Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 3, 2018
PRINT ISSN 284-7995, E-ISSN 2285-3952

EFFECT OF SOME INDIGENOUS TREES ON EARTHWORM ACTIVITIES AND PHYSICAL PROPERTIES OF AN ULTISOL IN UMUAHIA, SOUTHEASTERN NIGERIA

Ojimgba ONWUCHEKWA, Onyejiji OGECHI VICTORIA

Abia State University, Soil Science Department, Uturu, Nigeria, Phone:+2348030846974; Emails: onwuchekwao@yahoo.com; ojimgbachekwas59@gmail.com

Corresponding author: onwuchekwao@yaoo.com

Abstract

The effect of some indigenous trees on earthworm activities and physical properties of an ultisol were studied at Umudike, Nigeria. These studies were carried out under some indigenous tree canopies namely: cacao, breadfruit, avocado pear and mango, and were compared with the soils of their open adjacent sites, ten meters away at different soil depths (0-15 cm and 15 – 30 cm). Generally, soils under tree canopies at various soil depths had lower bulk density, higher total porosity, and water stable aggregates than the adjacent sites. Example, the soils under cacao (Theobroma cacao L.) canopy had significantly higher values of total porosity, water stable aggregate and lower values of bulk density than the soils under mango, avocado pear and bread fruit and their adjacent sites. Mango tree gave the least values at various soil depths. Also, soils under tree canopies gave significantly (P = 0.05) higher values of earthworm population and casts than those of their adjacent sites at various soil depths, for instance at 0 – 15cm soil depth, cacao (14.00 and 9.00) gave significantly higher mean values of earthworm population and casts than mango (5.00 and 2.33), breadfruit (9.67 and 6.00) and avocado pear (8.00 and 4.00) per M^2, respectively. They were in the following significant decreasing magnitude: cacao > Breadfruit > avocado > mango. Mango gave significantly (P = 0.05) the least mean values of earthworm population and casts'.

Key words: *indigenous trees, earthworms, physical properties, ultisol, Nigeria*

INTRODUCTION

Agroforestry has tremendous potentials to enhance productivity, sustainability and diversification of farming systems. Inclusion of trees and other woody perennials in farm lands can markedly improve soil physical conditions in the long run [4]. The major recognized avenue for addition of organic matter (and hence, of nutrients) to the soil from the trees standing on it, is through litter fall, that is, through dead and falling leaves, twigs, branches, fruits and so on [9]. Soils under trees have higher permeability, greater water-holding capacity, a higher infiltration rate and enhanced soil productivity [36],[1],[3]. Increased soil productivity is made possible by the build-up and subsequent decomposition of forest floor materials and release of nutrient elements. The buildup of the forest litter depends upon the annual input of litter and the rate of decomposition of the forest floor material by the decomposing community (Soil organisms) [23],[18].

Trees augment soil input, reducing losses, improving soil physical properties through soil organic matter build up form leaf litter. [31]. In addition, the presence of trees and litter restore soil organic matter as well as the physical condition which are considered the key factors in soil fertility, improvement and maintenance [28].

Tree plantations are becoming an increasingly common land use type in tropical areas. [15] indicates that this land cover in the tropics accounts for more than 60 million hectares of plantations which have been established for different reasons including the shift in timber production from native forests to plantation restoration of degraded lands or as catalysts of forest succession [8] and buffer zones for biodiversity conservation [33] among others.

[41] conceptualized that tree plantations may influence earthworm abundance by altering the chemical or physical properties of the soil such as the moisture regime, pH, soil organic matter levels and litter inputs. Also, native tree plantations can benefit the establishment

of populations of native earthworm species [40]. Since earthworms dominate soil macrofauna in tropical ecosystem, they greatly impact soil processes affecting plant growth. Their role as ecosystem engineers [21] is also important for biodiversity conservation and restoration of degraded lands. Plantation with native species, like breadfruit, can serve as refuge for native earthworm diversity and abundance.

[6] examined the influence of earthworms on surface litter decomposition in maize agro ecosystems and noted an increased rate of decomposition of the surface litter.

Earthworms are long time adored creatures in many cultures, probably because of the role they are believed to play in the fertility improvement of the soil. The Chinese characterized earthworms as the “angel of the earth”. Aristotle aptly referred to them as the ‘intestines of the soil”, though he might be referring to the appearance rather than their functions, and Cleopatra decreed them “Sacred” [5]. However, [19] observed the usefulness of earthworms as an active agent in introducing suitable physical and micro-biological changes in the soil, thereby, directly increasing the fertility and crop producing power of the soil. [24] noted that in Bangalore, India, earthworms successfully decomposed sugar factory residuals and turned them into soil nutrients that made farmers using the material reduce chemical fertilizer by 50 percent. Earthworm casts contain 5 times nitrogen, 1.5 times calcium, 3 times magnesium, 11 times potash as well as 1.4 times more humus than the already existing top soil [11]. [12] also noted that earthworm casts generally have a higher ammonium concentration as well as water holding capacity than the corresponding original top soil. In addition, earthworm casts have high denitrification potentials and assimilable products that mineralized rapidly and, therefore, represent a potentially significant source of readily available nutrients for plant growth [10]. [19] observed that there is early seedling and rapid plant growth when earthworm casts are mixed with soil.

Earthworm borrows provide network of passages through the soil which improves soil aeration [26]. [5] stated that earthworm burrows can make up 5% of the total soil volume, and observed that high earthworm population enhances soil aeration, drainage and infiltration. [27] noted that earthworms bring to the soil surface casts of about 2 - 5.8 t/ha on agricultural land, 15 t/ha in temperate woodland and about 50 t/ha in tropical forest. Trees affect earthworms positively (through litter inputs) thereby promoting the establishment of the earthworms benefited from the basal resource [37]. This study was carried to determine the effect of trees on earthworm activities and some physical properties of soils of southeastern Nigeria.

MATERIALS AND METHODS

General Description of the Site Location

The studies were carried out on the experimental research farm of the Cacao Research Institute of Nigeria (CRIN) Ibeku sub-station at Ajata-Ibeku, Umuahia North Local Government Area, Nigeria and Abia State University Umuahia Campus Teaching and Research Farm all in, Abia State.

The Cocoa Research Institute of Nigeria (CRIN) Ibeku sub-station at Ajata-Ibeku is located on latitude 0.5^0 29N and Longitude 0.7^0 33E in the rainforest ecological zone of south eastern Nigeria and lies at a mean elevation of 122 metres (400 ft) above sea level.

The Abia State University Teaching and Research farm Umuahia Campus is located on Latitude 5^0 25N and Longitude 7^0 35E in the ecological zone of South eastern Nigeria at about 122 m above sea level.

The study areas have most dry humid tropics with fairly even and uniform temperature throughout the two seasons (dry and rainy) each year. However, the mean annual rainfall of the area is between 1,000-2,000 mm, while rainfall distribution is biomodal [29]. Also, the mean annual maximum temperature is between 30^0c to 33^0c, whereas, the mean annual minimum temperature ranges from 21^0c to 29^0c [13]. In addition, the vegetation of the study area is tropical rainforest.

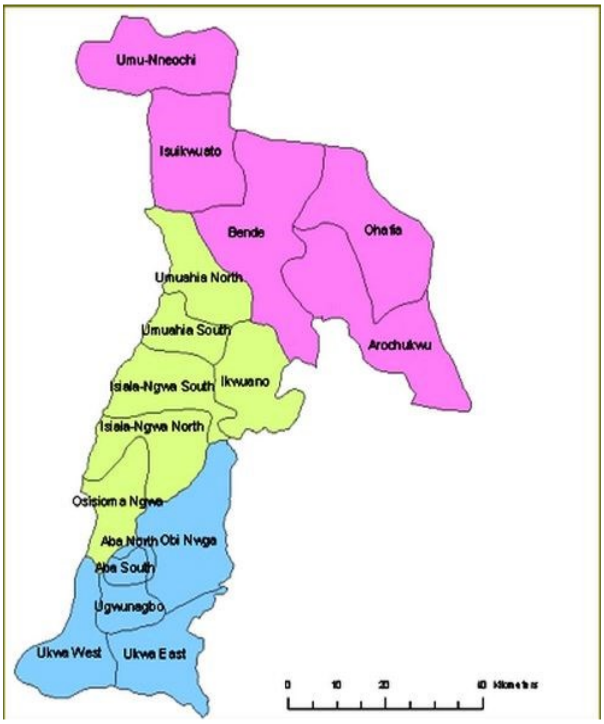

Fig. 1. Map of Abia State showing Umuahia, and Ikwuano Project Sites: Cocoa Research Institute of Nigeria, Ibeku Substation. Umuahia and Abia State University, Umuahia Campus, Nigeria

The soil associated with this experimental site is classified as ultisols (USDA) classification, [14]. These soils have a number of soil related constraint to agricultural productivity such as low inherent fertility, soil acidity, low clay, low organic matter content, low nutrient and water holding capacities, poor structural stability and high susceptibility to soil erosion and drought stress [32].

Selected Tress for the Study

Four trees were used for the study as follows;
Cacao (*Theobroma Cacao* L.*)* - Ca
Bread fruit (*Triculia africana*) - Br
Mango (*Mangifera indica*) - Ma
Avocado pear (*Persea americana*) - Av

The cacao was selected from the Cacao Research Institute of Nigeria (CRIN) Ibeku substation, Umuahia, Nigeria. While breadfruit, mango and avocado pear were selected from the Abia State University Umuahia Campus Teaching and Research Farm, Umudike, Umuahia, Nigeria.

Species Description

Mango (*Mangifera indica*) is one of the most important tropical fruits in Nigeria today. It is an indigenous to southern Asia and probably originates from the Indo-Burma region [7]. Cultivation of mango in Nigeria dates back over several decades and the trees flourish in many parts of the country. Worldwide, the major mango producing nations are India, Mexico, and Brazil, while the leading world export markets for fresh fruit include the United Kingdom, France, and Holland, [20].

Estimates show that up to 50,000 hectares with a corresponding yield of 625,000 tonnes of assorted mangoes are being grown in the states of Borno, Niger, Plateau, Oyo, Benue, and Kogi. The crop is grown by peasant growers and professional horticulturists on homestead gardens, and small, intermediate and large-scale plantations [22].

Cacao (*Theobroma cacao* L*)* developed in the upper Amazon region of Latin America. In classical Mexican mythology, cacao, one of the foods of the gods originated in the garden of life. Cacao was introduced into Nigeria from Fernando Po by Chief Saviss Ibanningo in 1874. The generic name *Theobroma* which means “drink” (broma) of the “god”; (theo) emphasize the high regard India native in its land of origin attach to the crop. The word “*Theorborma*” is derived from the Greek words meaning ‘food for the gods’. Cacao belongs to the family of the sterculiaceae over 20 species of *Theobroma* are recognized. All cacao cultivated for the international market belongs to the single species *Theobroma cacao* (*L*). Other *Theobroma species* are locally exploited by the indigenous populations either for making refreshing drinking from the sweatens or for making a type of chocolate from the cotyledons. Cacao is cultivated in tropical lowlands, 20^0N and S of the equator, but the main belt in 10^0N and S from sea level up to 500m, with rainfall range of between 1,800 and 2,000 mm. Cacao thrives in diverse soils. In Nigeria, cacao is grown mainly in the southern states of Ogun, Oyo, Ondo, Ekiti, Edo, Delta, Cross River, Abia and Akwa Ibom.

Cacao seeds are the source of commercial cocoa, chocolate and cacao butter. Cacao beans contain about 50% fat, 12% protein and other minerals. The most important food products from cocoa are chocolate products. The non food products include pure industrial alcohol, components of skin cream etc.

Avocado pear (*Persea americana*) is a tree (native to central Mexico) it is classified in the flowering plant family (Lauraceae) along with the cinnamon. However, avocado or alligator pear is classified as fruit and botanically also, as large berry that contains a single seed.

Avocados are commercially valuable and are cultivated in tropical and Mediterranean climates throughout the world. In Latin America, the leaves are both beneficial in medicine, to the soil and for its culinary uses. Avocado leaves are prepared as tea and make it as tonic every day; it is referred to as miraculous because its effect could not be illustrated by some doctors.

The Breadfruit (*Treculia africana*)

Breadfruit (*Treculia africana*) in Africa is cultivated by its seed. It is propagated through building, cutting and shielding, grafting, using scions. Budded trees have produce fruit with viable seeds within 2-4 years.

According to [2] breadfruit is underutilized especially in African Continental, Europe and United States of America where it is being newly introduced as ornamental trees. Treculia Africana seeds are sources of edible food which are rich in protein and fat [16]. They are commonly roasted, cooked, mashed and consumed either directly as snacks food or as flour for use in soup thickening and cake. The major part of fruit consists of 75-90% water [17].

Data Analysis

Significant differences in soil gravimetric moisture content, total porosity, bulk density, aggregate stability and particle size among the tree types were identified using ANOVA at 5% probability level. However, the treatment means were compared using Duncan's New Multiple Range Test [DNMRT]. Also, analysis of variance ANOVA were performed using linear model with means separated using the technique of [34] to assess the effect of trees on gravimetric moisture content, total porosity, bulk density, water stable aggregate and particle size as well as activities of earthworms. Significance was reported at [$P < 0.05$].

Laboratory Studies

Soil samples were randomly collected using four undisturbed cores under the canopy of individual trees and those in the surroundings without a tree cover (Adjacent open land) at different depths (0-15, and 15-30cm). The dimensions of the core were 5.0cm (height) and 5.7cm (internal diameter). The core soil samples were used to measure soil moisture retention, bulk density, total porosity, water-stable aggregates and particle size analysis.

Also under each tree canopy and its adjacent open land a quadrant of 1m x 1m in dimension were demarcated. In the quadrant, the numbers of earthworm casts were determined from 0-15 and 15-30 cm soil depth. The earthworm population was determined, by hand sorting method.

The procedures for soil analyses were outlined below.

Particle Size Analysis

Particle size analysis was determined on the soil sample using Bouyoucos hydrometer method. The technique used was the dispersion of sample with calgon (Sodium hexameta - phosphate). In this method, soil samples were soaked in calgon for 24hrs and later transferred into volumetric flask and was stirred for mechanical agitation before the hydrometer test.

Soil Moisture Retention

Also, disturbed soil samples were collected from the tree plot and 30g of each was weighed into robber bands (rings). This was used to determine the water content of the soil at 1.5 MPa (0.1 bar), using the pressure plate apparatus [36]. In each case the samples were placed on ceramic plate. Soil was soaked with water for 24hours. The plates with the samples were placed in the pressure chamber and were subjected to the different suctions until water ceased to drain out from the soil samples. The samples were weighed and over dry at 105^0C for 24hours.

Calculation

The field capacity was calculated, that is 0.01MPa suction, which simply entails the maximum amount of water the soil can hold after it has freely drained for 2-3days, and the saturation was followed without evapotranspiration occurring during the period.

Wilting point, this value was as lower limit of plant available water. It was equivalent to the soil water content with at least 1.5MPa (15bar) water potential. Equation is stated below:

$$\theta = \frac{\text{wet soil [g]-dry soil [g]}}{\text{Dry soil [g]}} \times \frac{100}{1}$$

Bulk Density

Bulk density (D_b) was the apparent density of the field soil and was calculated by dividing the mass of the soil that were dried in the oven.

$$D_b = \frac{Ms}{V} \quad g/cm^3$$

where

D_b = bulk density

M_s = Mass of soil samples

V = Volume of soil sample (equals volume of core)

Total Porosity

The total porosity was defined as the volume of the sample that is not occupied by solid materials and this was expressed as percentage of the sample volume [35].

This was calculated from the values obtained from bulk density. The calculation was the relationship between bulk density and particle density as well as on the assumption of particle density of 2.65mg m^{-3} for mineral soils.

The formula is

$$\frac{1\text{-Bd}}{pd} \text{ or } \frac{pd - bd}{pd} \times \frac{100}{1}$$

$$\frac{1 - \text{Bulk density}}{\text{Particle density}}$$

$$St = \frac{(1 - Dd)}{Dp} \times \frac{100}{1}$$

where;

S_t = total porosity (%)

D_b = bulk density (mg m^{-3})

D_p = Particle density (mg m^{-3})

Water Stable Aggregates (WSA)

This was sieved in order to sieve wet aggregate. This was carried out for 2 minutes at one oscillation per second after which the sieves were removed from water and then the oven dry weight of the materials was determined. Mean weight diameter were determined. The materials were used in the following relationship:

$$MWD = \Sigma X_1 W_1$$

MWD = Mean weight diameter

$\bar{X}$ = Mean diameter of each size fraction (mm)

W = The proportion of the total sample weight occurring in the corresponding size component.

RESULTS AND DISCUSSIONS

The physical properties of soils under some indigenous trees and its adjacent sites at various soil depths

Tables 1, 2, 3 and 4 summarized the physical properties of soils under some indigenous trees namely: Cacao (*Theobroma cacao* L.), Avocado pear (*Persea americana*), Mango (*Mangifera indica*) and Breadfruit (*Treculiar africana*) as well as their adjacent sites at Umuahia, Nigeria. Generally, the performance show that the values of gravimetric moisture content, bulk density, total porosity and water stable aggregates obtained under trees were better than those of the adjacent soils. Example, the gravimetric moisture values of 13.05, 12.30, 12.75 and 13.15% for cacao, avocado pear, breadfruit and mango, respectively gave significantly higher values than their adjacent soils of 9.85, 9.40, 8.38 and 9. 67%, which were ten (10) meters away from cacao, avocado, breadfruit and mango, respectively at soil depth of 0 - 15cm. In addition, the results of 15-30cm soil depth followed the same trend as in 0 – 15 cm. Also the Tables revealed that the results obtained under the trees at both 0-15cm and 15-30cm soil depths had significantly ($P < 0.05$) lower bulk density, higher total porosity and higher water stable aggregates values than those of the adjacent soils. Also, the soils of cacao and mango trees were clay loam and loam in texture, respectively, while breadfruit and avocado were sandy loam

Further evidence of the effects of trees on soils was obtained by comparing the physical properties under the tree canopy of individual trees with those in the surroundings without a tree cover by [39]. He observed cases of 50-100% increase in water holding capacity, total porosity and infiltration rate under tree canopies. Similar observations were made by [17], [1], [3]. The removal of the vegetative cover from the soil according to [30], generally results in an increase in bulk density, a decrease in porosity and a reduction in infiltration rate. This is also similar to the findings of [38] under bush fallow at Iwo, who reported, however, that the infiltration capacity and infiltration obtained were 118.9 and 21.1cm hr^{-1}, respectively. Also, at Oba, the infiltration capacity as well as rate were 107.7 and 25.4cm hr-[1], respectively.

Table 1. Some physical properties of soils under cacao tree and its adjacent site at different soil depth

Soil Depth (cm)		**Particle size analysis**			**Textual class**	**Bulk Density Mgm^{-3}**	**Total Porosity (%)**	**GMC (%)**	**WSA (%)**
		Total sand %	Silt %	Clay %					
0 - 15	Under	79.87	8.80	11.33	SL	1.38	57.01	13.50	64.49
15 - 30	Tree	70.49	14.11	15.40	SL	1.62	38.99	18.48	46.90
0 - 15		75.80	6.80	17.40	SL	1.67	37.98	9.85	48.67
15 - 30	Adjacent	65.80	12.80	21.40	SCL	1.73	34.50	12.72	41.52
F-LSD$_{0.05}$	Site	6.1*	3.4*	4.2*		0.15*	10.1*	3.5*	9.8*

SCL= Sandy clay loam, SL = Sandy loam, GMC = Gravimetric moisture content, WSA = Water stable aggregate,
* = Significant at $P < 0.05$
Source: Own results.

Table 2. Some physical properties of soils under Avocado tree and its adjacent site at different soil depth

Soil Depth (cm)		**Particle size analysis**			**Textual class**	**Bulk Density Mgm^{-3}**	**Total Porosity (%)**	**GMC (%)**	**WSA (%)**
		Total sand %	Silt %	Clay %					
0 - 15	Under	78.80	7.13	13.07	SL	1.50	48.13	12.30	64.41
15 - 30	Tree	75.80	8.80	15.40	SL	1.59	39.87	18.47	58.08
0 - 15		84.47	6.13	9.40	SL	1.62	38.86	9.40	57.59
15 - 30	Adjacent	79.80	8.80	11.40	SL	1.71	35.34	12.11	50.49
F-LSD$_{0.05}$	Site	3.5*	1.3*	2.5*		0.08*	5.4*	3.8*	5.6*

SCL= Sandy clay loam, SL = Sandy loam, GMC = Gravimetric moisture content, WSA = Water stable aggregate,
* = Significant at $P < 0.05$
Source: Own results.

Some physical properties of soils under Breadfruit tree and its adjacent site at different soil depth are shown in Table 3.

Table 3. Some physical properties of soils under Breadfruit tree and its adjacent site at different soil depth

Soil Depth (cm)		**Particle size analysis**			**Textual class**	**Bulk Density Mgm^{-3}**	**Total Porosity (%)**	**GMC (%)**	**WSA (%)**
		Total sand %	Silt %	Clay %					
0 - 15	Under	75.80	11.47	12.73	SL	1.51	43.01	12.75	60.39
15 - 30	Tree	69.80	3.13	17.07	SL	1.66	37.48	18.47	50.35
0 - 15		79.80	10.80	9.40	SL	1.68	36.60	8.38	53.16
15 - 30	Adjacent	74.47	15.13	10.40	SL	1.74	34.46	11.68	49.22
F-LSD$_{0.05}$	Site	4.1*	5.0*	3.4*		0.08*	3.1*	4.2*	4.3*

SCL= Sandy clay loam, SL = Sandy loam, GMC = Gravimetric moisture content, WSA = Water stable aggregate,
* = Significant at $P < 0.05$
Source: Own results.

Some physical properties of soils under Mango tree and its adjacent site at different soil depth are presented in Table 4.

Table 4. Some physical properties of soils under Mango tree and its adjacent site at different soil depth

Soil Depth (cm)		**Particle size analysis** Total sand %	Silt %	Clay %	**Textual class**	**Bulk Density Mgm^{-3}**	**Total Porosity (%)**	**GMC (%)**	**WSA (%)**
0 - 15	Under	77.80	8.13	14.07	SL	1.48	44.27	13.51	54.24
15 - 30	Tree	66.49	14.13	19.40	SL	1.58	40.25	19.08	50.12
0 - 15		64.47	10.13	25.40	SCL	1.65	37.73	9.67	46.49
15 - 30	Adjacent	59.80	10.80	29.40	SCL	1.74	34.46	12.07	40.29
F-LSD$_{0.05}$	Site	6.6*	2.1*	5.8*		0.09*	3.5*	3.4*	5.1*

SCL= Sandy clay loam, SL = Sandy loam, GMC = Gravimetric moisture content, WSA = Water stable aggregate,
* = Significant at P< 0.05
Source: Own results.

Comparison of the physical properties of soils under some indigenous trees and their adjacent sites at 0 – 15 and 15 - 30 soil depths

The textures of the soils under trees and their adjacent sites were affected significantly and gave statistically different results at various soil depths (0 – 15 and 15 – 30) (Table 5). In Fig. 2, it is shown that the clay contents of soils under cacao tree at various soil depths gave significantly the least values than other trees.

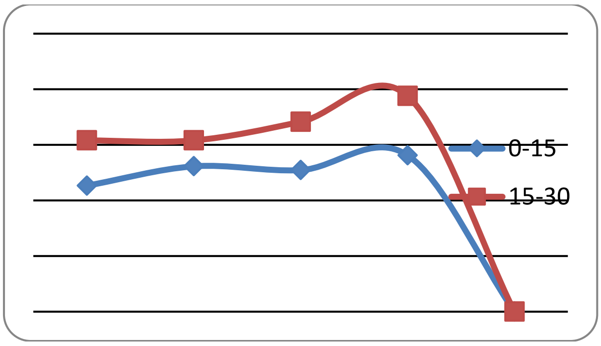

Fig. 2. Effect of the indigenous trees on the clay content of the soils
Source: Own design.

Table 5. Comparison of particle size distribution of soils under some indigenous trees and their adjacent sites at 0 – 15 and 15 - 30 soil depths

Soil Depth	**Treatment**	**Sand %**		**Silt %**		**Clay %**		**TC**	
		Particle size analysis							
0 - 15		Und	Adj	Und	Adj	Und	Adj	Und	Adj
	Cacao	79.87	75.80	8.80	6.80	11.33	17.40	SL	SL
	Avocado pear	78.80	84.47	7.13	6.13	13.07	9.40	SL	SL
	Breadfruit	75.80	79.80	11.47	10.80	12.73	9.40	SL	SL
	Mango	77.80	64.47	8.13	10.13	14.07	25.40	SL	SCL
	F-LSD$_{0.05}$	1.7*	8.5*	1.8*	2.0*	0.9*	6.6*		
15 - 30		Und	Adj	Und	Adj	Und	Adj	Und	Adj
	Cacao	70.49	65.80	14.11	12.80	15.40	21.40	SL	SCL
	Avocado pear	75.80	79.80	8.80	8.80	15.40	11.40	SL	SL
	Breadfruit	69.80	74.47	3.13	15.13	17.07	10.40	SCL	SL
	Mango	66.49	59.80	14.13	10.80	19.40	29.40	SL	SCL
	F-LSD$_{0.05}$	3.2*	7.7*	4.5*	2.3*	1.6*	7.7*		

TC = Textural class, BD = Bulk density, TP = Total porosity, HC = Hydraulic conductivity, SCL = Sandy clay loam, GMC = Gravimetric moisture content, NS = Not significant, * = Significant at P = 0.05, Und = Under tree canopy, Adj = Adjacent bush fallow
Source: Own results.

The results show that there were significant differences in dry bulk density among the indigenous tree species (P < 0.05) at 0 – 15 cm soil depth (Table 6).

Table 6. Comparison of some physical properties of soils under some economic trees and their adjacent sites, at soil depths of 0 – 15 and 15 – 30cm

Soil Depth	Treatment	GMC (%)		BD (Mg m^{-1})		TP(%)		WSA (%)	
0-15		Und	Adj	Und	Adj	Und	Adj	Und	Adj
	Cacao	13.50	9.85	1.38	1.67	57.01	37.98	64.49	48.67
	Avocado pear	12.30	9.40	1.50	1.62	48.13	38.86	64.41	57.59
	Breadfruit	12.75	8.38	1.51	1.68	43.01	36.60	53.16	60.39
	Mango	13.51	9.67	1.48	1.65	44.27	37.73	54.24	46.49
	F-LSD$_{0.05}$	0.5*	0.5*	0.01*	0.02*	2.0*	2.3*	5.3*	5.8*
15-30		Und	Adj	Und	Adj	Und	Adj	Und	Adj
	Cacao	18.48	12.72	1.59	1.73	38.99	34.50	46.94	41.52
	Avocado pear	18.47	12.11	1.62	1.71	39.87	35.34	58.08	50.49
	Breadfruit	18.47	11.68	1.66	1.74	37.48	34.46	49.22	50.35
	Mango	19.08	12.07	1.58	1.74	40.25	34.46	50.12	40.29
	F-LSD$_{0.05}$	0.2*	0.3*	0.03*	0.01*	1.0*	0.3*	4.1*	4.7*

TC = Textural class, BD = Bulk density, TP = Total porosity, HC = Hydraulic conductivity, SCL = Sandy clay loam, GMC = Gravimetric moisture content, NS = Not significant, * = Significant at P = 0.05, Und = Under tree canopy, Adj = Adjacent bush fallow

Source: Own results.

In addition, the trees decreased the dry bulk density relative to their open adjacent sites. Also, at 0 -15 cm depth, Cacao (1.38 Mg m^{-3}) gave significantly ($P < 0.05$) least bulk density value than Mango (1.48 Mg m^{-3}), Avocado pear (1.50 Mg m^{-3}) and Breadfruit (1.51 Mg m^{-3}) in the following order : Cacao < Mango < Avocado pear < Breadfruit. At 15 – 30 cm Breadfruit gave significantly higher dry bulk density value than the statistically similar values of Cacao, Mango and Avocado pear (Table 6).

The higher bulk density values were obtained at 15 -30 cm soil depth than the corresponding 0 – 15 cm soil depth which may be attributed to the high values of clay associated with the lower part of the soil (Table 6).

Also, the bulk density values under trees were lower than their corresponding adjacent sites. This may be because of the exposure of the bare soil to erosion. Also, dry bulk density increases with time after tillage as a result of trafficking during field operations as well as other natural factors like the alternate wetting and drying cycles that cause large " stresses", in a tropical climate. Dry bulk density is a soil physical parameter used extensively to quantify soil compactness which has a very influential effect on root growth as well as proliferation which are both 'indicators', of soil productivity[1]. The gravimetric moisture content of the soil was significantly ($P < 0.05$) influenced by the tree canopies. The values of the moisture content of soils under trees at 0 – 15 and 15 – 30 cm depth were higher than those of their corresponding open adjacent sites. Therefore, this could be as a result of the exposure of the top soil by erosion or other human factors. Also, at 0 – 15 cm depth, cacao (13.50%) and Mango (13.51%) under tree with statistically similar moisture content values were significantly higher than the similar values of Avocado pear (12.30%) as well as Breadfruit (12.75%). However, soil depth of 15 -30 cm followed the same trend. The significant improvement is in the order : Mango = Cacao > Breadfruit = Avocado pear (Table 6).

Also, the results in Table 6 at both 0 – 15 and 15 -30 cm soil depth show that total porosity increased ($P < 0.05$) under tree canopies more than their corresponding adjacent sites. Table 6 also shows that Cacao (57.01%) had significantly higher total porosity value than Avocado pear (48.13%), whereas Breadfruit (43.01%) and Mango (44.27%) had statistically ($P < 0.05$) similar values. The trend in increasing total porosity is Cacao > Avocado pear > Mango > Breadfruit.

The data obtained in Table 6 indicate that the values of water stable aggregate content under tree canopies was significantly ($P < 0.05$) higher than their corresponding adjacent sites. The results show statistical difference in water stable aggregate between the soils under the trees at both 0 – 15 and 15 – 30cm depth.

Generally, the results obtained show that Cacao gave significantly lower results of dry bulk density and higher values of gravimetric moisture content, total porosity as well as water stable aggregate than breadfruit, avocado pear and mango. Highest values obtained with cacao could be attributed to the highest earthworm population and casts associated with it. Further evidence of the effects of trees on earthworm activities under canopy of individual trees was compared with those in the surroundings without tree cover by [25]. The authors reported that earthworms under tree influence the establishment and conservation of soil structure. Also the organic matter building through the leaf litter helps to multiply earthworms under such tree canopies by feeding on the leaves. [26] made similar observations.

Effect of some Indigenous Trees on Earthworm Population

Figures 3 and 4 summarized the effect of some indigenous trees on earthworm population at different soil depths 0-15 and 15 – 30 cm, respectively, under tree canopies (cacao, mango, bread fruit and avocado pear) and their adjacent soils in Umuahia, Nigeria. At 0-15cm soil depth, the number of earthworms per square meter in the soils under tree canopies were significantly (p = 0.05) higher than those of the adjacent sites. The mean values of 14.00, 9.67, 5.00 and 8.00 were obtained for cacao, breadfruit, mango and avocado pear under tree canopies, while the lower values of 10.67, 7.00, 3.33 and 5.00 were obtained at the adjacent soils (10 meters away) of the various tree canopies, respectively. Also, the mean values of 15 – 30 cm soil depth had significantly similar trend with those of 0 – 15 cm. Generally, soils under cacao (14.00) had significantly higher (P = 0.05) mean values of earthworm population than the mean values of mango (5.00), breadfruit (9.67) and avocado pear (8.00) m^{-1}. They were in the following significant decreasing magnitude: Cacao > Breadfruit > Avocado > Mango. However, mango gave significantly (P = 0.05) the least mean values of earthworm population. Therefore, significant differences were observed among the trees. Similarly, the results of earthworm population outside the tree canopies followed the same trend in the following significant order Cacao > Breadfruit > Avocado > Mango.

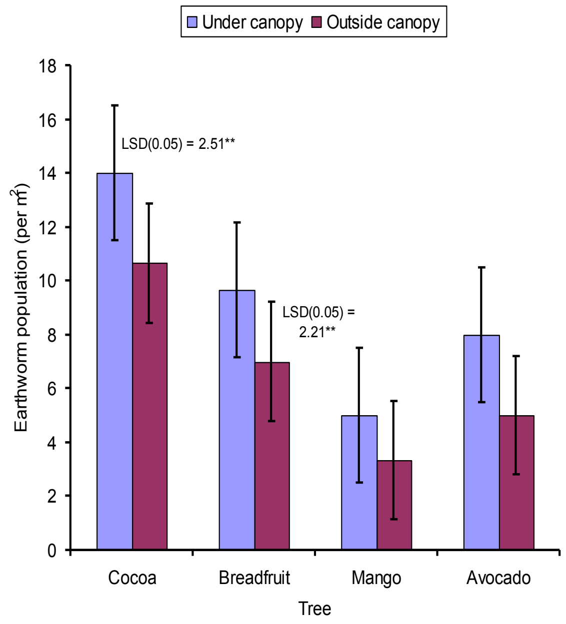

Fig. 3. Effect of trees on earthworms' population (per m^2) of an Ultisol at 0 – 15 cm depth at Umudike.
Source: Own results

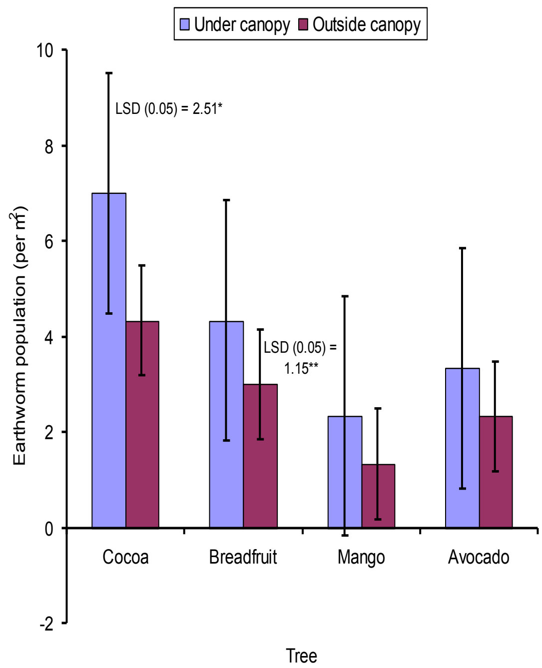

Fig. 4. Effect of tree on earthworm population (per m^2) of an Ultisol at 15 – 30 cm depth at Umudike
Source: Own results

Further evidence of the effects of trees on earthworm activities under canopy of individual trees was compared with those in the surroundings without tree cover by [24]. The authors reported that earthworms under tree influence the establishment and conservation of soil structure. Also the organic matter building through the leaf litter helps to multiply earthworms under such tree canopies by feeding on the leaves. [26] made similar observations. [19] added that tree plantation influence earthworm abundance by altering the physical and chemical properties of the soil. Also, [37] concluded that tree affect earthworms positively through litter inputs thereby promoting the establishment of earthworms.

Effect of Indigenous Trees on Earthworm Casts

Figure 5 summarized the effect of trees on earthworm casts at Umuahia, Nigeria. However, at 15-30 cm soil depth, no earthworm cast was observed. At 0 - 15cm depth, the number of earthworm casts under the canopies (cacao, breadfruit, avocado and mango) were significantly (P = 0.05) higher than those of the adjacent open sites.

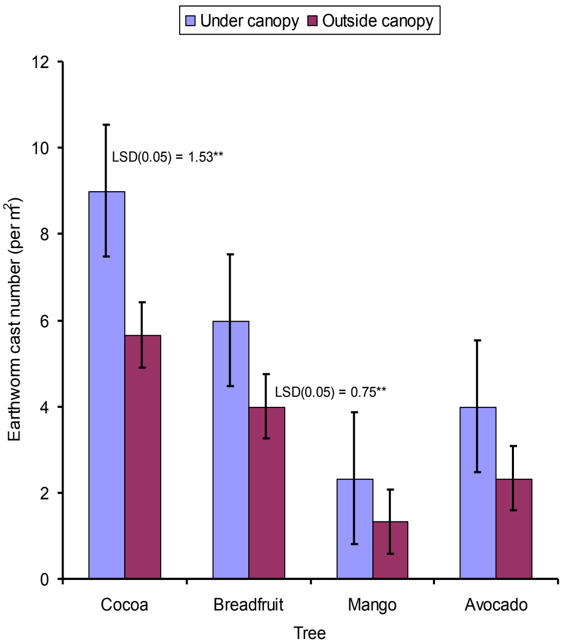

Fig. 5. Effect of tree on the earthworm cast number (per m^2) of an Ultisol at 0 – 15 cm depth at Umudike
Source: Own results

The results show that the mean values of 9.00, 6.00, 2.33 and 4.00 were obtained for cacao, breadfruit, mango and avocado, respectively which were significantly higher than the lower values of adjacent open sites of cacao (5.67) breadfruit (4,00), mango (7.33) and avocado (2.33). Also, there were significant differences existing between the earthworm casts under the tree canopies as well as the open adjacent soils.

The results obtained in Fig. 3 show that the number of earthworm casts under cacao canopy was significantly (P = 0.05) higher than those of breadfruit, avocado and mango in the following significant order: Cacao > Breadfruit > Avocado > Mango. However, mango had the least number of earthworm casts. The results of the member of earthworm casts outside the tree canopies (10 meters away) followed the same trend. The number of earthworms will, therefore, influence the number of casts. Hence, as the tree canopies enhance earthworm population, consequently this will also increase the number of casts. [5] stated that earthworm burrows can make up 5% of the total soil volume, and observed that high earthworm population enhances soil aeration, drainage and infiltration. [27] noted that earthworms bring to the soil surface casts of about 2 - 5.8 t/ha on agricultural land, 15 t/ha in temperate woodland and about 50 t/ha in tropical forest.

CONCLUSIONS

This research has documented basic information about the effect of trees on the physical properties of soils as well as earthworm population and casts in Umuahia southeastern Nigeria. The study has shown that soils under tree canopies at various soil depths (0 – 15 and 15 – 30 cm) had higher total porosity, water stable aggregates and lower bulk density than their open adjacent sites. Also, the study revealed that there were increase earthworm population and casts under the tree canopies (cacao, breadfruit, avocado and mango) than their adjacent sites. The results also pointed to the fact that leaf litter from trees especially cacao improved the soil physical properties, and increased earthworm population and casts.

Recommendations

(i)It is recommended that farmers should plant cacao or breadfruit trees along the contour bunds or boundaries as alley, prune them periodically or allow the leaves to fall and decay to improve the structure of the soils.

(ii)It is hoped that these trees if established on soils that are prone to erosion could help improve the soil aggregates, reduce the rate of runoff and encourage infiltration.

(iii)Farmers should be advised to stop deforestation and adopt the method of tree planting.

REFERENCES

[1]Arevalo-Gardini, E., Canto, M., Alegre, J., Loli, O., Julca, A., Baligar, V., 2015, Changes in soil physical and chemical properties in long term improved natural and traditional agroforestry management systems of Cacao genotypes in Peruvian Amazon. PLoS ONE; 10(7): e0132147.

[2]Ariah, C.C., Ukpabi, U., Mbajunwa, K.O., 1999, Production of African breadfruit for human nutrition Nig. Food Journal Institute of Food Science Technology Pp 19.University of Technology Owerri.

[3]Augusto, L., De Schrijver, A., Vesterdal, L., Smolander, A., Prescott, C., Ranger, J., 2015, Influences of evergreen gymnosperm and deciduous angiosperm on soil physical, chemical and biological properties in high elevation forests. Biol. Rev. Camb Philos Soc. 90 (2) 444 – 66.

[4]Bayala, J, Balesdent Ymarol, C., Zapata, F., Tekleha Imanot Z, Ouedraogo, S.J., 2006, Relative contribution of trees and crops to soil carbon content in a park land system in Burkinafaso using variations in natural C-13 abundance. Nutr cycl Agroecosys 76:193-201.

[5]Blakemore, R., 2003, Fact sheets on earthworms casting Queen Victoria Museum, Launceston.

[6]Bolhen, P.Y., Parmeler, R.W., McCaartney, D.A., Edwards, C.A.,1997, Earthworm effects on carbon and nitrogen dynamics of surface litter in corn agro ecosystem Ecol Appli 7(4): 1341:1349.

[7]Brekke, J.E., 1995, Mango: Processed Products AR.S – 23, USDA.

[8]Carpenter, F.L, Nicholas, J.O., Palt, R.I., Young, K.C., 2004, A Methods of Facilitating Reforestation of Tropical degraded land with the Native Timber tree. Terminalia Amazonia Forest Ecology and Management 202:281-291.

[9]Cleveland, C.C., Reed, S.C., Townsend, A.R., 2006, Nutrient Regulation of Organic matter Decomposition in a Tropical Rain Forest Ecology 87:492-503.

[10]Curry, J.P., Byrne, D., 1992, The role of earthworms in straw Decomposition and Nitrogen Turnover in Arable Land in Ireland Soil Biol. Biochem 27 (3): 341-348.

[11]Edward, C.A., Lofty, J.R., 1997, The invertebrate fauna of the park Grass plots: 1. Soil fauna Rothamsted Report part 2:133-154.

[12]Elliot, P.W., Knight, D., Anderson, J.M., 1990, Denitrification in earthworm casts and soil from pastures under different fertilizer and drainage regimes. Soil Bio. Biochem. 22(5): 601-605.

[13]Enwezor, W. O., Udo, E. J., Sobulo, R.A., 1981, Fertility status and productivity of the acid sands. In 'Acid Sands of Southeastern Nigeria' Udo, E. J. and Sobulo, R. A. (eds) Soil Sci. Soc. Of Nigeria Special Publication Monograph No. 1 Pp 56 – 75.

[14]FAO/UNESCO, 1977, Soil map of the Word Volume IV. Africa, UNESCO, Paris.

[15]FAO, 1999, State of the World's Forests, Rome.

[16]Fassie, O.S., Elemyimni, A., Fassi, A.R., 2004, Chemical properties of Raw and Processed Breadfruit (*T. africana*) seed flours. Journals of Food Agric Environment Vol.2. Pp.65-68.

[17]Felker, P., 1978, State of the art Acia Albida as a Complementary permanent inter Crop with Annual Crops Calnifornia University River Side 133 Pp.

[18]Gartner, T.B., Cardon, Z.G., 2004, Decomposition dynamics in mixed – species leaf litter. Oiko 104:230-46.

[19]Hilgado, P., Sindoni, M., Matta, F., Nagel D.H., 2002, Earthworm casting increase germination rate and seedling development of cucumber. CARES MAFES MISSIPPI State University.

[20]Jagtiani, J., Chan, H.T, Sakai, W.S., 1988, Tropical fruit processing Academic Press, New York. Pages 45-97.

[21]Jones, C.G., Lawton, J.H., Shachak, M., 1994, Organisms as Ecosystem Engineers. Oikos 79:373-386.

[22]Kader, A.A. (ed), 1992, Post harvest Technology of Horticultural Crops, 2nd ed. University of California Publication 3311.

[23]Kuers, K.S. Simmons, J., 2003, Leaf litter composition. The Highlands Institute for Environmental Research and Education at West Virginia Wesleyan College. Pp. 1-5.

[24]Logsdon, G., 1994, Worldwide Progress in vermicomposting Biocylce 35 (10): 63-65.

[25] Logsdon, S.D., Linden, D.R., 1992, Interaction of Earthworms with soil Physical Conditions Influencing Plant Growth. Soil sci. 154:330-337.

[26]Maier, C., 2018, How do earthworms most likely affect the soil? Home Guides/SF Gate, http://homeguides.sfgate.com/earthworms likely-affect-topsoil.html, Accessed Jan.10, 2018.

[27]Morgan, R.P.C., 1995, Soil Erosion and Conservation 2nd ed. Longman.

[28]Mulongoy, K., Murckx, R., 1993, Soil organic matter dynamics and sustainability of tropical agriculture. Bio and Fertility of soils, 6:282-285.

[29]National Root Crops Research Institute (NRCRI), 2017, Meteorological Center, NRCRI Umudike Nigeria. 2008-2017 Records.

[30]Ojimgba, O., Mbagwu, J. S. C., 2007, Evaluation of the Physical and Chemical properties of an eroded Ultisol and their an maize yield. Jour. Sc. Agric. Food Tech. and The Env. Vol. 7. No. 1. Pp 57 – 64 Fac. of Agric. Ebonyi State Uni. Abakaliki, Niger.
[31]Ojimgba, O., 2010, Evaluation of the Effects of Cacao (*Theobroma* c*acao L*) leaf litter on the Physical properties of an ultisol in South Eastern Nigeria.
[32]Opara-Nadi, O.A., 2000, Soil Resource and Agricultural Productivity in Nigeria. In Food and fibre Production Nigeria in the 21st Century. Nwaigbo, L.C., Ukpabi, U.H. and Anene, A. (eds). Pp 195-210. Proceedings of the first Annual Conference of the College of Agriculture and Veterinary Medicines, Abia State University, Uturu, Nigeria.
[33]Sayer, J., Chokkalingam, U., Poulsen, J., 2004, The restoration of forest Biodiversity and Ecological values. Forest Ecology and Management 201:3-11.
[34]Steel, R. G. D., Torrie, J. H., 1980, Principles Procedures of Statistics. A Biometric Approach . Mc Graw – Hill Publications, New York, 633 pp.
[35]Stolte, J., 1997, Manual of Soil Physical Measurements. Version 3. Wageningen, D. L. O. Staring Centre. Tech. Doc.37.
[36] Van Goor, C.P., 1985, The impact of trees species on productivity. Neth. J. Agric Sci, 33:133-140.
[37]Wardle, D.A., 2002, Communities and Ecosystems: Linking the Above ground and Below Ground Components. Princeton: Princeton University Press.
[38]Wikinson, G. E., Ania, P. O., 1976, Infiltration of water into two Nigerian soils under Secondary Forest and Subsequent Arable Cropping. Geoderma 15: 51-59.
[39]Young, A., 1989. Agroforestry for soil Conservation CAB International, UK, P, 26.
[40]Zou, X.M., Gonzalez, G., 2002, Earthworm in Tropical tree – plantations. Effects of management and relations with soil carbon and nutrient use efficiency. In management of Tropical plantation forests and their soils litter system in M.V. Reddy, Editor Enfield (NH), USA: Science Publishers, Inc.
[41]Zou, X., Borges, S., Gonzalez, G., 1996, Earthworm Abundance and Species Composites in abandoned tropical croplands: comparison of tree plantations and secondary forests, http://vivo.uprm.edu/vivo/display/n171422, Retrieved Jan.15, 2018