

Effect of forest species on soil nutrient stocks in derived savannah ecosystem, in Abeokuta, southwest Nigeria

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Abstract

The study aims to determine the impact of forest tree species on some soil properties and soil nutrient stocks. Triplicate soil samples were collected from mono species tree clusters consisted of *Gmelina arborea*, *Bambusa vulgaris*, *Treculia africana*, were selected with arable crop farm, fadama and organic farm and analyzed for some soil chemical properties and nutrient stocks at 0–20 cm, 20–40 cm, 40–60 cm and 60–80cm using standard procedures. Results indicated that soil organic matter under the different tree types are concentrated between 0–20 cm and 20–40 cm. There was increase in soil pH, electrical conductivity, organic matter, hydraulic conductivity and bulk density at 20–40 and 40–60 cm depths. Soil nutrient stocks (sulphate, phosphate and nitrates) are concentrated at depths 20–40 cm and 40–60 cm. On the average soils accumulated $75.57 \text{ Mg PO}_4^{3-} \text{ ha}^{-1}$, $56.19 \text{ Mg SO}_4^{2-} \text{ ha}^{-1}$ and $37.57 \text{ Mg NO}_3^- \text{ ha}^{-1}$. Soils under tree plantations had higher nutrient stocks compared with the non-tree land use, with *Bambusa vulgaris* having the highest accumulation of nutrients. Tree species improved soil properties and nutrient stocks than the non-tree land use. *Treculia africana* and *Bambusa vulgaris* had higher soil nutrient stocks than other land use.

Introduction

The practice of growing trees as commercial woodlots in land fallow systems (Azeez, 2019) or as component of agroforestry system has been an age long practice due to its beneficial effects on the economy of the farmers, soil nutrient rejuvenation and the mitigation of the effects of greenhouse gases (Gautam, 2002). The over-exploitation of the trees in the wild and those in managed arboreal systems have exacerbated global warming and hence, the justification of the global advocacy to replace trees where harvest have been made. This has given rise to the compensation of strict compliance to the practice of afforestation REDD+ (Reducing Emissions from Deforestation and Forest Degradation). Growing of trees for timber or as component of agroforestry system with the aim to sequester carbon, enhance forest carbon stocks, and improve the supply of forest products is very popular globally and it's been promoted even among rural dwellers. The practice is hinged on the ability of the trees to accumulate large biomass from atmospheric carbon. The C accumulated in the trunks and leaves which are eventually buried and kept safe in the soil. About $0.29\text{--}15.21 \text{ Mg ha}^{-1} \text{ year}^{-1}$ have been reported as the potential contribution of agroforestry to carbon accumulation in the soil (Dhyani, 2020). This is the scientific basis for carbon sequestration by trees but most research work have focused mainly on the carbon dynamics in the atmosphere and trees' system but very few has made attempts to document the contribution of the grown trees to other important soil nutrients.

Agroforestry systems on the other hand have been reported to have indirect positive effects on carbon sequestration (Magar et al 2020). This is basically due to the reduction in the harvest pressure on natural forests. Incorporation of trees and shrubs in food crop systems have assisted immensely in reduction of food insecurity, increasing carbon dioxide sequestration, and reducing the vulnerability of agricultural systems.

Apart from the deliberate planting of leguminous trees in agroforestry systems for the purpose of fertilizing the adjoining farming plots with their foliage, none or at best few studies have focused on the contribution of the commercial timber species to soil nutrient rejuvenation. This is particularly important in farming communities that cultivate in the wild and that insists on not destroying existing tree stands on their farm as long as it is not obstructing their farming activities.

Due to the high pressure on forest and the resource exploitation eg., FAO (2010) reported an estimate of 13 million hectares per year of trees are were loss between 2000 and 2010, the amount could have increased in 2022. The continuous increase in the demand for timber and other forest products, have significantly increased the rate of the depletion of natural forest and thus, many countries have endorsed commercial plantation establishment as an alternative to reduce the pressure on natural forest (Liu, 2018). Consequently, Asare et al. (2020) reported that vast areas

of degraded forest lands globally are being converted into plantations of different tree species (both indigenous and exotic) in single or mixed species stands.

Soil nutrient management and their improvement is an important goal for the farmers that intend to benefit from the input from the trees' biomass to the soil. It has been reported that typical forest soils are a major sink of terrestrial carbon (and probably other nutrients), containing more than double the amount of carbon found in forest tree biomass (Zheng et al, 2008; Scharlemann, 2014). However, the monitoring of tree ages, biomass and nutrient deposition under different woodlands are important because they provide information on forest use that is important in the management decisions to ensure sustainability, as recently done in Tanzania (Manyanda, 2019). Consequently, the objective of this study was to determine the impact of forest tree species of varying ages on some soil properties and soil nutrient stocks.

Materials And Methods

Site description

The study was carried out in Abeokuta, the sites are generally undulating while the original vegetation of the area was derived savannah. Information about some of the study sites have been reported by Azeez, (2019). Except that the *Gmelina arborea* Roxb., plot is a privately-owned plantation, established in 2012 on a gently sloppy terrain without any history of fertilization. For the purpose of comparing the forest land uses with other agricultural land uses, arable crop plots, organic farm and a fadama land uses were also included in the study. The arable land has been in use since 1998 for the cultivation of maize and cassava, there have been years when the plots were left to fallow. The plot also has occasional application of NPK 20-10-10 fertilizer at approximately 100 kg ha⁻¹. However, there was no history of fertilizer use on the plot more than two years prior this study. The organic farm was the same used by Azeez et al., 2018; established in 2007 with no history of inorganic fertilizer and pesticide application. The organic materials mostly used are cured poultry manure and compost (made from poultry manure or cow dung, plant debris, and kitchen waste); the pests are controlled by applying organic bio-pesticides. The fadama is a gently sloping plot that is hydromorphic, the lowest portion of the land scape is completely inundated in water in the rainy season and used for dry season vegetable farming in the dry season when the water would have drained out. The sampling for this study is done in the dry period at the upper slope of the terrain. The arboreal land use type is made up of monospecie plantation of the individual tree types (*Gmelina arborea* Roxb., *Bambusa vulgaris* Schrad. Ex Wendl., *Treculia Africana*, Decne.). The trees have established a continuous cluster of trees with litter of the same tree on the ground of the canopy formed by the tree cluster. For each of the landuse there were control plots on the same soil type but adjacent the individual land uses. The control plots were dominated by several shrubs and grasses; *Chromola odorata* (L.) R.M. King & H. Rob. is the dominant fallow species.

Climate, Soil Sampling And Analysis

The study sites have a typical tropical climate with two peaks of rainy season (March to July and from September to October) and the dry season, which is usually from November to February. The average annual rainfall of the study area, is about 1059 mm. Other details of the climatic parameter are reported in Azeez, (2019).

Soil samples were collected from the middle of the plantation and other land uses and also at the respective control plots. The details of the land use are shown in Table 1. Samples are collected using a stainless bucket type auger at 0-20cm; 20–40 cm; 40–60 cm and 60–80 cm depths. The systematic sampling of three replicates were done carefully to avoid cross contamination of samples. The collected samples were air-dried and sieved with 2 mm screen for further laboratory analyses. On the same plot, undisturbed soil samples were also taken insitu at the depths mentioned earlier with a cylindrical core sampler with height of 5 cm and a diameter of 5 cm and used for bulk density determination as described by Grossman and Reinsch (2002). Bulk density was determined using the undisturbed core sampling method of Okalebo

et al. (2002). Bulk density, Db ($\text{g}\cdot\text{cm}^{-3}$), was calculated as the relationship between dry soil mass and total ring volume as: $Db = M / V$ where: Db = Bulk density ($\text{g}\cdot\text{cm}^{-3}$); M = Dry weight of the core sample (g); V = Volume of the soil core (cm^3). The soil saturated hydraulic conductivity was measured using the constant head method (Reynolds et al., 2002).

Table 1
Land Use types, year of establishment, locations and their coordinates

Land Use	Year of Establishment	Latitudes	Longitudes	Altitude* (m)
<i>Gmelina arborea</i>	2012	N7° 14' 39.44"	E3° 27' 40.25"	157
<i>Gmelina arborea</i> (Control)	NA	N7° 14' 35.11"	E3° 26' 28.12"	155
Bamboo (<i>Bambusa vulgaris</i>)	1990	N7° 13' 40.41"	E3° 26' 52.92"	160
Bamboo (Control)	NA	N7° 13' 37.63"	E3° 27' 16.26"	158
Arable crops landuse	1998	N7° 14' 10.26"	E3° 26' 14.14"	151
Arable landuse (Control)	NA	N7° 14' 15.94"	E3° 26' 16.64"	149
<i>Treculia africana</i>	2001	N7° 13' 40.50"	E3° 26' 52.22"	167
<i>Treculia africana</i> (control)	NA	N7° 13' 40.94"	E3° 26' 52.62"	157
Organic farm	2007	N7° 14' 03.94"	E3° 26' 3.84"	171
Organic farm (control)	NA	N7° 14' 14.91"	E3° 26' 16.42"	165
Fadama	2005	N7° 14' 10.20"	E3° 26' 12.20"	159
Fadama (control)	NA	N7° 14' 10.10"	E3° 26' 12.30"	161
NA = Not applicable; * Above sea level				

The prepared soil samples were analyzed for pH in a 1:2 soil to water ratio using a glass electrode attached to a digital pH meter (McLean et al., 1982). The electrical conductivity (EC) of the soils was measured in 1:5 soil/water extract and converted into the saturated extract value by multiplying the value by 5 (Kaira and Maynard 1991). Particle size distribution was determined by the hydrometer method as described by Bouyoucos (1962). Total organic carbon (TOC) was determined using acid dichromate wet oxidation procedure as reported by Nelson and Sommer (1996). Available phosphate-phosphorus (P) was extracted by Bray-1 procedure (Bray and Kurtz 1945) and determined colorimetrically using a spectrophotometer by measuring the absorbance at 880 nm wavelength. Soil nitrate-nitrogen was determined spectrophotometrically by extracting with K_2SO_4 ; for the colorimetric determination, salicylic acid solution and NaOH were added and read on a spectrophotometer at 410 nm. The sulphur in the soil samples were extracted as $\text{SO}_4\text{-S}$ by using $\text{CaCl}_2\cdot 2\text{H}_2\text{O}$. The extracts were allowed to form turbid solution by the addition of BaCl_2 . The turbidity of the solutions was read at 410 nm on a UV-visible spectrophotometer and the concentration of the sulphate was calculated.

Soil nutrient stock computations were made by using equations adapted from Chave et al. (2014) and Adu-Bredu et al. (2010).

Soil nutrient stock (SNS) was calculated according to a modified formular of FAO (2019) as:

$$\text{SNS (Mg nutrient ha}^{-1}\text{)} = \text{SOQ} \times Q_b \times Z \times 0.1$$

where:

SOQ = soil nutrient content ($\text{mg nutrient g}^{-1}$ fine earth) of the fine earth fraction (< 2 mm) in the

depth increment “i”.

Z = soil depth or the thickness of the soil horizon (cm) of the depth increment “i”.

Q_b = bulk density (mass of fine earth per total volume of the soil sample = mass (g) of fine earth / total volume of soil sample (cm^3) in the depth increment i).

0.1 is a factor for converting $\text{mg nutrient cm}^{-2}$ to $\text{Mg nutrient ha}^{-1}$.

Statistical Analyses

Data generated were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS) software, (SAS, 2016) and significant treatment means separation was done using Duncan Multiple Range Test at 5% level of probability.

Results And Discussion

The effect of soil depth on the pH and electrical conductivity (EC) of the soils is shown in Table 2. The means indicated that the different land uses had the soil pH not differentiated across the soil depths except at the *G. arborea* landuse where the soil depth at 60–80 cm had significantly lower pH compared with other depths. Generally, across the landuse the surface depths seem more basic in reactions, particularly in the landuse with tree plantation. The landuse with annual crops are more acidic and this could be due to the leaching of basic cations from the soil and nutrient extraction and migration by the harvested part of the grown crops. The droppings from the forest tress (leaves, twigs, dead trunks etc.) could have served as the liming material for the surface and sub surface soils in these plantations. Similar increase in soil pH have been reported by Azeez and Van-Averbeke (2012) with the addition of organic manure to soil in incubation, (though the effect of the manures here reported might be more intense because of the higher reactivity of manures compared with leaf litters), several mechanisms or combinations have however been propounded for this effect. It ranges from proton consumption by functional groups associated with the organic materials (Wong et al., 1998), proton consumption during decarboxylation of organic acid anions, at decomposition (Yan et al., 1996), specific adsorption of organic molecules by ligand exchange with the release of OH^- (Hue et al., 1986), and the release of OH^- ions during reduction reactions associated with localized anaerobic microsites. Eghball (1999) and Whalen et al. (2000) have also reported that increase in pH due to manure application was due to the buffering effect from CaCO_3 in manures. Amongst the forest land use, *Bambusa vulgaris* plantation is more acidic and this is perhaps due to the ecology of the plantation. The *Bambusa vulgaris*, here reported, are grown in a waterlogged area, close to a seasonal stream. This could have resulted in the seasonal leaching and runoff of basic cations and hence the acidification of the soil layers.

Table 2
Variations in soil pH and electrical conductivity of different land use with soil depth

<i>Variation of soil pH across soil depth</i>						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	7.95 a	7.48 a	6.18 a	8.18 a	6.47 a	7.78 a
20–40	7.88 a	7.77 a	6.20 a	7.70 a	6.55 a	7.28 b
40–60	7.73 a	7.48 a	6.15 a	7.82 a	6.93 a	7.92 a
60–80	7.68 a	7.42 a	6.42 a	7.15 b	6.72 a	8.05 a
Soil electrical conductivity (EC) dS/m						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	116.67a	138.33 a	111.67 a	116.67 a	183.33 a	116.67 a
20–40	90.00 a	151.67 a	88.33 a	113.33 a	123.33 b	98.33 b
40–60	78.33 a	98.33 b	98.33 a	108.33 a	88.33 c	103.33 ab
60–80	83.33 a	85.00 b	70.00 a	83.33 b	81.67 c	91.67 b
Means with the same letters along the same column under the same parameter are not significantly different (p < 0.05)						

The amount of dissolved salts in the soil as measured by soil electrical conductivity (EC), also shown in the Table, indicated that most of the salts are concentrated at the soil surface depths. Across the forest landuse, the EC values up to 60 cm soil depths is still significantly higher than lower depth and comparable to the surface depths. The soil depths have no effect on soil EC under the arable crop landuse and fadama while the EC at the 40–60 cm and 60–80 cm depths are significantly similar to the surface depths. The deposition of plant materials and the subsequent mineralization and the addition of emanating salts to the soil would have impacted an increase on the soil EC. Materials deposited through plant biomass from the tree landuse could be responsible for the higher EC while the constant addition of manures from plant and animal sources could be responsible for the higher EC at surface depths in the fadama and organic farms.

In Table 3, there is evidence of deposition of organic matter at the surface soil depths in all the landuse. It thus, showed that the leaching of soil organic materials in the soils are not yet pronounced, at least not beyond 40 cm depth. The least amount of soil organic matter is recorded at the 80 cm depth. This reason for the pattern of variation could be similar to that expounded earlier for the soil EC and pH. Similar result of decreasing soil OM with soil depth was reported by Magar and Aryal, (2020). Soils with rich organic carbon levels generally indicate high fertility, and therefore, it is important to maintain its optimum level adequate land use and management practices (Dahal and Bajracharya, 2013). Gautam and Mandal (2013) also reported a decreasing trend of soil organic carbon with increased depths of soil in a tropical moist forest in Nepal. Similarly, Song et al., (2016), reported that the concentrations of soil organic carbon decreased with depth, and the greatest concentration was in the 0–10 cm topsoil in selected forests of China.

Table 3
Variations in soil organic matter and clay content of different land use with soil depth

Soil organic matter (%)						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	1.17 a	2.26 a	1.83 a	2.26 a	2.15 a	2.53 a
20–40	0.74 b	2.11 a	1.17 ab	2.26 a	1.51 b	2.43 a
40–60	0.81 b	1.43 b	1.32 ab	2.30 a	0.93 c	2.22 a
60–80	0.93 ab	1.32 b	0.77 b	1.91 b	0.77 c	2.45 a
Soil clay content (g kg⁻¹)						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	24.00 a	94.33 d	130.00 a	94.33 d	97.17 d	94.33 d
20–40	37.00 c	165.33 c	120.00 a	130.33 c	127.00 c	165.33 c
40–60	49.17 b	191.67 b	141.67 a	151.67 b	145.00 b	191.67 b
60–80	71.17 a	232.00 a	130.00 a	178.67 a	163.67 a	232.00 a
Means with the same letters along the same column under the same parameter are not significantly different (p < 0.05)						

Expectedly, there is an evidence of clay eluviation in the soils. The movement of soil clay is pronounced in the soils irrespective of the land use. In most of the landuse studied most of the lowest amount of clay was recorded at the 0–20 cm depths. Soil clay eluviation is a known pedological process that happens in soil, particularly, older soils, as a result of the movement of the clay separates with soil water and the subsequent deposition at lower depths. In this study the materials deposited the by trees and those added by the organics applied seems not have effect at moderating this movements.

The hydraulic conductivity (HC) of the soil is a measure of its ability to transmit water under saturated or nearly saturated conditions. This is shown in Table 4. It is evident that the soil HC are higher at the surface depths compared with the subsurface soil depths. The arable crop landuse, fadama, *Gmelina arborea* plantation soil and organic farm had higher HC at 0-20cm depth compared with deeper soil layers, a contrast of this trend was however, observed at *Bambusa vulgaris* and *Treculia africana* tree plantations. The movement of clay down the profile would have made the upper soil layers more porous (by the increase in sand and silt fractions) and hence allow the flow of water faster than the lower depths that are higher in clay amount, as reported earlier.

Table 4
Variations in soil hydraulic conductivity and bulk density of different land use with soil depth

Soil hydraulic conductivity (cm hr^{-1})						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	8.59 a	1.65 b	2.25 b	2.29 a	2.53 a	5.56 a
20–40	2.16 b	4.99 ab	3.51 a	2.13 ab	0.67 b	6.92 a
40–60	4.12 ab	7.82 ab	0.22 c	0.97 b	0.64 b	5.58 a
60–80	6.69 ab	9.12 a	0.27 c	0.89 b	1.02 b	8.16 a
Soil bulk density (g cm^{-3})						
Depth (cm)	Arable landuse	<i>Bambusa vulgaris</i>	Fadama	<i>Gmelina arborea</i>	Organic farm	<i>Treculia africana</i>
0–20	1.63 a	1.11 a	1.35 b	1.38 a	1.35 a	1.40 a
20–40	1.59 a	1.35 a	1.47 a	1.33 a	1.41 a	1.29 b
40–60	1.50 a	1.29 a	1.11 c	1.29 a	1.35 a	1.35 ab
60–80	1.48 a	1.23 a	1.14 c	1.28 a	1.16 b	1.31 ab
Means with the same letters along the same column under the same parameter are not significantly different ($p < 0.05$)						

The Table also showed that the bulk density of the soils under the different land uses are higher at the surface layers. The additions from the plant biomass seems not to have effect on the reduction of the soil bulk density at the surface layers. The higher values might be due to human and animal traffic on these land uses. It however means nutrient concentrations are expectedly supposed to be higher at these depths compared with the layers at the subsurface depths.

The soil nutrient stocks as affected by the soil depths among the different landuse types are shown in Figs. 1, 2 and 3. In Fig. 1, there is the gradual increase in soil nitrate-nitrogen stock with increase in soil depth. The migration of the soil NO_3 could be partly due to the soil texture and the high solubility of soil nitrates. There were no significant differences in the soil nitrates amongst the different soil depths in the *Bambusa vulgaris* and fadama landuse. Across the land use, soil depth 40–60 cm seems to have the highest concentration of the soil nitrates. This implies that the vegetations, particularly the tree species would have enough NO_3 for uptake because of their deep rooting system, however, this scenario is a lost to the arable plants /crops grown in the arable and fadama land use because the rooting zone of most arable crops does not extend beyond 30 cm. The sources of the nitrate could be the mineralization of the plant biomass deposited by the various trees grown on the plots and the organic materials applied to the organic farm. The soil accumulation of nitrate across soil depths was in the order: Fadama > *Gmelina arborea* > arable crop farm > *Bambusa vulgaris* > organic farm > *Treculia africana* plantation. Specifically, the high amount of nitrate in the fadama could be due to the surface deposition of organic materials and their subsequent mineralization and surface loss of fertilizer materials from the farming activities in the early season, similar reason could be attributed to the high nitrate in the arable farmland. However, those in the plantations is majorly due to the litterfalls decay in these plantations and occasionally from cattle fecal materials deposited during dry season grazing of understory vegetations.

The soil P stocks is shown in Fig. 2. Here, it was observed that there were no significant differences in the soil P stock between the depths under arable crop farm and *Treculia africana* plantation landuse. Across the land use, significant proportion of the soil P stock is concentrated in the 20–40 and 40–60 cm depths. *Bambusa vulgaris* plantation had the highest concentration of the soil P, followed by *Treculia africana* > *Gmelina arborea* > fadama > organic and least in arable crop farm. For all the land use there were no statistical difference between the P values at 20–40 cm and 40–60 cm but there were clear evidence of soil P migration to lower depths, at least up to 60 cm of the profile. The concentration of the soil at 60 cm depth thus shows the availability of P for the nutrition of the tree crops.

In Fig. 3, the soil sulphate-sulphur stock are shown to be concentrated at lower soil depths across all the landuse. The sulphur stock observed are concentrated at the 40–60 cm depth, while the order of sulphate-sulphur accumulation in the land use are: *Bambusa vulgaris* > *Treculia africana* > Fadama > arable crop farm > organic farm > *Gmelina arborea* plantation.

The data shown in the Figs. 1–3 shows that the nutrient stocks across land use types and depths are in the order: PO_4^{3-} > SO_4^{2-} > NO_3^- . Indicating that nitrate is the least nutrient stock in the soils. This could be due to the high solubility of nitrates; perhaps excess nitrate had been leached beyond the soil depths considered in this study. Nitrogen absorbed as nitrate is also a major plant nutrient for all plants and usually the amount uptake by plants is usually very high. These could have been some of the reasons for the relatively lower amount of nitrate compared with phosphate and sulphate. On comparing the land use types in terms of nutrient stocks, there were more nutrient stocks in *Bambusa vulgaris* and *Treculia africana* plantations, followed by fadama and least in organic farm landuse. Earlier studies have reported that soils under Bamboo is relatively more fertile compared with some other forest landuse considered in the reported research (Azeez 2019).

The net effect of the individual land use over their control plots is shown in Table 5. The data indicated that soils under *Gmelina* and *Treculia* plantations were acidified while those of the organic farm are more alkaline over their control plots. There were more dissolved salts in the soils of the land uses than those of their control plots. Similarly, organic matter content and hydraulic conductivity of the soils under the different land use were significantly higher than those of their control plots. In all the landuse except the fadama, there were significantly higher nutrient (N, P, S) stock over the values observed in the control plots. As discussed earlier, it could have been due to the deposition from tree biomass, organic inputs and the fecal input from cattle grazing in the plantations.

Table 5
Effect of different land uses on soil properties

	pH	Electrical conductivity	Organic matter	Clay	Hydraulic conductivity	Bulk density	Sulphur stock	Phosphorus stock	Nitrate stock
		dS/m	%	g kg ⁻¹	cm hr ⁻¹	g cm ⁻³	(Mg ha ⁻¹)		
Arable crops landuse	7.73 a	100.83 a	1.10 a	42.25 b	6.54 a	1.51 a	55.36 a	83.75 a	43.58 a
Control	7.89 a	83.33 a	0.73 b	48.42 a	4.23 a	1.59 a	41.03 b	42.33 b	30.12 b
<i>Bambusa vulgaris</i>	7.58 a	170.00 a	2.55 a	186.25 a	6.85 a	1.20 a	77.86 a	131.26 a	36.18 a
Control	7.49 a	66.67 b	1.01 b	155.42 b	4.94 b	1.28 a	58.56 b	67.94 b	27.76 b
Fadama	6.24 a	112.50 a	1.60 a	112.50 b	2.00 a	1.23 a	54.45 a	86.24 a	29.83 b
Control	6.23 a	71.67 a	0.95 b	148.33 a	1.12 b	1.30 a	71.49 a	52.13 b	59.77 a
<i>Gmelina arborea</i>	7.43 b	133.33 a	2.63 a	136.25 a	1.82 a	1.37 a	54.14 a	97.54 a	47.04 a
Control	7.99 a	77.50 b	1.73 b	141.25 a	1.32 a	1.27 a	39.67 b	60.43 b	31.83 b
Org. farm	7.28 a	153.33 a	1.86 a	137.67 a	1.31 a	1.40 a	62.73 a	92.98 a	43.52 a
Control	6.06 b	85.00 b	0.82 b	128.75 a	1.12 a	1.23 b	31.78 b	24.91 b	30.13 b
<i>Treculia africana</i>	7.48 b	119.17 a	3.09 a	186.25 a	6.68 a	1.43 a	79.29 a	119.35 a	44.25 a
Control	8.04 a	85.83 b	1.63 b	155.42 b	6.42 a	1.25 b	47.87 b	52.52 b	26.85 b
Means with the same letters along the same column under the same landuse are not significantly different (p < 0.05)									

Computations were done (across landuse types) on the changes (Δ) in soil properties at different soil depths with respect to the control plots. The results of the analyses of the variance of the changes is shown in Table 6. The results showed that there were (though not significant) net increases in soil reaction at 20–40 cm and 40–60 cm depths. This implies that the net liming effect of the biomass addition was more pronounced at these two depths while the soil was acidified at the upper most layer and at 60–80 cm depths. Similarly, the soil organic matter content and HC had significantly higher values at the two depths (20–40 cm and 40–60 cm).

Table 6
Variations in changes (Δ) in soil properties with soil depths (Values across land use types).

Depth	Δ pH	Δ Electrical conductivity	Δ Organic matter	Δ Hydraulic conductivity	Δ Bulk density	Δ Sulphur stock	Δ Phosphorus stock	Δ Nitrate stock
(cm)		dS/m	%	cm hr ⁻¹	g cm ⁻³	(Mg ha ⁻¹)		
0–20	-0.08 a	60.00 ab	0.95 ab	1.24 ab	-0.03 b	9.52 b	43.88 b	2.90 a
20–40	0.11 a	75.00 a	1.24 a	3.62 a	0.10 a	14.80 ab	63.35 a	8.74 a
40–60	0.11 a	37.22 c	0.97 ab	3.90 a	0.02 ab	23.80 a	53.37 ab	6.69 a
60–80	-0.11 a	40.56 bc	0.82 b	-1.71 b	-0.07 b	14.23 ab	45.96 b	6.96 a
Means with the same letters along the same column are not significantly different ($p < 0.05$)								

The effect of land use types on the changes in soil pH, organic matter and bulk density (relative to control site and mean across soil depths) is shown in Fig. 4. It is evident that the liming of the soil acidity was most pronounced at the organic farm, while the use of the crops for arable cropping, growing of *Gmelina arborea* and *Treculia africana* acidified the soil. Previous studies by Azeez, (2019) have reported that soils under the two plantations are acidic. There was significantly higher increase in the soil organic matter under *Bambusa vulgaris* and *Treculia africana*, followed by those of organic farm and *Gmelina arborea* plantation and least in arable crop farm. The figure also revealed that the soils under *Bambusa vulgaris*, organic farm and *Treculia africana* had higher bulk densities while the *Gmelina arborea*, fadama and arable crop land resulted in lowering the soil bulk density.

The net changes in the soil nutrient stocks with land use is indicated in Fig. 5, here, it was observed that significant increase in soil nitrate stock with the growing of trees while soils under fadama has net decrease in soil nitrate stock. Similarly, soil from *Treculia africana* plantation, organic farm, *Bambusa vulgaris* plantation had significantly higher P stocks compared with the amounts in arable crop land, fadama and *Gmelina arborea* plantation. Similar trend was observed in the soil S stocks, except that there was significant reduction in the soil S under fadama conditions. Generally, the influx of nutrients into the forest ecosystems have been reported to be a function of rate and quantity of litter falls (Tella et al. 2005., Lawson and Michler 2014). Hence, soils under forest trees are expected to be richer than those from arable crops cultivation that usually record nutrient migration at crop harvest. Additionally, forest species like *Bambusa vulgaris* has tougher litter, high in lignin and carbon and it also persists in the soil, this has a potential of delaying nutrient release (Azeez, 2019., Palm, 1995., Tian et al. 1992., Constantinides and Fownes 1994; Lawson and Michler 2014)

Conclusions

Results from this research have shown that soil organic matter under the different tree types are concentrated between 0–40 cm, the effect of the soil depths on the soil bulk density and hydraulic conductivity was erratic. Soil nutrients (sulphate, phosphate and nitrates) are concentrated at depths 20–40 cm and 40–60 cm. On the average the order of nutrient stocks is: phosphate > sulphate > nitrate while the tree plantations had higher nutrient stocks compared with the non-tree land use, with *Bambusa vulgaris* having the highest accumulation of nutrients.

With respect to their control plots the land uses resulted to soils with higher EC and organic matter and higher nutrient stocks. There was positive changes (increase) in soil pH, EC, organic matter, hydraulic conductivity and bulk density at 20–40 and 40–60 cm depths. The increase in soil nutrient stocks are also higher at these depths. The tree species

impacted more on soil dissolved salts, organic matter bulk density and nutrient stocks than the non-tree land use. *Treculia africana* and *Bambusa vulgaris* had higher soil nutrient stocks than other landuse. Hence the afforestation should be encouraged to boost soil nutrients.

Declarations

Compliance with ethical standards

Conflict of interest: The authors declare that he has no conflict of interest.

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Figures

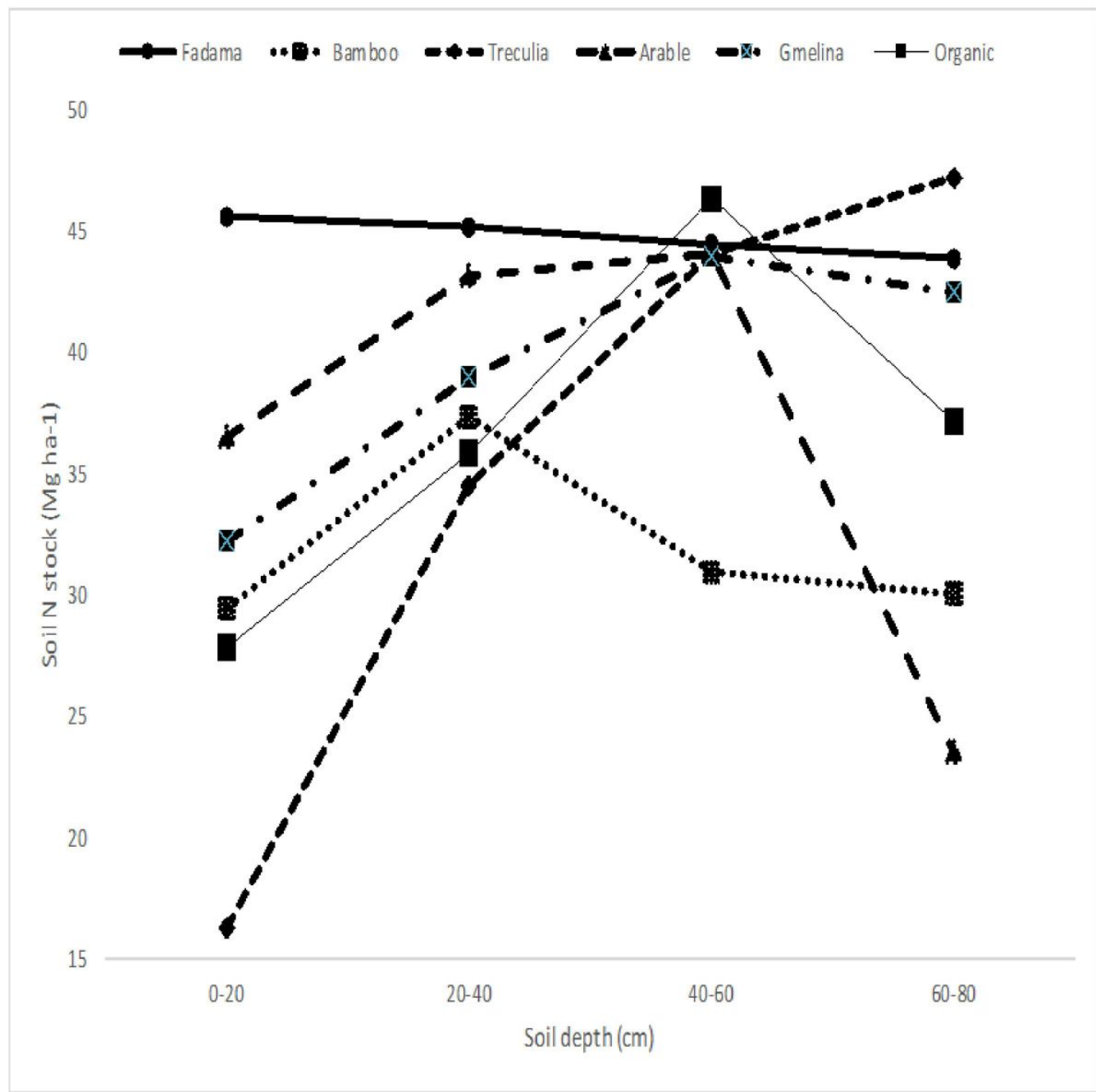


Figure 1

Changes in soil nitrate-nitrogen stock with soil depth

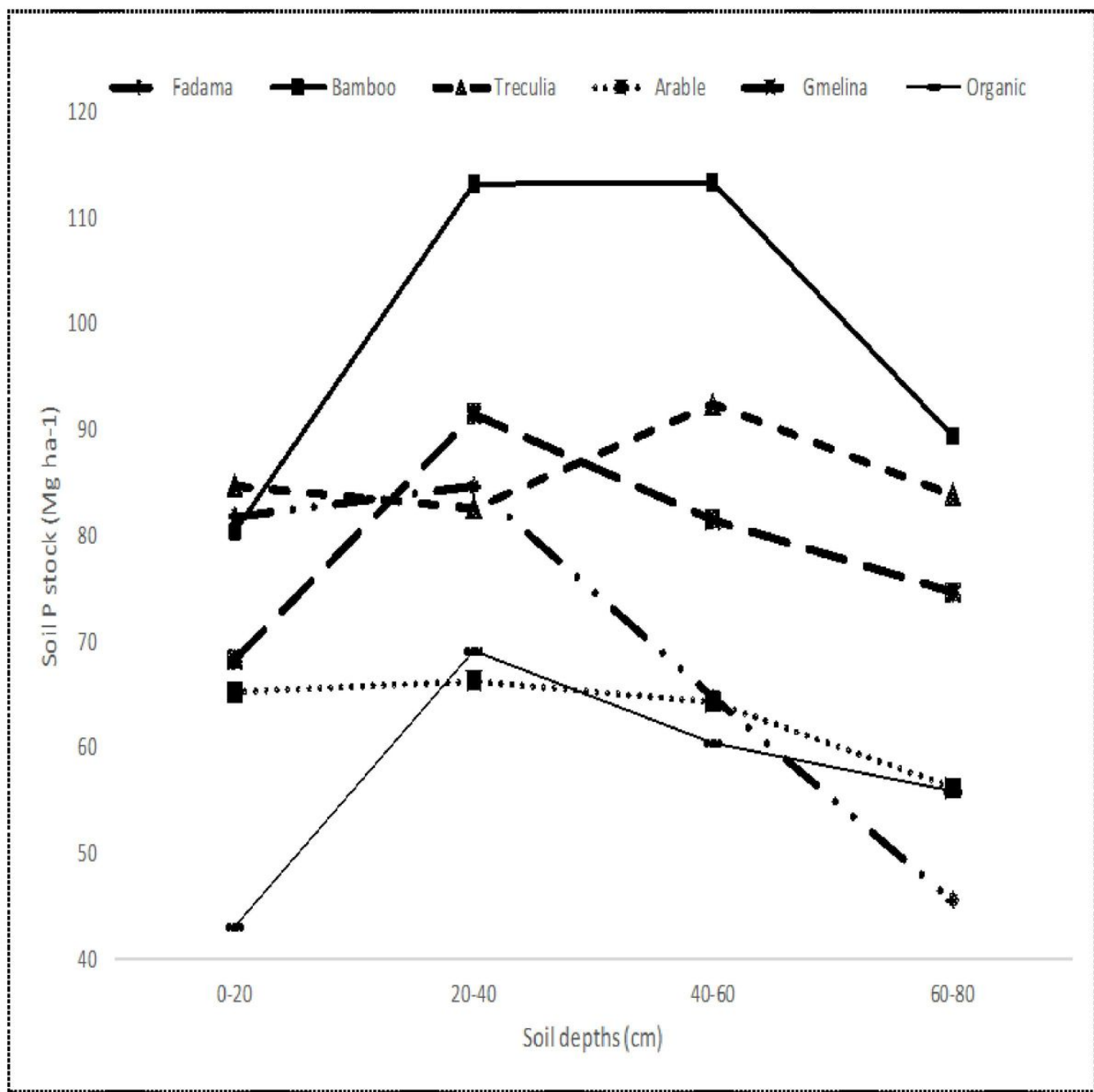


Figure 2

Changes in soil phosphorus stock with soil depth

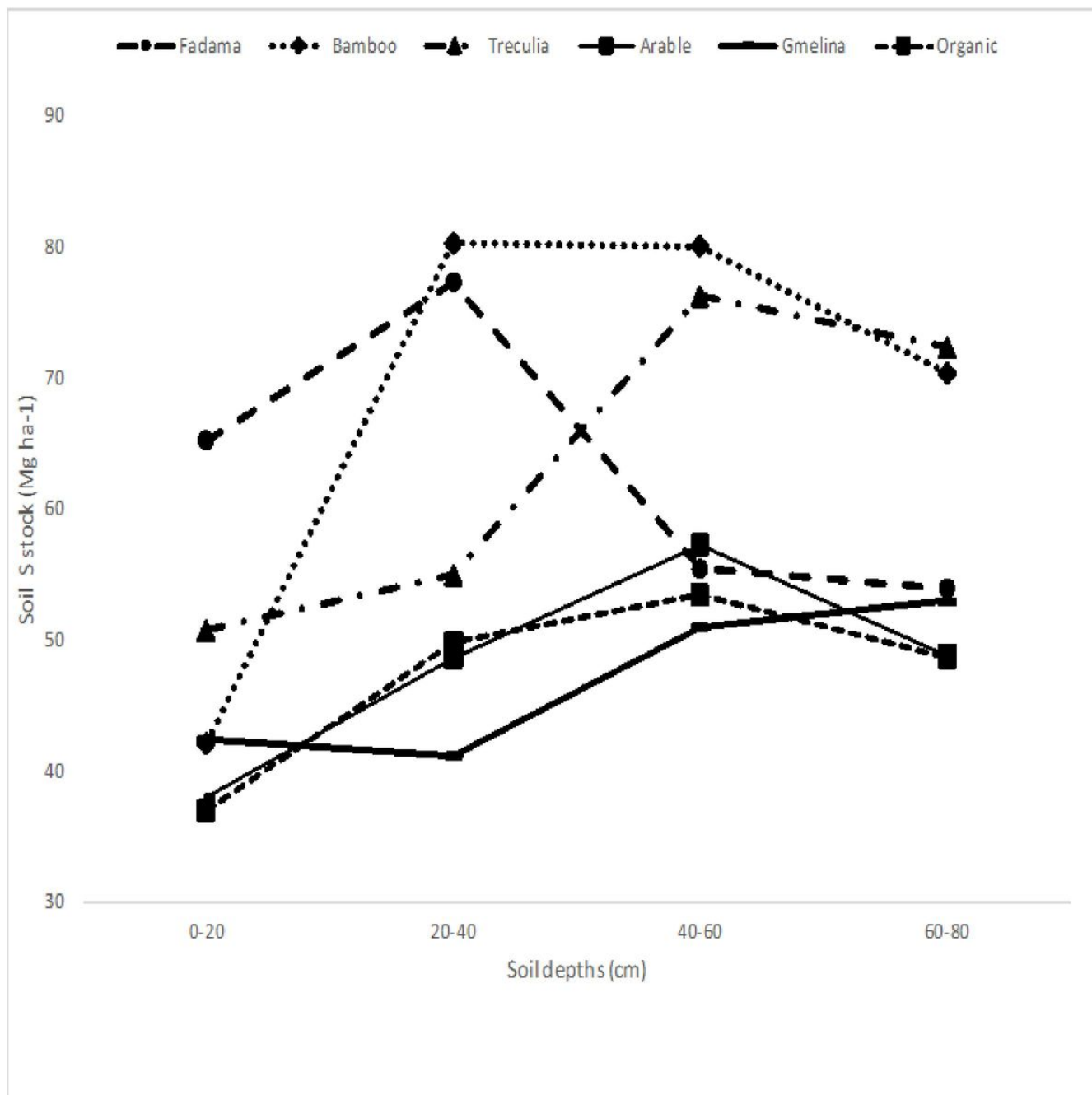


Figure 3

Changes in soil sulphate-sulphur stock with soil depth

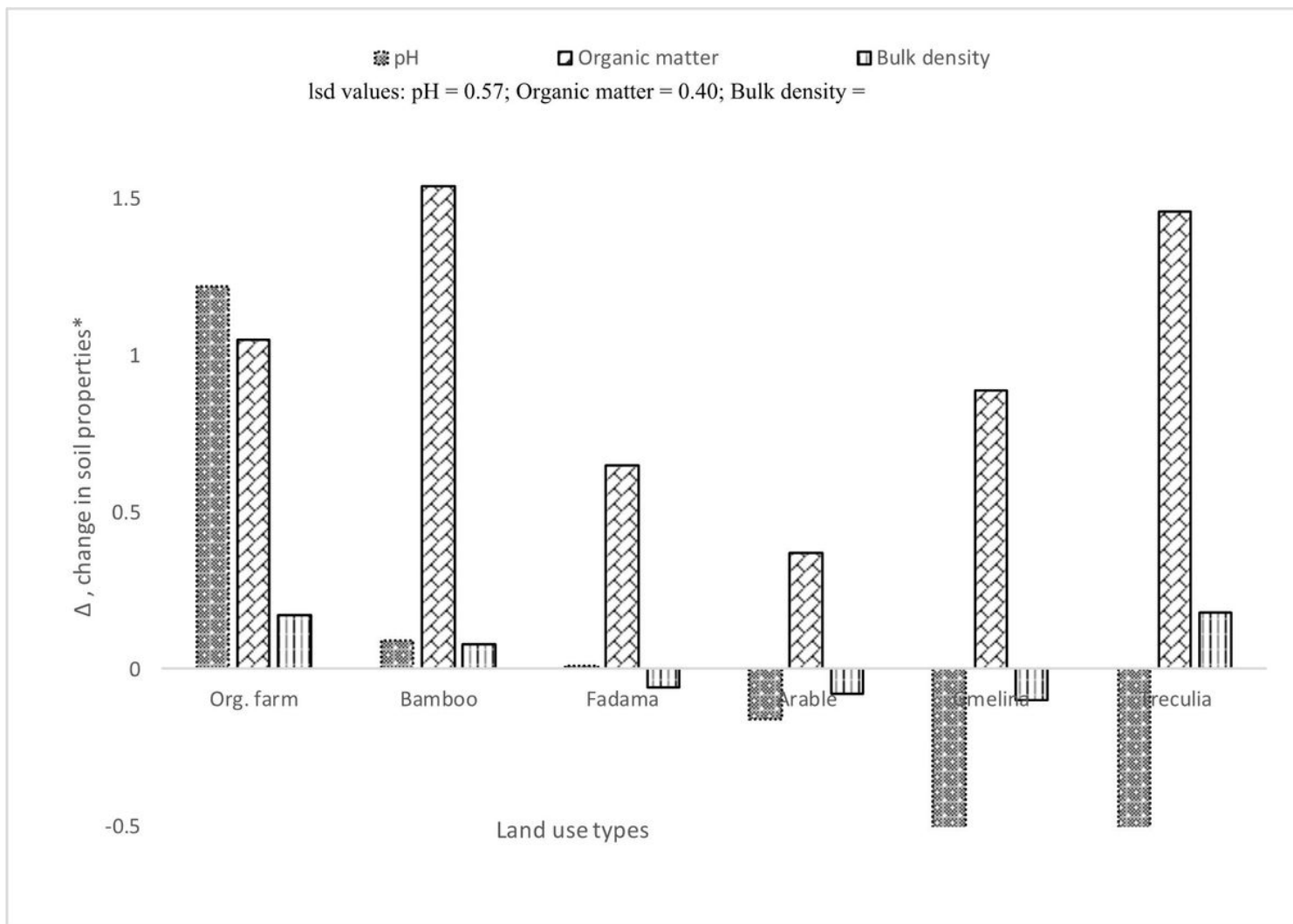


Figure 4

Effect of land use types on the changes in soil pH, organic matter and bulk density (*relative to control site and mean across soil depths)

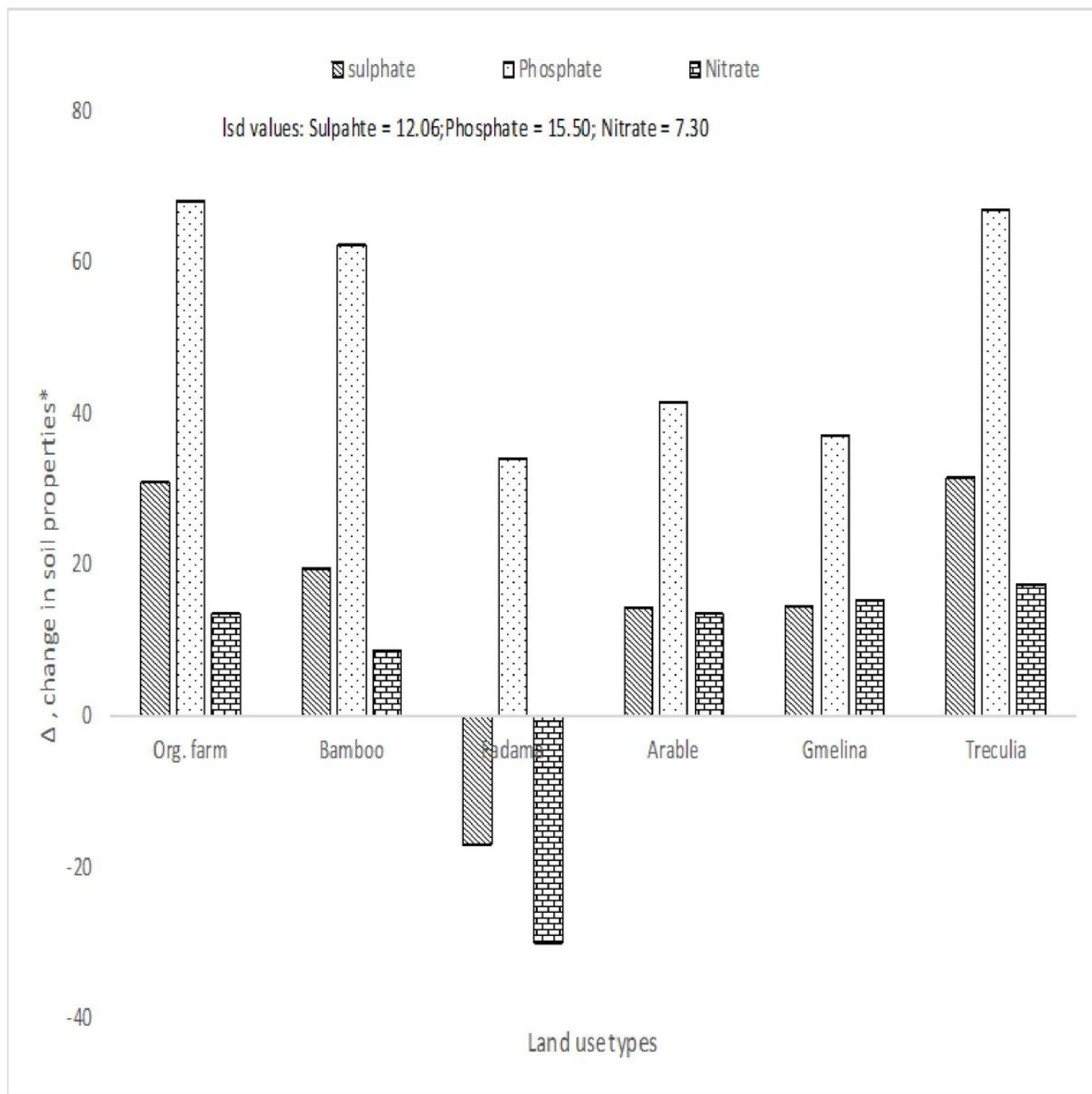


Figure 5

Effect of land use types on the changes in soil nutrient stocks (*relative to control site and mean across soil depths)