Land Evaluation and Productivity of Organically-Fertilized Crop Mixtures in a Degraded Tropical Soil

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Abstract: We investigated the fertility status of degraded soil and consequently amended them with varying rates of poultry manure in 2005 and 2006 cropping seasons. Yam – maize –Cassava intercrop was used for the productivity assessment. Soil samples and amendment were characterized before the experiment which was laid out in a randomized complete block design (RCBO) using 5 rates of poultry manure, namely O, 5000, 10000, 15000 and 20000 kg ha^{-1}. These rates of poultry manure were replicated thrice. Performance indices were plant height and tuber and grain yield, and they were enhanced by poultry manure amendment. Maize and cassava had their optimum yield at 15000 kg ha^{-1} poultry manure while yam did not reach its optimum performance in the highest rate of 2000 kg ha^{-1}, suggesting increased rate of poultry manure for yam production. [Nature and Science. 2008;6(1):34-42]. ISSN: 1545-0740.

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Introduction

Food is the most basic of human needs and the foundation for human and economic development (Smith et al., 2006). Farmers in large parts of the sub-Saharan Africa have no tradition of aiming at maximum production per hectare, possibly due to poor marketing facilities to dispose surpluses. Instead, most African farmers fight against crop failure (Verheij, 2003). Farmers still hold tenaciously to slash-and –burn method of land clearing which removes vegetal wastes and contributes to global warning and land degradation (Reich *et al.,* 2001). Land degradation causes declining yield and varying productivity (Holdren *et al.,* 2005). Declining productivity is worsened with increasing demographic pressure and conflictive land use types.

As most farmers prefer annual crops, there is need to put in place such types that can relatively protect soil against degradative forces in addition to practise fertility supplementation attributes. Van School (1998) suggested the use of intercropping among other agronomic practices to improve productivity. However, the status of these soils require organic manure input since organic matter improves physical, chemical and biological properties of soils (Linger and Critchley, 2007). The inherently

poor fertility characteristics of tropical soils have made nutrients availability in them to be largely controlled by organic matter (Agboola and Omueti, 1982). Mbagwu *et al*. (1994) reported that organic manures improved physical properties of soils; with poultry droppings enhancing soil fertility (Ajayi *et al*., 2003). However, there are reported incidences Oniawa *et al*., 1998) of pollution of nearby water bodies, hence the need to monitor effect of poultry waste on soil and water resources (Ajayi *et al* 2003). Poultry droppings increase soil hydraulic conductivity and reduced bulk density (Mbonu and Elenwo, 2006) thereby improving water infiltration and aeration necessary for optimum performance of crops. These benefits formed the premise for the recommendation of biological wastes so soil fertility enhancement by Scholars (Agele, 2000; Ojeniyi *et al*., 2000) although a combination of organic and organic fertilizers gave highest yield (Adediran and Banjoko, 2003).

Yams (Dioscrea spp.) is the most widely cultivated indigenous crop in West Africa (Onwueme 1978) with a daily consumption of 0.5 – to 1.0 kg (Purseglove, 1981). Maize (*Zea mays L*.) is a major cereal crop whose importance is underscored by competing, and sometimes conflictive use. Maize is grown on about 1.5 million hectares of soil (CIMMYT, 1994). Cassava (*Manihot esculenta* Crantz) is one of the dominant starchy staple crops in Africa with a root yield of 17. 4 to ha-1 (sole crop) and 14.7 t ha^{-1} (Intercrop)(John *et al*., 2006). Cassava grows n soils too poor for many other crops (Ahn, 1993) Traditionally, cassava is often grown as an intercrop with yam, maize, banana and melon (Usman *et al.,* 2001). They maintained that such intercrops protect soils, and permit optimum utilization of available soil nutrients. However, crop mixtures on a farmland may result to in soil mining, and consequent degeneration in soil quality. This calls for the fertility –enhancing technologies including the application of organic manures. The major aim of this study was to evaluate the current soil fertility status and determine optimal level of poultry droppings supplementation capable of promoting yam-maize-cassava mixtures.

Materials and Methods

Study Area: The study was carried out during the 2005 and 2006 wet seasons at the university farm of Federal University of Technology, Owerri Nigeria, lying on latitude $5^0$43'14.623'' and longitude $7^0$37'34.490''. The University farm cover about 600 hectares of land, and its soils are derived from coastal plain sands. Owerri is humid tropical, having a mean annual rainfall of about 2500 mm and mean annual temperature range of 26-29 ^{0}C. It is characterized by a depleted rainforest vegetation. Socio-economically, farming, fishing, hunting, cottage industrial activities, sand mining and construction works are major enterprises in the area.

Analysis of Poultry manure used for the Experiment: Poultry manure used for the study was cured and samples of cured manure were air–dried at room temperature for 3 days. Ground poultry manure was digested with nitric-perchloric-sulphuric acid mixture and resulting aliquot was used to chemically characterize the amendment. The manure contained the following: organic carbon (68 gk g^{-1}), total

nitrogen (14.2 gk g^{-1}) ,Ca^{2+} (69.5 g kg-1) ,Mg^{2+} (20.2g kg^{-1}), K^{+} (5.8 g kg^{-1}) and available P (13.6 g kg^{-1}) .Poultry manure was incorporated manually at 0, 5000, 10000, 15000 and 20000 kg ha^{-1}

Field Experiment: There were 5 levels of poultry droppings .namely 0,5000, 10000, 15000 and 20000 kg ha-1. These levels were replicated three times and arranged in a randomized complete bock design (RCBD). The varieties of crops grown included Okuocha (Yam: *Dioscorea rotundata*), 8341-6 (Maize: *Zea mays* L.) and 30555 (**Cassava:** *Manihot esculenta* Crants). Field work involved land preparation, planting, weeding and harvesting. Earlier 15 soil samples were collected, prepared and using for preplanting soil characterization.

Laboratory Analyses: Particle size analysis was determined by hydrometer method (Gee and Or, 2002). Exchangeable cations, Ca, Mg and K were measured using inductively coupled plasma atomic emission spectrometer (ICP-AES) (Integra XMP, GBC, Arlington Heights, IL).

Soil pH was estimated potentiometrically in a glass electrode in deionized water (pH water) at a soil/ solution ratio of 1:2:5. Total carbon and total nitrogen were measured on aliquots by dry combustion at 1060 ^{0}C and detection of evolved $C0_2$ and $N0_2$, was done with a Carlo Element Analyzer (Carlo Erba, Italy). Organic matter was obtained by multiplying total carbon by a factor of 1.724 while available phosphorus was determined by Olson method (Emteryd, 1989).

Data Analysis: Soil data were subjected to analysis of variance (ANOVA) using PC SAS version 8.2 (SAS Institute, 2001).

Results and Discussion

Land Evaluation: The status of soils in terms of selected properties are shown in Table 1. Soils were sandy, very strongly acidic and of medium organic matter content. Consequently, total nitrogen value (mean) was low. Similar low values were obtained in exchangeable basic cations and available phosphorus. Calcium – magnesium ratio was very low and below threshold limit of 3.0 (Landon, 1984). Results on particle size distribution and Ca – Mg ratio are consistent with the findings of Oti (2002) in the study of erosion-degraded lands of Otamiri watershed in the same agroecology. Sandiness in these soils deficient in optimal organic matter is indicative of poor water and nutrient retentivity as macropores inherent in the soils permit rapid horizontal and vertical movements within the pedosphere. However, the dominance of sand-sized fractions among other particle sizes is attributable to parent material land use and climate of the study area. High rainfall amount, duration and intensity promote leaching of basic cations leaving a preponderance of acidic cations hence soils are very strongly acidic,suggesting unavailability of essential plant nutrients especially phosphorus, boron and molybdenum. This condition is further confirmed by very low Ca/Mg ratio as Landon (1984) observed that soils having such low ratios of these basic cation ratios

suffer from calcium and phosphorus deficiencies. These cations are very low when compared with quality control (QC) standards (FDALR, 1985; Enwezor *et al.,* 1989). High temperature of the area accelerates organic matter mineralization, and this could account for low organic matter content of soils. However values of organic matter were higher and contrasted with findings of Osodeke *et al*. (2002). In the same agroecology. organic matter in the study area is associated with processes that influence vegetation, litter decomposition and those cause by land users (Isirimah *et al.,* 2003).

Effect of Poultry Manure on Soil Properties: Poultry manure significantly ($p \leq 0.05$) improved all the chemical properties of soils investigated (Table 2). However, percentage increase in soil property value differed among the measured soil properties and rates of application (Table 3). Greatest influence was recorded in total nitrogen (TN) .Similar findings were made by Duruigbo *et al.* (2007) on soils derived from coastal plain sands in southeastern Nigeria . Highest increases in TN implies high responsiveness of soils to its application, suggesting that such soils might have lost a great deal of their TN by leaching. Increases in the values of other properties could be attributed to rise in organic fractions. Pitram and Singh (1993) reported increase in pH due to poultry manure application, which was attributed to ion exchange reactions which occur when terminal OH^- of Fe or Al hydroxides are replaced by organic anions such as tartrate, malate and citrate (Besho and Bell, 1992). These anions compete with soil phosphorus (Liu and Huang, 2000), implying that their abundance in the exchange site increases P-availability in the soil system, and this depends on the concentration of legend and soil pH (Giesler *et al*., 2005).

Performance of Crop Mixtures: Table 4 shows growth and yield characteristics of yam, maize and cassava, indicating significant ($p \leq 0.05$) in these attributes. Maize and cassava had highest height increase between 15000 and 2000 kg ha^{-1} while yam growth increase was between 5000 and 10, 000 kg implying that as more poultry manure was added the tuber crop was translocation gains to the tuber, and this could be why greatest yield difference was at the same poultry rate interface. However, tillage method may have affected tuber development and yield (Ohiri, 1995). Increased plant height in maize is consistent with the findings of Ojo *et al.* (2003) that poultry manure produced greater vigour than other organic amendments. Optimum yields for maize and cassava were obtained at 15000 kg ha^{-1} while further increase in rate of application of poultry manure is required for yam in the degraded soils. In cassava production in the area, John *et al* . (2006) suggested the se of organ mineral fertilizer for improved growth and yield of cassava. Although some scholars obtained significantly higher yields in cassava-based intercrop (Eke-Okoro *et al.,* 2003; Jalloh and Daphnia, 2003), a involving sole crops in this experiment would be necessary for comparative purposes such studies would also use the same degraded soils.

Table 1. Preplanting characterization of soils (mean values) (n=15)

Property	Unit	Value	Fertility class
Sand	g kg^{-1}	830.0	NA
Silt	g kg^{-1}	40.0	NA
Clay	g kg^{-1}	130.0	NA
Ca^{2}+	Cmol kg^{-1}	0.95	Very low**
Mg^{2}+	Cmol kg^{-1}	0.6	Low**
Kt	Cmol Kg^{-1}	0.1	Low*
Ca/mg		1.5	
pH (H_20)		4.4	Very strongly acidic**
OM	g kg-1	23.4	Medium*
TN	g kg-1	0.8	Low*
Av.P	mg kg-1	9.8	Low*

(*sources* Enwezor et al, 1989, **FDALR, 1985)

OM = organic matter, TN = total nitrogen, Av. P = available phosphorus

NA = not applicable.

Table 2. Effect of poultry manure on some soil characteristics

Treatment (kg)	Ca^{2+}	Mg^{2+}	K^{+}	pH (water)	OM	TN	Av.P
	← (cmol kg^{-1}) →				← (g kg^{-1}) →		(mg kg^{-1})
0	0.8	0.5	0.18	4.6	23	0.8	8.8
500	1.3	0.7	0.20	5.2	28	1.6	11.9
10,00	1.5	0.8	0.30	5.5	30	1.7	13.6
15,000	1.7	1.1	0.42	5.8	31	1.8	14.2
20,000	2.1	1.2	0.53	6.1	34	2.1	14.8
LSD $_{0.05}$	0.5	0.3	0.08	0.9	3.8	0.7	0.8

OM > organic matter TN = total nitrogen, Av.P available phosphorus

LSD = least significance difference

Table 3. Percentage increases in selected soil properties due to poultry manure application

Property	500	Treatments (kg)		20000
		10000	15000	
Ca^{2}+	62.5	87.5	112.5	162.5
Mg^{2}+	40	60.0	120.0	140.4
K+	11.1	66.0	133.3	194.4
pH (water)	13.0	19.5	26.0	32.6
OM	21.7	30.4	34.7	47.8
TN	50.0	112.5	12.50	162.5
Av.P	35.2	54.5	61.3	68.2

OM > organic matter TN = total nitrogen, Av.P available phosphorus

Table 4. Growth and yield characteristics

Treatment	Plant height (cm)at 8 WAP			Yield		Kg ha^{-1}
				M	C	Y
	M	C	Y	(grain)	(tuber)	(tuber)
O kg	22.0	12.0	296.8	300	9500	8000
5000 kg	29.4	16.3	298.2	690	10500	9800
10,000 kg	34.2	20.5	340.2	1260	11800	10750
15,000 kg	38.8	26.4	341.8	1320	12160	11600
20,000 kg	49.2	35.2	345.2	980	11240	11,850
LSD $_{0.05}$	8.2	3.6	3.6	79.0	89.8	62.5

Conclusion

Soils of the study sites were highly degraded and marginally suitable for arable production. However, poultry manure improved the fertility status of soils and consequently increased performance of fest crops. But rates for optimum performance differed among crops. It is suggested that further studies should incorporate fertility enhancing crops adaptable to this agroecology characterized by increasing population.

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