



## Fertility Status of Soils Under Silvopastoral System on Two Soil Types in Imo State, Southeastern Nigeria.



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*Received: 3 June 2019*

*Accepted: 4 November 2019*

### Abstract

Understanding the fertility status of soils under different agricultural systems is imperative for sustainable crop production and ecological sustainability. This study examined the fertility levels of soils under silvopastoral system of two soil types in Southeastern Nigeria. Two towns in two states with two parent materials in the region were covered namely Owerri in Imo State with coastal plain sand and Uturu in Abia State with false bedded sand stone. Surface soil samples collected within 30 cm depth were analyzed using standard methods. Silvopastoral system and parent materials guided the sampling points. Data obtained from analyzed soil samples were statistically analyzed. Significant variations existed in the particle distribution of the soil while highest gravimetric moisture content (249.7 g/kg), total porosity (67.5%) and lowest soil bulk density (0.85 g/cm<sup>3</sup>) were recorded in the silvopastoral lands than in non silvopastoral lands. Silvopastoral lands contained higher soil organic matter (36.88 g/kg), total nitrogen (1.87 g/kg) and exchangeable bases than non silvopastoral lands. There was higher clay content (274 g/kg) in false bedded sandstone than in coastal plain sand silvopastoral lands. The highest value of soil organic matter (36.88 g/kg) and total nitrogen (8.7 g/kg) were recorded in false bedded sandstone under silvopastoral system. There was significant negative correlation between bulk density and base saturation ( $r = -0.946$ ) and positive relationship between total exchangeable acidity and soil bulk density ( $r = 0.865$ ). This work revealed that parent materials under silvopastoral systems differ in soil physical, chemical and plant nutrient concentration. Therefore it is recommended that silvopastoral system should be adopted under coastal plain sand for soil fertility improvement due to its poor soil quality.

**Keywords:** Livestock grazing, parent materials, silvopastoral system, soil fertility

### Introduction

The world today is facing food security problem (Sasaki. et al, 2012). In order to provide enough food for the rise in human population, silvopastoral land system has been advocated (McAdam, et al., 2007). Silvopastoral system refers to a practice that involves pasture farming system in combination with varying densities of economic trees (Sasaki et

al., 2012). This method of farming is common under agro-forestry in developed countries but due the problem of limited viable agricultural lands for food production, it has spread to all parts of the world (McAdam et al., 2007).

Silvopastoral system enhances biodiversity and soil conservation (Van- Wieren and Bakker, 2008; McAdam et al., 2007) and also provides shade for cattle (Shi et al., 2010) as well as provides humidity in dry periods (Van - Wieren and Bakker, 2008). The system provides forage for ruminants (Harvey et al., 1999). Silvopastoral system has been shown to improve soil quality and enhance soil conservation and maintain environmental sustainability (Plieninge et al., 2011). Shi et al., (2010) have demonstrated that silvopastoral system improves soil organic carbon and soil macro nutrients when compared to non silvopastoral lands.

In Southeastern Nigeria, there are different parent materials such as coastal plain sand, false bedded sand stone, Imo clay shale and alluvium deposit. These parent materials have their inherent characteristics and are found in regions where silvopastoral land systems are practiced. Most of the research works on silvopastoral systems concentrated on tree species (Plieninge et al., 2011) and its effect on vegetation and yield of crops (Sasaki et al, 2012) as well as the type of animals used in the pastoral system without putting into consideration the parent material under the silvopastoral environment. It is therefore pertinent to understand the effect of silvopastoral system on soils of different lithology for proper soil management.

### **Materials and Methods**

This study was carried out at Uturu (latitude 5° 45'N; longitude 6° 26'N) in Abia State and Owerri (latitude 5° 22'N; longitude 6° 59'N) in Imo State both in Southeastern Nigeria. Parent materials and silvopastoral systems were used to identify the sampling locations. The two locations are within the rain forest zone. Some meteorological data like rainfall, temperature and rainfall days in the studied region are presented in Table 1. The area has average relative humidity of 79% during the raining months. Rainy season (April – October) and the dry season (November – March) are experienced in the region. The soil in Owerri has been classified as a typic haplustult (FDALR, 1985) while Uturu soil is derived from false bedded sand stone. The major parent material of soils in Owerri is coastal plain sand and this soils are known to have strong acidity, low exchangeable bases and organic matter (Onwudike, et al., 2017) while the parent material in Okigwe location is false bedded sand stone and are characterized by low organic matter and exchangeable cations with strong acidity (Onweremadu et al., 2007).

### **Field Study**

Three soil samples were collected at 0 – 30 cm depth from four villages within the same parent material (false bedded sandstone) under silvopastoral system at Uturu in Abia State. This was repeated in non silvopastoral system. At Owerri in Imo State the same sampling procedure was carried out given a total of 48 soil samples. The samples were collected using a soil auger, packed in well labeled black nylon, air dried and sieved with 2 mm mesh sieve for laboratory analysis.

**Table 1.** Rainfall and Temperature Data of 2016 in the studied locations

Month	Rainfall in Uturu Abia State (mm)	Rainfall in Owerri Imo State (mm)	Total Rainfall Days in Abia	Total Rainfall Days in Imo	Temp (°C) in Abia State	Temp (°C) in Imo State
January	0.0	0	0	0	34.8	35.2
February	25.7	23.3	2	2	35.2	32.2
March	36.2	36.9	4	4	33.6	33.6
April	153.9	132.4	8	8	35.9	30.9
May	317.4	317.5	25	20	33.5	33.5
June	261.6	261.7	20	20	32.8	32.8
July	305.2	305.2	20	20	26.8	28.3
August	506.7	476.4	21	21	26.1	26.1
September	366.0	363.4	22	21	26.3	26.2
October	241.2	231.8	19	19	26.9	23.5
November	49.7	44.3	4	5	28.0	25.4
December	24.8	23.7	1	2	28.4	28.4
<b>Total</b>	<b>2288.4</b>	<b>2216.6</b>	<b>146</b>	<b>142</b>	<b>Mean = 30.69</b>	<b>Mean = 29.675</b>

### Laboratory analysis

Soil particle sizes (sand, silt and clay fractions) were determined by hydrometer method according to Gee and Or (2002). Bulk density was determined with core sampling method using the procedure of Grossman and Reinsch (2002) as follows

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{mass oven soil dried (g)}}{\text{volume of core sampler (cm}^3\text{)}} \dots\dots\dots \text{equation 1}$$

Total porosity (TP) was determined from bulk density using the equation

$$\text{TP} = 1 - \frac{\text{bulk density}}{\text{particle density}} \times 100\% \dots\dots\dots \text{equation 2}$$

(particle density = 2.65)

Soil moisture content was determined by gravimetric method as

$$\%MC = \frac{W_2 - W_3}{W_3 - W_1} \times \frac{100}{1} \dots\dots\dots \text{equation 3}$$

where,  $W_1$ =weight of moisture can,  $W_2$ =weight of air – dried soil + moisture can,  $W_3$ =weight of oven dried soil +moisture can, %MC=percentage soil moisture

Soil pH was determined using a pH metre in soil / liquid suspension of 1: 2.5 according to Hendershot et al., (1993). Soil organic carbon was determined using chromic acid wet oxidation method as used by Nelson and Somers (1982). Total nitrogen was determined by kjeldahl digestion method using concentrated  $H_2SO_4$  and sodium copper sulphate as catalyst according to Bremner and Yeomans (1988). Phosphorus availability was analyzed using

Olsen and Somers (1982) procedure. Mg and Ca cations were determined using Thomas (1982) method and K and Na cations were extracted using flame photometer (Thomas, 1982). Exchangeable H and Al ions were determined according to Mclean (1982) method. ECEC (effective cation exchange capacity) was mathematically computed by adding all exchangeable cations and exchangeable acidity. Base Saturation (BS) was calculated using the formula.

$$\text{BS (\%)} = \frac{\text{total exchangeable bases}}{\text{effective cation exchangeable capacity}} \times \frac{100}{1} \dots\dots\dots \text{equation 4}$$

Results obtained were subjected to analysis of variance (ANOVA). Significant treatment means were separated using least significant difference at 0.05 probability level. Relationship among soil physicochemical properties was determined using correlation analysis.

## Results and Discussion

### Soil physical properties of the studied locations

Results of soil physical properties of the studied locations are presented in Table 2. There were significant differences ( $p = 0.05$ ) among soil particle size distributions, soil bulk density, soil total porosity and moisture content. Under silvopastoral lands, coastal plain sand had higher sand fraction than the false bedded sand stone. This agrees with the earlier research works of Onwudike et al., (2016) which showed that coastal plain sand has high sand fraction due to high level of weathering. However, false bedded sand stone had higher clay particles than coastal plain sand. Soil bulk density was highest at silvopastoral soils when compared to non silvopastoral land. This could be attributed to movement of animals which could compact soil particles thereby increasing the density of the soil. Anderson et al., (2010) and Papanastasis et al., (2009) reported that livestock grazing though may improve soil fertility level but the activities of the livestock may have some negative consequences on soil quality such as increase in soil bulk density. The highest moisture content was found in false bedded sand stone. This could be due to high clay fractions resulting from parent materials and this will help in moisture retention. This confirmed the previous findings of Zhou et al., (2011) that animal grazing increases soil moisture content.

**Table 2.** *The physical properties of the studied locations*

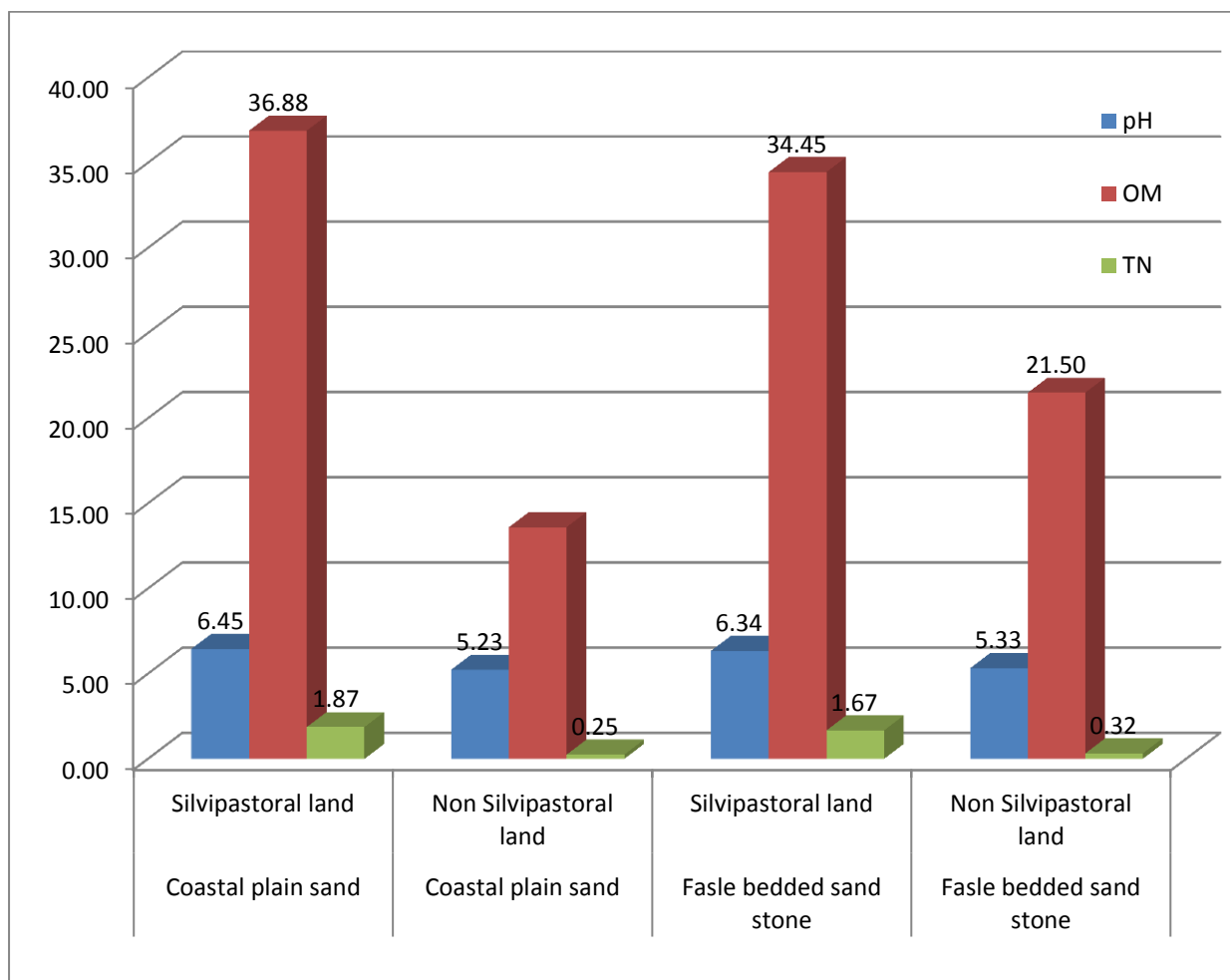
Parent material	Land use type	sand g/kg	Silt g/kg	Clay g/kg	Textural Class	BD g/cm <sup>3</sup>	TP %	MC g/kg
CPS	Silvopastoral land	878.5	38.76	89.36	Sandy laom	1.25	52.57	122.5
CPS	Non Silvopastoral land	876.7	33.40	103.2	Sandy loam	1.24	53.08	110.1
FSS	Silvopastoral land	602.9	123.0	274.0	Loamy sand	0.85	67.54	249.7
FSS	Non Silvopastoral land	635.4	91.06	273.5	Loamy sand	1.01	61.76	172.5
	LSD <sub>(0.05)</sub>	12.4	23.4	14.3		0.05	3.65	11.8

CPS = coastal plain sand; FSS = false bedded sand stone; LSD = least significant difference

### Distribution of organic matter, soil pH and total nitrogen in the studied location

Effect of silvopastoral system on soil organic matter, total nitrogen and soil pH are presented in Figure 1. Results showed that coastal plain sand in non silvopastoral system

recorded the lowest soil pH followed by false bedded sand stone. Higher organic matter was recorded in silvopastoral lands than non silvopastoral lands. This observation was similar to the previous results as recorded in the works of Shi et al., (2010), Smit and Kooijmani (2001) and Beukes and Cowling (2003) who observed that livestock grazing increases soil organic matter. Silvopastoral lands recorded higher soil pH than non silvopastoral lands. The highest soil pH of 6.45 was recorded in coastal plain sand under silvopastoral land. Higher soil pH as found in grazed lands as compared to non-grazed lands could be attributed to animal droppings which contain higher organic matter that can reduce the acidity of the soil. Silvopastoral lands had higher soil organic matter content when compared on non silvopastoral location. The highest total N (1.87 g/kg) was recorded in coastal plain sand under silvopastoral system. Higher organic matter and total N in grazed lands could be attributed to animal litters with increased soil pH.



OM = organic matter (g/kg), TN = total nitrogen (g/kg)

**Fig. 1.** Distribution of organic matter, soil pH and total nitrogen in the studied location

There were significant differences ( $p = 0.05$ ) among other soil chemical properties such as available phosphorus, exchangeable bases, base saturation and effective cation exchange capacity in silvopastoral and non silvopastoral systems (Table 3). The highest available P (2.57) was recorded in silvopastoral false bedded sand stone while the lowest (1.39) was in non silvopastoral coastal plain sand. This could be due to animal waste

deposits. The same trend followed in exchangeable bases and ECEC. There is therefore need to utilize the available nutrients in silvopastoral system for crop production

**Table 3.** Some chemical properties of the area.

Parent material	Land use type	Avail.		Ca	Mg	K	Na	TEB	TEA	ECEC	BS
		P	Mg/kg								
CPS	Silvopastoral land	2.07	2.25	1.57	0.22	0.10	4.14	1.62	5.74	72.49	
CPS	Non Silvopastoral land	1.39	1.93	1.07	0.15	0.08	3.23	1.23	4.43	73.33	
FSS	Silvopastoral land	2.28	2.07	1.30	0.20	0.15	4.01	0.72	4.73	84.56	
FSS	Non Silvopastoral land	1.68	1.93	1.27	0.13	0.09	3.42	0.63	4.06	84.38	
	LSD(0.05)	0.35	0.13	0.55	0.11	0.02	0.69	0.01	0.21	2.66	

CPS = coastal plain sand; FSS = false bedded sand stone; LSD = least significant difference

### Relationship among soil properties

Table 4 showed the relationship among soil properties in the studied locations. Results showed that base saturation significantly correlated negatively with bulk density ( $r = -0.946$ ) and sand ( $r = -0.996$ ) but correlated positively with total exchangeable acidity ( $r = 0.865$ ), moisture content ( $r = 0.864$ ), total porosity ( $r = 0.948$ ) and silt ( $r = 0.951$ ). Also soil moisture content, total porosity and soil particle sizes has significant relationship with some soil chemical properties as shown in Table 4. Reduction in bulk density due to animal wastes in silvopastoral lands increased base saturation, soil organic matter and total N which increased exchangeable bases and ECEC since according to Onwidike et al., (2016), soil organic matter acts as a reservoir for macro and micro nutrients which favor positively soil reactions and microbial activities in the soil. Increase in organic matter due to animal litters could help to reduce soil bulk density and increase total exchangeable bases. This will result to a decrease in soil bulk density since negative correlation existed bulk density and total exchangeable bases. This is because increase in organic matter will help to increase soil microbial population whose through their translocations, improves soil aggregation and aeration that reduces soil bulk density.

**Table 4.** Relationship among soil properties.

Property	BD	Clay	MC	TP	Sand	Silt
BS	-0.946**	0.476	0.864**	0.948**	-0.996**	0.951**
Avail. P	0.516*	-0.390	-0.633*	-0.514*	0.464	-0.572*
ECEC	0.415	-0.592*	-0.229	-0.419	0.521*	-0.373
K	0.051	-0.310	0.155	-0.057	0.217	-0.021
Mg	0.101	-0.153	0.024	-0.102	0.098	-0.025
OM	-0.272	0.097	0.433	0.268	-0.181	0.327
Ph	-0.187	-0.046	0.375	0.182	-0.048	0.228
TEA	0.865**	-0.953**	-0.741**	-0.868**	0.927**	-0.849**
TEB	-0.195	-0.006	0.371	0.191	-0.083	0.245
TN	-0.151	-0.084	0.342	0.146	-0.009	0.191

\*and \*\* = significant difference at 0.01 and 0.05 probability level respectively

## Conclusion and Recommendation

Silvopastoral systems under coastal plain sand and false bedded sand stone differ in physical and chemical characteristics with non silvopastoral systems. This research showed that silvopastoral systems under false bedded stand stone contained higher values of organic matter, total nitrogen and basic cations which are vital for crop production than silvopastoral systems under coastal plain sand. Therefore due to poor fertility level of soil under coastal plain sand in non silvopastoral system, it is recommended that this system of farming should be practiced on coastal plain sand to boost its fertility for crop production.

## Acknowledgement

The assistance of Mr Okoroiwu Michael is appreciated in this work for his help during field work in identifying the sampling locations in Uturu. We also appreciate Mr N. N. Nti and other soil science laboratory technologists of Federal University of Technology Owerri during laboratory analysis.

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