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Assessment of soil properties and crop yield under agroforestry in the traditional farming system

Adewole M. B.[1]* and Adeoye G. O.[2]

[1]Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]Department of Agronomy, University of Ibadan, Ibadan, Nigeria.

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The rate at which soil ecosystem is being degraded in crop production systems in the tropics is alarming. This study therefore attempts to assess the physico-chemical properties of soil and crop yield under agroforestry in the traditional farming systems. This was a researcher-designed, farmer-managed participatory experiment. Two farming systems (cashew/maize intercropping and sole maize cropping) were used. The two farm locations were in Wasangari village, near Saki. From 5 ha cashew plantation established in 1998 using a plant spacing of 9.0 × 9.0 m^2 by the collaborating farmer, two plots of 20 × 20 m^2 were mapped out for maize, intercropped at a plant spacing of 90 x 40 cm^2 in 2002. Also, to a fallowed land since 1998 adjacent to cashew plantation but cultivated to sole maize in 2002 using the same plant spacing, two plots of 20 × 20 m^2 were mapped out. The maize seedlings in the 4 plots were thinned to 2 stands per hole 2 weeks after planting (WAP) to give a plant population of 55,555 plants/ha. The two collaborating farmers weeded their farms 2 times (2 and 5 WAP) using hoe. The experiment was conducted over two planting seasons. Values of the soil nutrients (0 to 15 cm) evaluated before maize introduction in cashew/maize plots were significantly ($p< 0.005$) higher than those from sole maize plots. Also, the mean yields of maize in the intercropped plots (1.34, 1.02 t ha^{-1}) were significantly ($p < 0.05$) higher than mean yields in sole maize fallowed plots (1.05, 0.81 t ha^{-1}) in the early and late season studies respectively. The study demonstrated that intercropping maize with cashew, in the early stage serves as additional source of income to traditional farmers in the tropics.

Key words: Agroforestry, traditional farming system, cashew, soil nutrient depletion, litter falls,cashew/maize intercrop.

INTRODUCTION

Soil is a dynamic ecosystem for crop production and a living medium that houses the life-sustaining nutrients for crop growth formed from the consolidated rock (Tel and Hagarty, 1984). Soils are also homes to many diverse populations of species including earthworms, insects and micro-organisms (Olayinka, 2009). Soils of the humid tropics are sandy and fragile in nature (Agboola, 1982). Agboola and Omueti (1982) further summarized natural problems peculiar to tropical soils to include: low organic matter, low activity clay and high soil acidity level. The moment the native vegetation is cleared for crop production, the soil potential is exposed to all manner of external influence (Salami et al., 2002). The current increase in population in the humid and sub-humid

*Corresponding author. E-mail: adewoledele2005@yahoo.co.uk

tropics has led to various increases in human activities which have brought about destabilization of the ecological equilibrium of forest ecosystem (Stewart, 1984). In Africa, and especially in Nigeria, nature has created a delicate balance between the soil, plant cover and micro-climatic conditions (Igboanugo, 1997). Rainfall pattern in Africa is torrential which encourages leaching of soil nutrients beyond the root-zones of plants into the ground water. Crop cultivation, generally, depletes soil nutrients (Mbagwu, 2008). Addition of soil amendments in the form of fertilizer, if properly used increases not only the yield of crops but also discourages soil nutrients' imbalance (Adewole and Adeoye, 2008). Blanket fertilizer application to crops is detrimental to crops' qualities and human health (Adeoye, 1993). Also, addition of one nutrient element may lead to the inhibition or stimulation of the absorption of other nutrient elements by plants (Adewole and Adeoye, 2008). An increase in P uptake with addition of N fertilizer to hybrid maize was observed by Barber and Mackey (1986). Most of the available forms of N, P and S in Nigerian soils are in the organic forms (Agboola, 1982). Any farming system that enhances the soil organic matter will also increase the values of N, P and S. This study therefore attempts to assess the impact of two farming systems (intercropping and sole cropping) on the physico-chemical characteristics of soil over a period of two planting seasons. This was done using two derived savanna sites located in the same climatic zone.

MATERIALS AND METHODS

Site and experimental design

The study area is located in Wasangari and lies within latitude 8° 45´ and 9° 05´N longitude 3° 05´ and 3° 50´E in Saki West Local Government Area of Oyo State, Nigeria. Ayanwale (1990) reported the abundance of gneiss due to metamorphic process of igneous rock in soils of the study area. Adewole (1995) described the study area as dry sub-humid tropical with derived savanna vegetation. From the 2 farms selected, one was cultivated to sole maize and the other farm was cultivated to cashew/maize intercrop. The 5 ha sole maize plot cultivated in March and July 2002 had been under fallow since 1998. Also, cashew plantation that was established in 1998 on another 5 ha farm plot adjacent to the maize plot was also intercropped with maize in March and July 2002. The two test crops; Brazilian variety of cashew and SUWAN-I-Y maize seeds were planted.

In cashew plantation, a plant spacing of 9.0 × 9.0 m with one stand per hole to give a plant population of 123 plants/ha was used. Core soil samples taken to the depths of 0-15 cm and 15-30 cm using systematic random technique from each quadrant of 2 × 2 m in four of the 20 × 20 m mapped-out plots (two plots from each farm) were thoroughly mixed for homogeneity. A total of five composite soil samples were obtained from each of the four farm plots per soil depth and per cropping season just before the planting of maize seeds. Also, 90 × 40 cm plant spacing at the seed rate of 3 seeds per hole was used for maize (in the sole cropping and intercropping plots with cashew). The maize seedlings were thinned to 2 stands per hole at 2 weeks after planting (WAP) to give a plant population of 55,555 plants/ha. The experimental plots were weeded 2 times (2 and 5 WAP) using hand hoe. No fertilizer treatment was imposed. The experiment was conducted over 2 planting seasons; the early and late seasons of 2002.

Laboratory analysis

Laboratory analyses of the soil samples were carried out using standard methods. The particle size analysis was determined using hydrometer method in 5% calgon as the dispersing agent (Bouyoucos, 1951). Soil pH was determined potentiometrically in 1 M KCl solution at a ratio of 1: 1 (soil to KCl) (Mclean, 1982). Soil organic carbon was determined using Walkey-Black method (Nelson and Sommers, 1982). Total nitrogen of the soil was determined by the macro-Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus in the soil was determined using Bray P1 method (Olsen and Sommers, 1982). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined using 1 M NH_4OAc (Ammonium acetate) buffered at pH 7.0 as extractant (Thomas, 1982). The K^+ and Na^+ concentrations in soil extracts were read on Gallenkamp Flame photometer while Ca^{2+} and Mg^{2+} concentrations in soil extracts were read using Perkin-Elmer Model 403 atomic absorption spectrophotometer.

The exchangeable acidity (H^+ and Al^{3+}) in the soil was extracted with 1 M KCl (Thomas, 1982). Solution of the extract was titrated with 0.05 M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of NaOH used was equivalent to the total amount of exchangeable acidity in the aliquot taken (Odu et al., 1986). The total sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) gave the cation exchangeable capacity. The extractible micronutrients (Fe, Mn and Zn) were extracted with 0.1 M HCl (Juo, 1982) and their concentrations in soil extracts were read on AAS (Perkin-Elmer Model 403).

Statistical analysis

Soil data and crop yield obtained were analyzed using descriptive statistics and the treatment means were separated using new Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Table 1 shows the results of laboratory analysis of the sampled soils to the depth 0 -15 cm from cashew/maize intercropped and sole maize plots before maize was planted in the early season of 2002. The mean of soil pH in 1:1 soil – 1M KCl ratio ranged from 6.3 to 6.8 indicating slight acidic soil conditions. The soil texture was sandy loam. The soil organic carbon (OC) mean values were (range, g kg^{-1}) 13.05-30.05 with cashew/maize 2 plot having significantly ($p < 0.005$) highest value. The total nitrogen (TN) mean values were (range, g kg^{-1}) 1.19 - 4.21 with the same plot, cashew/maize 2 having significantly ($p < 0.005$) highest value. The available P mean values were (range, mg kg^{-1}) 18.15-45.17 with cashew/maize 2 plot having significantly ($p < 0.005$) highest value. The observed highest values of OC and TN were however considered moderate while available P was considered high by Singh (2002) for maize cultivation in Nigeria.

The cation exchangeable capacity (CEC) mean values were (range, cmol kg^{-1}) 11.80-19.77 with cashew/maize 2 plot

Table 1. Physico-chemical properties of soil (0 – 15 cm) in the early cropping season.

Plot	pH in 1 M KCl	Sand gkg $^{-1}$	Clay gkg $^{-1}$	Silt gkg $^{-1}$	P mg kg^{-1}	OC gkg^{-1}	N gkg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	Na cmol kg^{-1}	K cmol kg^{-1}	Exchangeable acidity cmol kg^{-1}	CEC cmol kg^{-1}	Fe cmol kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}
Cashew/maize 1	6.40^{bc}	750^{c}	65^{c}	185^{b}	35.51^{b}	21.75^{b}	3.15^{b}	8.70^{b}	8.10^{a}	1.50^{b}	1.20^{b}	0.18^{b}	19.68^{b}	85.09^{d}	45.95^{d}	10.22^{b}
Cashew/maize 2	6.50^{b}	715^{d}	70^{b}	215^{a}	45.17^{a}	30.05^{a}	4.21^{a}	9.61^{a}	6.63^{b}	1.75^{a}	1.60^{a}	0.18^{b}	19.77^{a}	130.25^{a}	115.14^{a}	12.10^{a}
Maize 1	6.80^{a}	748^{b}	71^{a}	181^{c}	25.25^{c}	18.15^{c}	2.07^{c}	7.55^{c}	5.03^{c}	0.45^{c}	0.37^{d}	0.20^{a}	13.66^{c}	103.54^{c}	85.25^{b}	9.09^{d}
Maize 2	6.30^{c}	795^{a}	60^{d}	145^{d}	18.70^{d}	13.05^{d}	1.85^{d}	6.78^{d}	4.15^{d}	0.30^{d}	0.40^{c}	0.15^{c}	11.80^{d}	125.00^{b}	75.15^{c}	10.14^{c}

Values within a column followed by different letter are significantly different according to new Duncan Multiple Range Test at $p < 0.005$.

Table 2. Physico-chemical properties of soil (15 – 30 cm) in the early cropping season.

Plot	pH in 1 M KCl	Sand gkg $^{-1}$	Clay gkg $^{-1}$	Silt gkg $^{-1}$	P mg kg^{-1}	OC gkg^{-1}	N gkg $^{-1}$	Ca cmol kg^{-1}	Mg cmol kg^{-1}	Na cmol kg^{-1}	K cmol kg^{-1}	Exchangeable acidity cmol kg^{-1}	CEC cmol kg^{-1}	Fe cmol kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}
Cashew/maize 1	6.30^{b}	748^{b}	72^{b}	180^{c}	30.42^{b}	18.14^{b}	2.46^{b}	6.92^{b}	4.05^{b}	1.15^{b}	1.25^{a}	0.18^{c}	13.55^{b}	80.65^{d}	33.60^{d}	7.99^{b}
Cashew/maize 2	6.60^{a}	720^{d}	83^{a}	197^{a}	36.58^{a}	20.98^{a}	2.70^{a}	8.09^{a}	5.65^{a}	1.18^{a}	1.07^{b}	0.25^{a}	16.24^{a}	85.18^{b}	75.14^{a}	11.20^{a}
Maize 1	6.70^{a}	745^{c}	70^{c}	185^{b}	24.95^{c}	12.17^{d}	1.38^{d}	5.55^{d}	2.00^{d}	0.65^{c}	0.40^{c}	0.25^{a}	8.85^{d}	98.10^{a}	62.01^{b}	6.55^{c}
Maize 2	6.30^{b}	780^{a}	61^{d}	159^{d}	17.17^{d}	13.00^{c}	1.59^{c}	6.65^{c}	2.95^{c}	0.55^{d}	0.33^{d}	0.22^{b}	10.70^{c}	85.15^{bc}	60.98^{c}	5.98^{d}

Values within a column followed by different letter are significantly different according to new Duncan Multiple Range Test at $p < 0.005$

having significantly ($p < 0.005$) highest value. There was a direct positive relationship, separately, between OC and CEC; and OC and the extractible micronutrients (Fe, Mn and Zn). It is therefore important to note here that TN, available P, CEC and extractible cations were OC dependent.

Table 2 shows the results of soil samples taken to the depth 15-30 cm from the four plots before maize seeds were planted in the early season of 2002. The observed trend of higher values of OC, TN, exchangeable cations and extractible cations at the topsoil than the subsoil could be attributed to the fact that most of the plant nutrients in their available form domicile in the topsoil. These findings agreed with those reported in earlier studies of Agboola (1982) and Nill and Nill (1993). Tables 3 and 4 show the results of the soil samples taken to the depths 0-15 and 15-30 cm from the four plots after the early season maize had been harvested, but before the planting of late season maize. Tables 3 and 4 further show clearly that TN, available P, CEC and extractible cations were OC dependent. Also, cashew/maize plots showed superiority of all these soil chemical properties over sole maize plots.

The soil chemical properties measured in cashew/maize intercrop plots are generally higher in values than in the sole maize plots despite the 4 years of fallow. Rind-weeding of cashew stands and slashing of weeds in between the rows of cashew stands were regularly carried out before maize was intercropped with cashew 4 years after establishment. These were litter falls that positively enhanced the organic matter content and all the OC dependents (TN, available P, CEC and extractible cations). This agreed with the earlier findings of Kang (1993) that TN and available P are organic matter dependent.

The mean yields of maize seed obtained at full maturity are presented in Table 5. Mean yield of SUWAN-I-Y maize seed of 1.34 t ha^{-1} from cashew/maize intercrop was significantly higher than 1.05 t ha^{-1} from sole maize in the early season cropping. Similar trend in the mean yields of maize seed were obtained in the late season cropping of cashew/maize intercrop and sole maize but at a lower magnitude. First set of

Table 3. Physico-chemical properties of soil (0 – 15 cm) in the late cropping season.

Plot	pH in 1 M KCl	Sand gkg $^{-1}$	Clay gkg $^{-1}$	Silt gkg $^{-1}$	P mg kg $^{-1}$	OC gkg $^{-1}$	N gkg $^{-1}$	Ca cmol kg $^{-1}$	Mg cmol kg $^{-1}$	Na cmol kg $^{-1}$	K cmol kg $^{-1}$	Exchangeable acidity cmol kg $^{-1}$	CEC cmol kg $^{-1}$	Fe cmol kg $^{-1}$	Mn mg kg $^{-1}$	Zn mg kg $^{-1}$
Cashew/maize 1	6.40^{b}	750^{b}	65^{c}	185^{b}	30.55^{b}	21.56^{b}	2.45^{b}	8.00^{b}	5.54^{a}	1.85^{a}	1.15^{b}	0.18^{b}	16.72^{a}	88.65^{d}	50.25^{d}	10.86^{a}
Cashew/maize 2	6.60^{ab}	710^{c}	73^{a}	217^{a}	48.67^{a}	28.80^{a}	3.06^{a}	8.50^{a}	3.58^{d}	1.74^{b}	1.78^{a}	0.20^{a}	15.85^{b}	95.05^{c}	105.15^{a}	10.35^{b}
Maize 1	6.60^{ab}	750^{b}	71^{b}	179^{c}	24.85^{c}	16.57^{c}	1.48^{c}	6.00^{d}	4.10^{b}	0.55^{c}	0.40^{c}	0.20^{a}	11.35^{d}	95.17^{b}	100.67^{b}	8.10^{a}
Maize 2	6.70^{a}	790^{a}	61^{d}	149^{d}	22.77^{d}	10.10^{d}	1.35^{d}	6.56^{c}	4.05^{c}	0.51^{d}	0.38^{d}	0.20^{a}	11.94^{c}	108.17^{a}	80.65^{c}	7.30^{d}

Values within a column followed by different letter are significantly different according to new Duncan Multiple Range Test at $p < 0.005$.

Table 4. Physico-chemical properties of soil (15 – 30 cm) in the late cropping season.

Plot	pH in 1M KCl	Sand gkg $^{-1}$	Clay^{-1} gkg	Silt gkg $^{-1}$	P mg kg $^{-1}$	OC gkg $^{-1}$	N gkg $^{-1}$	Ca cmol kg $^{-1}$	Mg cmol kg $^{-1}$	Na cmol kg $^{-1}$	K cmol kg $^{-1}$	Exchangeable acidity cmol kg $^{-1}$	CEC cmol kg $^{-1}$	Fe cmol kg $^{-1}$	Mn mg kg $^{-1}$	Zn mg kg $^{-1}$
Cashew/maize 1	6.50^{c}	719^{d}	69^{c}	212^{a}	30.42^{b}	21.50^{b}	2.15^{b}	5.18^{b}	4.00^{b}	1.06^{a}	1.36^{b}	0.18^{b}	11.80^{a}	69.52^{c}	89.96^{a}	6.57^{c}
Cashew/maize 2	6.70^{a}	725^{c}	77^{a}	198^{b}	30.65^{a}	22.85^{a}	2.29^{a}	4.95^{c}	4.07^{a}	0.95^{b}	1.50^{a}	0.20^{a}	11.72^{b}	63.31^{d}	86.10^{b}	6.62^{b}
Maize 1	6.60^{b}	740^{b}	72^{b}	188^{c}	21.18^{c}	13.10^{c}	1.38^{c}	4.98^{c}	3.33^{c}	0.70^{c}	0.36^{c}	0.20^{a}	9.62^{c}	79.96^{b}	57.15^{c}	7.10^{a}
Maize 2	6.60^{b}	773^{a}	63^{d}	164^{d}	21.00^{d}	12.06^{d}	1.19^{d}	6.00^{a}	2.27^{d}	0.32^{d}	0.36^{c}	0.20^{a}	9.20^{d}	100.27^{a}	56.67^{d}	5.88^{d}

Values within a column followed by different letter are significantly different according to new Duncan Multiple Range Test at $p < 0.005$.

Table 5. Mean yield of maize (t ha^{-1}) as affected by different farming practices*.

Farming practice	Early season	Late season
Cashew/maize	1.34^{a}	1.02^{a}
Maize	1.05^{b}	0.81^{b}

Values within a column followed by different letter are significantly different according to new Duncan Multiple Range Test at $p < 0.05$, *Native soil fertility (No application of fertilizer).

matured nuts of cashew that dropped in 2002 was 92 kg ha^{-1} and this could serve as additional income to the collaborating farmer.

Conclusion

The rate of soil nutrient depletion in cashew/maize intercropped compared with sole maize plots was low. OC, TN, available P, CEC and extractible cations values were higher under cashew/maize intercropped compared with sole maize plots. This could be attributed to the canopies of cashew trees protecting the topsoil and nutrients' input from the decomposed litter falls from cashew trees. The study concludes that agroforestry in the traditional farming system of this nature helps to reduce the rate of soil nutrient depletion, while the yield of 'participating crop'; maize could still be reasonably high

Conflict of Interests

The author(s) have not declared any conflict of interests.

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