Greener Journal of Agricultural Sciences

ISSN: 2276-7770 Impact Factor 2012 (UJRI): 0.7904 ICV 2012: 6.15

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Research Article

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Abstract

A study was conducted at Ongot in the humid forest zone (HFZ) of Cameroon to determine the extent to which selected soil quality indicators are affected by cassava cultivation along a chronosequence of 5, 10 and 20 years. Soil samples were collected from cassava farms along this chronosequence and from a nearby forest as reference. The samples were analyzed for soil organic matter (SOM), organic carbon (OC), total nitrogen (TN) and pH. SOM, OC and TN decreased significantly ($P<0.05$) following years of cassava cultivation. Thus after 20 years of cultivation, SOM and OC contents reduced by 50% compared to the reference (SOM=35.08 g kg^{-1}, OC=20.39 g kg^{-1}). TN decreased from 2.19 g kg^{-1} in the reference to 1.24 g kg^{-1} in farms where cassava has been cultivated for 20 years. Soil pH ranged from 5.4 to 5.6 but did not differ ($P<0.05$) irrespective of years of cassava cultivation. Generally, significant differences in soil quality indicators were not observed between the forest soil and soils from five-year old cassava farms. This could imply that management strategies to improve soil quality in the HFZ of Cameroon are warranted mainly after four years of cassava cultivation.

Key words: Carbon, Chronosequence, *Manihot esculenta* cranz, Nitrogen, pH.

Introduction

Cassava (*Manihot esculenta* Cranz) is one of the most important staple food crops grown in Africa (Duindam and Hauser, 2008; Janssens, 2001). The crop plays a major role in efforts to eradicate famine in Africa because of its high starch content, tolerance to poor soil conditions and drought, year-round availability, and suitability for diverse smallholder farming systems (Echebiri and Edaba, 2008; Hauser et al., 2006).

In Cameroon, more than 2.5 million tons of cassava roots are produced annually (IITA, 2010). The tuberous roots are consumed either boiled, or transformed into other products like gari, water foufou, Baton de manioc and mitumba, while the leaves are consumed as a vegetable alongside the boiled roots. Cassava also contributes a great share in the household income of the rural population of Cameroon through the sale of tuberous roots and other transformed products. The continuous cultivation of cassava on the same piece of land without adequate farm management practices in Cameroon is likely to affect soil quality attributes and possibly cassava production in the long term.

Soil organic carbon and nitrogen are soil quality indicators (Ngome et al., 2011a) and major determinants of the sustainability of agricultural production systems (Blair et al., 1995). Other soil quality attributes may include pH, phosphorus, potassium, calcium and magnesium.

Although it has been well documented that cultivation of soils possibly results in structural degradation and decreased soil quality (Blair and Crocker, 2000), the extent to which this practice affects soil carbon, nitrogen and pH in smallholder cassava farms is not well known. It is postulated in this study that the carbon, nitrogen and pH of cassava farms will decrease following a chronosequence of cultivation. Thus, the objective of this study was to determine the extent to which soil quality attributes are affected by cassava cultivation along a chronosequence of 5, 10 and 20 years in the humid forest zone of Cameroon. In addition, the study intended to determine appropriate period to implement intervention strategies along the chronosequence.

Materials and methods

Experimental site

The study was conducted at Ongot, Center Region, in the humid forest agro ecological zone of Cameroon. Ongot (Altitude: 300 m, Lat: 3°52 N, Long: 11° 32 E) is approximately 18 km from Yaoundé. The area is characterized by a bimodal rainfall pattern, with four seasons: Long rainy season from September to November, long dry season from December to February, short rainy season from March to June and short dry season from July to August. The average daily temperature is estimated at 23-24°C and annual rainfall at 1617 mm (Atangana,1998). The dominant soil type is rhodic ferralsol derived from basic rocks. The soils are generally acidic, low in organic carbon content, total nitrogen and deficient in exchangeable potassium and available P (Yerima and van Ranst, 2005).

Farm selection

Field visits were organized in Ongot village in March 2012 to select cassava farms based on the following criteria: (i) years of continuous cassava cultivation, respectively, 5 years, 10 years and 20 years, (ii) absence of intercrops particularly legumes that could possibly influence the amount of nitrogen, (iii) absence of the use of organic and inorganic fertilizer, (iv) accessibility of the cassava farms to ease data collection and (v) the use of local cassava varieties. Five farms were selected for each of the years of cultivation, making a total of 15 farms. A forest very close to the farms was used as reference. The forest is within the same agro ecological zone, of the same soil type (rhodic ferralsol) and has not been cultivated before.

Treatment application and sampling

Ten soil samples were taken with an auger from the upper soil layer (0-20 cm) in each of the selected cassava farms and mixed, air-dried, finely ground, sieved (< 2mm) and stored in labeled plastic bags. The same procedure was used to obtain soil samples from the reference. Soil sampling was done following the transect method (Okalebo et al., 2002).

Soil analysis

The soil analyses were carried out at the Institute of Agricultural Research for Development (IRAD), in the Laboratoire d'Analyse de Plants, Sols, Engrais et Eaux (LAPSEE), Nkolbisson, Yaoundé (Cameroon). Soil pH was measured with a glass electrode using a soil:water ratio of 1: 2.5. Organic carbon (OC) was determined by Walkley and Black wet combustion method. Organic matter was determined as OM = OC x 1.72. Total N was measured by Kjehldahl method. All analyses were done following the procedures by Okalebo et al., 2002.

Data analysis

Data generated on soil carbon, nitrogen and pH were entered into a Microsoft Excel spread sheet and then subjected to analysis of variance (ANOVA), using SPSS version 17.0 for Windows (SPSS, 2008). Statistical differences among treatment means were declared at 5% level of significance. Means were separated using Tukey test.

Results and Discussion

Effects on soil organic matter

Soil organic matter content reduced significantly ($P<0.01$) with years of cassava cultivation (Figure 1). Thus, after five years of cassava cultivation the organic matter content reduced from 35.60 g kg^{-1} observed with the reference forest soil to 25.60 g kg^{-1} (approximately 28% reduction). The decline in soil organic matter was severe after 20 years of cassava cultivation, as only about half (18.70 g kg^{-1}) of the initial amount was observed in the cassava fields. This may suggest the use of technologies to improve soil organic matter in cassava fields before five years of continuous cultivation. The use of leguminous cover crops (Ngome et al., 2011b; 2012), application of animal manure (Rufino et al., 2007) and *Tithonia* biomass transfer (Rutunga et al., 2003) are some of the technologies used elsewhere for soil organic matter improvement that could be promoted in the study area.

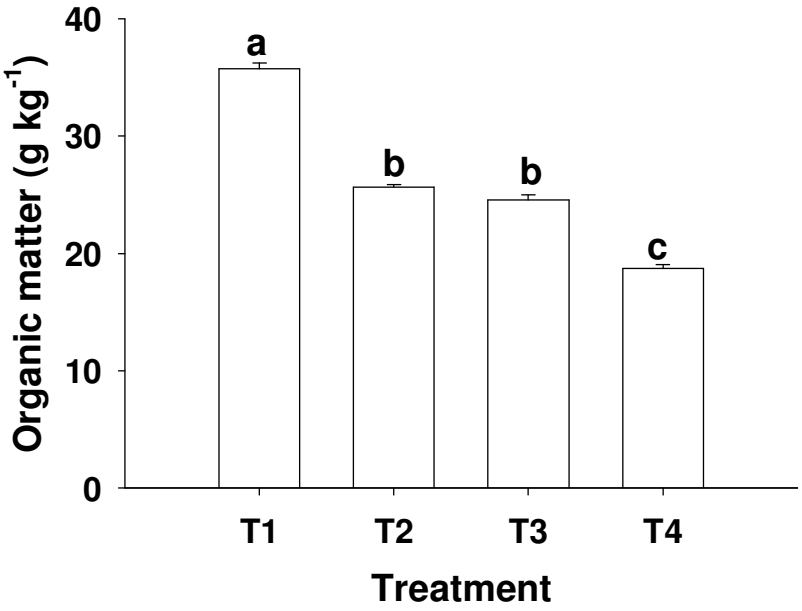

Figure 1: Effects of continuous cassava cultivation on soil organic matter content in the humid forest zone of Cameroon. Bars are standard errors of the means. Means with the same letters are not significantly different (P<0.05) by Tukey. T1: Reference forest soils; T2: Soils from fields where cassava has been continuously cultivated for 5 years; T3: cultivated for 10 years; T4: cultivated for 20 years.

Effects on soil organic carbon

Effects of continuous cassava cultivation on soil organic carbon followed similar trends as in soil organic matter (Figure 2). The reference forest soil had the largest amount (20.75 g kg^{-1}) while the smallest amount (10.90 g kg^{1}) was observed in farms where cassava has been cultivated for 20 years. This amount was two-fold that observed in fields where cassava was cultivated continuously for 20 years. Meanwhile, no major changes in soil organic carbon occurred between cassava fields of age five and ten years.

Soil organic carbon is directly linked to soil organic matter (Olson et al., 2005). This explains why the results of soil organic carbon followed a similar trend as soil organic matter in the current study.

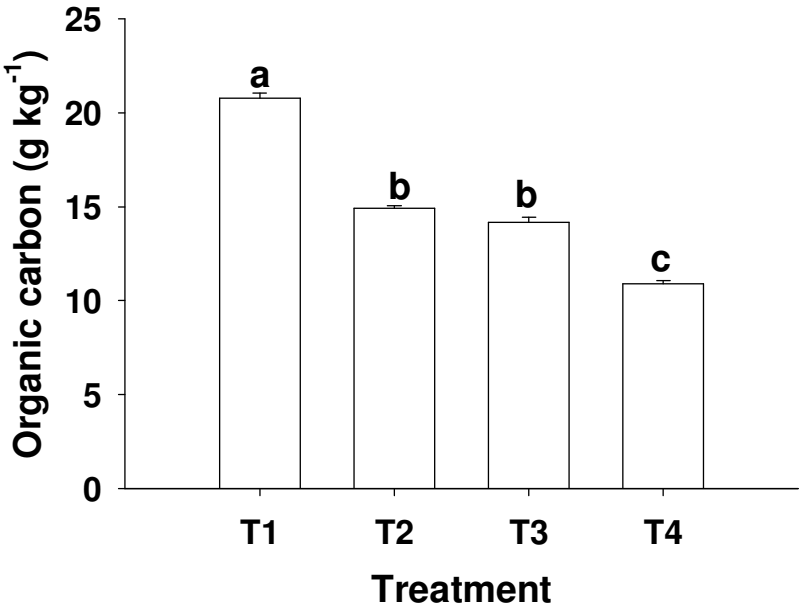

Figure 2: Effects of continuous cassava cultivation on soil organic carbon content in the humid forest zone of Cameroon. Bars are standard errors of the means. Means with the same letters are not significantly different (P<0.05). T1: Reference forest soils; T2: Soils from fields where cassava has been continuously cultivated for 5 years; T3: cultivated for 10 years; T4: cultivated for 20 years.

Effects on soil nitrogen

The amount of total nitrogen in the cassava fields varied proportionately with years of cassava cultivation (Figure 3). After 20 years of continuous cassava cultivation, the total nitrogen content in these fields decreased significantly (P<0.01) from 2.2 g kg^{-1} registered in the reference forest soil to 1.0 g kg^{-1}. Although differences were observed in total nitrogen in fields where cassava was cultivated continuously for five to ten years, these differences were not significant (P<0.05).

Nitrogen is a major nutrient element for growth and development in crops (Ngome and Mtei, 2010). In smallholder cassava cropping systems of Africa, the use of mineral fertilizer is uncommon. Additionally, the long duration fallows to restore soil quality practiced in the past are no more possible because of high pressure on croplands (Ngome et al., 2011a). The introduction of grain legumes such as groundnut into smallholder cassava cropping systems is suggested for restoring soil nitrogen in the cassava farms.

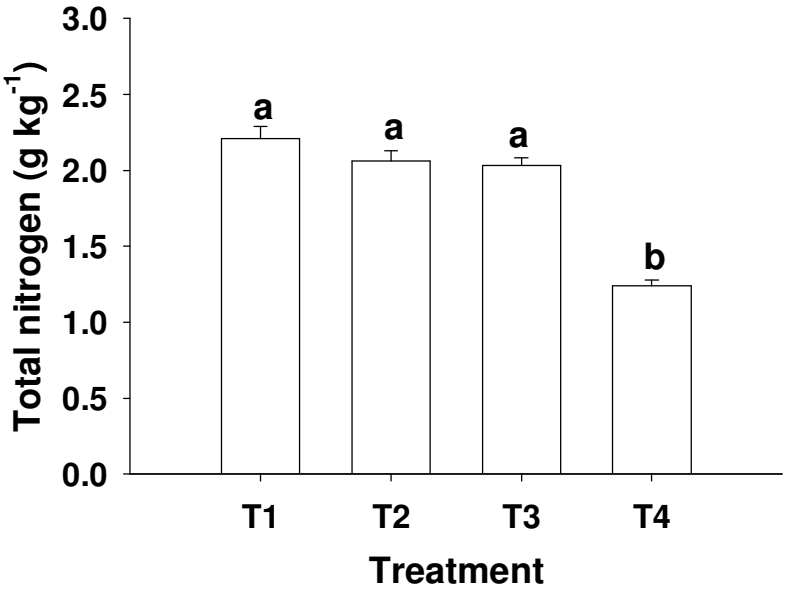

Figure 3: Effects of continuous cassava cultivation on total soil nitrogen content in the humid forest zone of Cameroon. Bars are standard errors of the means. Means with the same letters are not significantly different (P<0.05). T1: Reference forest soils; T2: Soils from fields where cassava has been continuously cultivated for 5 years; T3: cultivated for 10 years; T4: cultivated for 20 years.

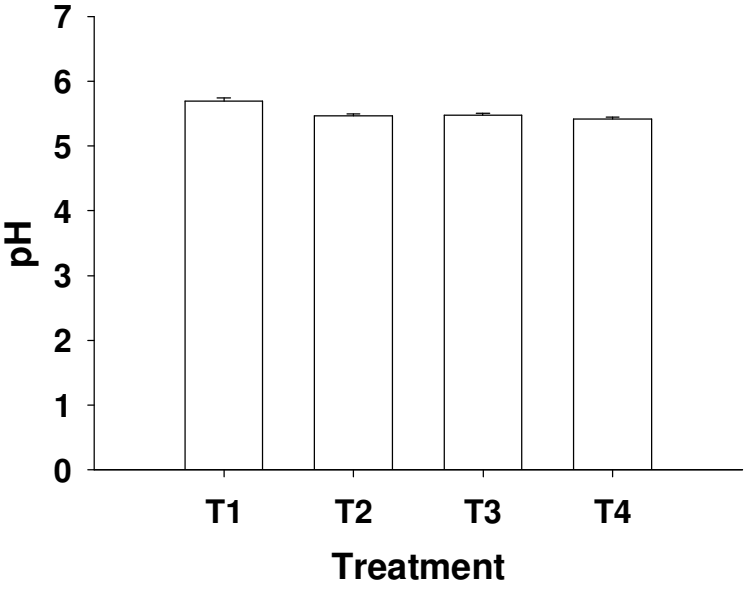

Figure 4: Effects of continuous cassava cultivation on soil pH in the humid forest zone of Cameroon. Bars are standard errors of the means. T1: Reference forest soils; T2: Soils from fields where cassava has been continuously cultivated for 5 years; T3: cultivated for 10 years; T4: cultivated for 20 years.

Effects on soil pH

Soil pH in the cassava fields ranged from 5.4 to 5.6 but did not differ ($P<0.05$) irrespective of years of cassava cultivation (Figure 4). This result is in contrast with an earlier study conducted by Araki et al. (2013), who observed a significant decrease in soil pH of approximately 0.5 after one season of cassava cultivation. However in their study, the scientists used improved cassava varieties that could possibly have different effects on soil properties compared to local varieties.

Conclusion

Soil carbon and nitrogen contents reduce in cassava farms along a chronosequence of cultivation particularly after five years of cultivation. However, soil pH apparently does not change regardless of years of cultivation. These results are preliminary and so warrant additional studies using both local and improved cassava varieties before disseminating to users. Future studies should also consider continuous cultivation durations lower than five years so as to estimate the critical point along the chronosequence for timely implementation of management interventions.

Acknowledgement

The authors are grateful to the Centre for International Migration (CIM) and World University Service (WUS), Germany, for providing the equipments for soil sampling and preparation. Our appreciation also goes to Mr Atangana Augustin for his assistance in data collection and the staff of LAPSEE of IRAD Nkolbisson for analyzing the samples.

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