil Sci 1964;15:84-92.
17. Jackson ML. Soil Chemical Analysis. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973. p. 38-56.
18. Habtamu FG, Negussie R, Gulelat DH, Ashagrie ZW. Nutritional quality and health benefits of okra (*Abelmoschus Esculentus*): A review. Global J Med Res 2014;14:28-37.
19. da Silva EB, Li S, de Oliveira LM, Gress J, Dong X, Wilkie AC, *et al*. Metal leachability from coal combustion residuals under different pHs and liquid/solid ratios. J Hazard Mater 2018b;341:66e74.
20. Chapman HD. Cation-exchange Capacity. In: Black CA, editor. Method of Soil Analysis, Part 2: Chemical and Microbiological Properties. Madison, Wisconsin: American Society of Agronomy; 1965. p. 891-900.
21. Asadu CL, Dixon AG, Ajogu GM, Ugadu M, Edeh I. Comparison of the suitability of contiguous fallow-forest lands for cassava, yam, cocoyam and sweet potato production in Nsukka, Southeastern Nigeria. Path Sci Int Electron Sci J 2017;3:1-12.
22. Alef K, Nannipieri P. Enzyme activities. In: Alef K, Nannipieri P, editor. Methods in Applied Soil Microbiology and Biochemistry. London: Academic Press; 1995.
23. American Society of Anesthesiologists. American Society of Agronomy Plant and Soil Environ. United States: American Society of Anesthesiologists; 2007.
24. Kalembasa S, Symanowicz B. Enzymatic activity of soil after applying various waste organic materials, ash, and mineral fertilizers. Pol J Environ Stud 2012;21:1635-41.
25. Sabba RN. Soil Microbiology: Soil Micro-organism and Plant Growth. New Delhi: Oxford Publisher; 1995. p. 509.
26. Efroymson RA, Will ME, Suter GW II, Wooten AC. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. United States: ES/ER/TM-85/R3.U.S. Department of Energy, Office of Environmental Management; 1997. p. 123.
27. Renella G, Ortigoza AL, Landi L, Nannipieri P. Additive effects of copper and zinc on cadmium toxicity on phosphatase activities and ATP content of soil as estimated by the ecological dose (ED 50). Soil Biol Biochem 2003;35:1203-10.
28. Geiger G, Brandi H, Furner G, Schulin R. The effect of copper on the activity of cellulose and b-glucosidase in the presence of montmorillonite or Al-montmorillonite. Soil Biol Biochem 1998;30:1537-44.
29. Bi Y, Zhang Y. Role of the different planting age of seabuckthorn forests to soil amelioration in coal mining subsidence land. Int J Coal Sci Technolol 2014;1:192-7.
30. Gonnety JT, Assémien EF, Guéi AM, N'Dri AA, Djina Y, Koné AW, *et al*. Effect of land-use types on soil enzymatic activities and chemical properties in semi-deciduous forest areas of Central-West Cote d'Ivoire. Biotechnol Agron Soc Environ

2012;16:478-85.
31. Brallier S, Harrison RB, Henry CL, Dongsen X. Liming effects on availability of Cd, Cu, Ni and Zn in a soil amended with sewage sludge 16 years previously. Water Air Soil Pollut 1996;86:195-206.
32. Ibrahim AK. Rattle tree (*Albizia lebbeck)* effects on soil properties and productivity of Irish potato (*Solanum tuberrosum)* on the Jos Plateau, Nigeria. Ratar Povrt 2003;2:141.
33. Naidu R, Bolan N. Contaminant chemistry in soils: Key concepts and bioavailability. Chem Bioavailabil Terrestrial Environ 2008;9:38.
34. Alamgir M, Islam M, Hossain N, Kibria MG, Rahman MM. Assessment of heavy metal contamination in urban soils of Chittagong city, Bangladesh. Int J Plant Soil Sci 2015;7:362-72.
35. Chen M, Ma LQ, Harris WG. Baseline concentrations of 15 trace elements in Florida surface soils. J Environ Qual 1999;28:1173-81.
36. Chandrakar V, Verma P, Jamaluddin. Removal of Cu and Zn by fungi in municipal sewage water. IJABR 2012;2:1-4.
37. Mishra UK, Sahu SK, Mitra GN, Das R. Effect of sulphur and lime on yield and oil content of Kharif groundnut grown in Haplaquept. J Indian Soc Soil Sci 1990;38:772-4.
38. Holtan-Hartwig L, Bechmann M, Hoyas TR, Linjordet R, Bakken LR. Heavy metals tolerance of soil denitrifying communities: N2O dynamics. Soil Biol Biochem 2002;34:1181-90.
39. Majer BJ, Tscherko D, Paschke A, Wennrich R, Kundi M, Kandeler E, *et al*. Effects of heavy metal contamination of soils on micronucleus induction in *Tradescantia* and on microbial enzyme activities: A comparative investigation. Gen Toxicol Environ Mutage 2002;515:111-24.
40. Galli U, Schuepp H, Brunold C. Heavy metal binding by mycorrhizal fungi. Physiol Plant 1994;92:364-8.
41. Lasat MM, Baker AJ, Kochian LV. Altered Zn compartmentation in the root symplasm and stimulated Zn absorption into the leaf as mechanisms involved in Zn hyperaccumulation in *Thalspi caerulescens*. Plant Physiol 1998;118:875-83.
42. Wyszkowska J, Kurcharski J, Lajszner W. The effects of copper on soil biochemical properties and its interaction with other heavy metals. Polish J Environ Stud 2006;15:927-34.
43. Burns RG. Soil Enzymes. London, UK: Academic Press; 1978.
44. Yang Z, Liu S, Zheng D, Feng S. Effects of cadmium, zinc, and lead on soil enzyme activities. J Environ Sci 2006;18:1135-41.
45. Pruvot C, Douay F, Herve F, Waterlot C. Heavy metals in soils, crops and grass as a source of human exposure in the former mining areas. J Soil Sediment 2006;6:215-20.
46. Zhuang P, Zou B, Li NY, Li ZA. Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: Implications for human health. Environ Geochem Health 2009;31:707-15.
47. Huang Q, Shindo H. Effects of copper on the activity and kinetics of free and immobilized acid phosphatase. Soil Biol Biochem 2000;32:1885-92.
48. Khan S, Cao Q, Hesham AE, Xia Y, He J. Soil enzymatic activities and microbial community structure with different application rates of Cd and Pb. J Environ Sci 2007;19:834-40.
49. Hu C, Cao Z. Size and activity of the soil microbial biomass and soil enzyme activity in long-term field experiments. World J Agric Sci 2007;3:63-70.
50. Liu YM, Yang HY, Li XR, Xing ZS. Effects of biological soil crusts on soil enzyme activities in revegetated areas of the Tengger Desert, China. Appl Soil Ecol 2014;80:6-14.