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DYNAMICS OF SOIL NUTRIENT AND MACRO-ORGANISM POPULATION FOLLOWING LAND CONVERSION FROM FALLOW TO CULTIVATED FARM

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ABSTRACT
An assessment of soil physical and chemical features as well as the species richness of macro-organisms was carried out in a 2-year cultivated farm, 3-year fallow,8-year fallow and a 50 –year undisturbed relic forest all located within 1 km radius within Umudike. The 3-year cultivated plot had the lowest levels of N, P, k, Ca and organic matter which were 0.14%, 2.3, 0.012, 1.6 and 0.226, respectively. The percentage sand was highest in the 3-year cultivated plot while clay % was highest in the 50 year undisturbed vegetation. The difference in textural characteristics was more pronounced between 3-year cultivated soil and the 8 year fallow than between the 8 year fallow and the 50-year undisturbed relic forest, a condition attributable to the loosening of the soil and increased run-off occurring in the 3-year cultivated farm. The abundance of soil macro-organisms increased with advance in years of fallow and it was found to be associated with increased level of organic matter and species diversity of the vegetation cover. Only species in the annelida phyla occurred in all field conditions.
Keywords: *Fallow, Cultivation, Nutrient status and Soil macro-organism*

Introduction

Rural farmers employ different land use techniques to ensure the sustenance of arable food production season after season. Such management techniques including fallow practice, mixed cropping, crop protection, soil fertilization either by organic manure or chemical fertilizers and crop rotation are aimed at putting available lands into optimum use through improved land productivity and crop yield (Buttner and Hauser, 2003).

Fallow has been an ancient practice that allows restoration of soil fertility and regeneration of animal and plant communities. Where the progression through ecological development continues undisturbed, fallow culminates into a stable system having semblance with the original native community both in structure and function (Odum, 1969; Alegre *et al;* 2005). Mature fallow plots have enhanced inherent ecological processes such as soil biological activity, vigorous nutrient cycle, stability and cover of soil and enhanced interaction among components of the community. Fallow period over the years have been shortened to accommodate the expanding demand for more food production due to growing population and industries. Farming communities, particularly those with communal land tenure system, allow average fallow periods of 5 – 8 years as against 20 or more years obtained in the past. Again, the method of land clearing after a cycle of fallow has been modified in some areas by allowing many life shrubs to re-coppice with crops in order to retain, to a certain degree, some natural ecological processes while supporting crop production at the same time. The pattern of land management determines the extent of profitability and quality of the production system (Marshall and Moonen, 2002). There are a number of ecological processes which are biological, physical and chemical in nature that could effectively serve as indicators of environmental quality (Marinari *et al;* 2005). Arable farming operations which involved land clearing, burning, tilling, planting, fertilization and other maintenance practices which eventually end with crop harvest alter significantly the ecological processes which have sustained the preceding matured plant community (Montagnini and Sancho, 1990; Sanchez, 1976). For example, the clearing of the vegetation which removes the land cover predisposes the soil to erosion and eliminate differential macroclimatic conditions provided by the native environment including the organic matter content. These changes that manifest eventually in form of decline in crop yield result in abandonment of farm lands and conversion of more fallow lands even where the fallow period is insufficient to allow reasonable recovery of the system.

Agroecological systems in southeastern Nigeria is no doubt undergoing transformation in response to emerging pressure on land and cropping environment (Okafor and Fernandes, 1987; Okeke and Omaliko, 1994). Matching the evolving challenges in the production system with suitable management approach appears to be the only way forward. Therefore it has become necessary to keep track with and understand the systemic ecological changes that follow after land conversion from years of fallow to cultivation and apply such findings in modifying local management of crop production system for sustainability.

Materials and Methods

Study Area Description: The investigation was conducted using 2- and 8-year old fallow plots, a 3-year consecutively cultivated farm land and a 50-year old relic forest all located within Umudike autonomous community, Umuahia. Umuahia lies between 5^{o} 28' N and 7^{o} 32' E within the humid tropical vegetation. The mean annual rainfall in the area is 2100mm but it is distributed through most of the year however about 4 months of dry season occur every year (Nzegbule and Mbakwe, 2001). The major occupation of the natives is farming and the common grown crops are cassava, yam, maize, cocoyam and plantain. The community use both communal land tenure system for farms distant from their settlements and individual system for those around homesteads.

Methodology: The investigations were carried out with 4 different plots namely: a plot under cultivation consecutively for 2 years; a plot in early stages of fallow for 3 years; another plot in its matured stages of fallow for 8 years; and a plot which is a 50 year relic forest. Each of the 4 plots had minimum size of 0.8 ha and was all located within a 1 km radius. These plots served as treatments to determine changes that occur under these transitions in the farming system in the zone. Each of these plots was divided into 4 sub-plots of 40m x 40m which served as replicates. Using a soil auger, soil samples were collected from the top soil layer (0-15cm depth) in every replicate of each type of plot and were analyzed in the laboratory for textural and chemical differences. Also a 250 g of soil sample was collected from 0-30 cm depth and filled in polybags and later taken to the laboratory for extraction of soil macro-organisms using flotation method (Madge and Sharma , 1969). They were identified with the aid of a shank hand lens(x10) before enumeration of their populations (Bonteau and Leblank 2005).

Results and Discussion

The results showed a measure of difference in the soil characteristics in the 4 plots under various conditions that range from 3-year post-fallow cultivation to 50 year undisturbed vegetation.

Table 1: Differences in soil analysis of samples across the four plots

Parameter	3-yr cropping	2-yr fallow	8-yr fallow	50-yr relic Forest
Total N(%))	0.140a	0.149a	0.175ab	0.203b
Av. P (mg/kg)	2.3a	5.8a	14.0b	24.0c
Ex. K(cmol/kg)	0.012a	0.011a	0.017ab	0.027b
Ex. Ca (cmol/kg)	1.6a	1.8a	4.0b	3.10b
Ex. Mg (cmol/kg)	0.4a	0.42a	1.6b	1.6b
Sand (%)	68.9b	62b	57.0b	58.0bb
Silt (%)	3.7a	4.6a	9.7b	10.7b
Clay(%)	27.4a	28.1ab	33.3b	31.3b
pH (1:2.5H_20)	5.12a	5.16a	5.56a	5.51a
OM (%)	0.226a	0.390a	0.992c	0.617b

From the results of the chemical analysis, N, P, K, Ca, and OM and organic matter were lowest in the soils of the plot that was continuously cropped for 3 years (Table 1). Arable farming without external input gradually depletes the nutrient stock in the soil causing a decline in crop yield with every additional season of post-fallow farming on the same plot (Lal and Kang, 1982; Derry *et al;* 2005). However the extent of nutrient depletion is influenced by the species of crops grown and the quantity of initially available nutrients (Muller-Samann and Kotschi, 1994). Generally there were increments in all the soil physical and chemical parameters measured beginning from the 2-year fallow plot except the pH and sand (%) which recorded decreases. The percentage increase of N, P, K, Ca and OM in the 8- year fallow over the 3 - year cropped plot were 12, 72, 17, 42 and 62%, respectively. During fallow a naturally slow but progressive process of nutrient replenishment occurs in soils; this is particularly so as the area remains uncultivated from a period of about 2 years and continues towards 50 years. In table 1, the rate of nutrient accretion over the years becomes reduced than the initial years of fallow; thus the increment in the concentration of the nutrients did not persist with years of fallow. Calcium and Mg contents were noticed to be similar or lower in the soil of 50-year undisturbed plot, although not significantly, when compared with the 8-year fallow (Table 1). Among the possible reasons for the reduced levels of nutrient accretion in the soil with advanced period of fallow could be attributable to immobilization of some elements such as P and the greater position which tree biomass assume over the soil as a nutrient reservoir in undisturbed vegetation such as forest ecosystem (Montagnini and Sancho, 1990; Nwoboshi, 2000).

The percentage sand was highest in the 3-year cultivated plot, while silt (%) and clay (%) were highest in the 8-year and 50-year fallow plots, respectively. The 3-year cultivated plot had the highest percentage sand but was the least in % silt and % clay contents. The difference in the percentages of sand, silt and clay between the 3 –year cultivated plot and 8-year fallow plot were 11.9, 6.0 and 5.9 which are considered as wider differences compared with that between 8-year fallow plot and 50 year undisturbed plot whose differences were 1.0, 1.0 and 2.0, respectively. The reduced differences in the percentage values of the soil textural characteristics between the 8- year fallow and the 50 – year undisturbed plot indicate that with improved stability in ecological structure, soils within close proximity and from the same parent material show less variation in their physical characteristics (Agboola, 1981).

The pattern of soil texture particularly on the cultivated land may have been influenced by the increased movement of surface run-off and soil loosening process that accompany removal of vegetation cover and tillage practices, respectively. However with the increase in period of fallow and non-disturbance of the soil there appeared to be appreciation in the percentage of clay and silt. The increases in percentage silt and clay were occurring simultaneously with increasing organic matter content which was a contribution from the existing vegetation cover comprising of diverse species under fallow conditions. A related study reported a correlation coefficient of 0.922 between organic mass and percentage clay (Agboola, 1975).

The progression of fallow period from 2 – 50 years created improvement in soil quality based on nutrient content but there were no significant changes at the 2 –year fallow compared to the 3 year cultivated land particularly for N, K, Mg and organic matter content of the soil suggesting that the fallow period was inadequate and would need a compliment of external fertilizer input for profitable production system (Buttner and Hauser, 2003). The inadequacy of the 2 -year fallow period to restore fertility and sustain profitable cropping in addition to the constraint of limited access to inorganic fertilizer are reasons why farmers in the study area prefer to clear forest estates, where available, for arable farming**.**

The pH of the soils were 5.12, 5.16, 5.56 and 5.51 for the 3-year cultivated plot, 2-year fallow, 8-year fallow and 50 year undisturbed vegetation, respectively. The pattern shows that as years of fallow advance, there is reduced acidity of the soil. This is supported by the gradual increase in nutrient bases such as Ca and K. Also the higher clay content and less leaching in the soils of the 8-year fallow plot and the 50-year undisturbed plot are other factors responsible for the increased content of nutrient bases and higher pH status of the soil. The study also indicated that there was increased presence of OM in the soils with more years of fallow which act as a buffering system for the pH-value and regulates the balance of nutrients in the soil solution unlike the 3-year cultivated plot (Agboola and Corey, 1973; Muller and Kotschi, 1994).

SOIL MACROBIAL ORGANISMS AND ASSOCIATION

The total estimated abundance of macro-organisms in the soil was 1.0/250g, 6.25/250g, 14.40/250g and 19.25/250g in the 3-year cultivated plots, 2-year fallow, 8-year fallow and 50-year undisturbed plots respectively. From the results there was more soil microbial activity with long period of non-disturbance of the vegetation. Although the macro-organisms are mostly polyphagous, their prevalence in an ecological system is promoted by the existence of diverse litter material (Attignon *et a*l, 2005). The species richness of the microbial population is not the same in all the four studied fields.

Lumbricus spp and Ascaris spp occurred in all the four plots in varying proportions. Two species belonging to 2 zoological phyla were observed in the cultivated plot while 6 species belonging to 4 zoological phyla were found in the 50 year undisturbed relic forest. The low species richness and abundance of soil arthropods in the cultivated soil possibly was caused by the deterioration in habitat quality as a result of tillage process and depletion of organic materials (Armbrecht and Perfecto, 2003).

Table 2: Kind and abundance of soil macro-organisms in plot A, B and C of the soil of the area studied

Phylum	Soil organisms	3-Yr Cultivated Plot/250g	2-Yr Fallow /250g	8-Yr Fallow /250g	50-Yr Relic Forest/250g
Annelida	Lumbricus spp (earthworm)	0.50	2.25	4.5	5.25
Arthropoda	Macrotermes spp (termite)	-	1.00	3.75	1.75
	Musca sp (House fly)	-		2.5	-
	Papilio (Butterfly)	-	0.75	2.5	0.75
	Ophiulus sp (millipede)	-	0.50	3.0	4.75
	Scolopendra sp (centipede)	-		-	7.0
Mollusca	Achatina sp (Land snail)	-		-	1.25
Platyhelminthes	Ascaris sp (worm)	0.50	1.75	3.25	2.0
Total		1.0	6.25	14.4	19.25

The pattern of accumulation of organic matter in the four plots and the build-up in population density of macro-organism were found to be related. A correlation (r= 0.784) exist between the quantity of organic matter and total population density of macro-organisms (Table 3). The population of macrotermes particularly, increased with number of years of fallow but the increment did not continue after 8 year. Although canopy cover is a very important habitat variable capable of causing differences in species richness of soil arthropods, but the existence of diverse tree species in the canopy formation provides an additional significant factor especially for termites in Arthropoda phylum (Attignon *et al*, 2005). This explains why members of the arthropoda were not encountered in the 3 –year cultivated plot and was sparse in the 2-year fallow plot.

Table 3: Correlation coefficients between the abundance of soil organisms and some soil chemical parameters

	3-year Cultivated plot				2-year fallow				8-year fallow				50-year undisturbed vegetation			
Parameter	Ar	An	Pl	Mo	Ar	An	Pl	Mo	Ar	An	Pl	Mo	Ar	An	Pl	Mo
pH	a	0.076	A	a					-0.542	0.773	0.767	A	-0.166	0.312	-0.660	0.192
OM	a	0.088	A	a					0.754	0.741	0.808	A	0.637	0.791	0.234	0.849
CEC	a	0.694	A	a					0.364	0.819	-0.807	A	0.721	0.052	-0.057	-0.255

a: correlation is incomplete because of uniform absence of soil organisms in the replicate samples in the plot

A: Arthropoda; An: Annelida; Pl: Platyhelminthes; Mo: Mollusca

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