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Plant species richness and soil nutrients in a 35-year old cashew nut plantation in Isuochi, Southern Nigeria

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Abstract: Plant species richness, composition and standing state of soil nutrients were compared between a 35-year old cashew plantation and a natural forest in Isuochi area of south Nigeria. Six sites each in cashew plantation and natural forest were sampled. Vegetation sampling was done using belt transects and soil analysis involved random soil sample collection using soil auger from 2 soil depths (0 - 15 cm, 15 - 30 cm) and levels of N, P, K, organic matter (OM) and pH were determined. One square meter quadrats were laid randomly for collection of leaf litter to study the nutrient contents such as N, P, K, OM and pH. Species Richness Index (SRI) was 0.415 in the cashew plantation and 1.073 at control site. In the cashew plantation, nutrients in the soil were generally higher than in the litter indicating decreased mineralization on the floor. However, fertility index for crop production was higher in the cashew plantation than in the control area; indicative of possibility for rapid growth and comparatively better chances of performance for crop plants on plantation soils. This can serve as a pre-test on lands for choice of crops in a land re-conversion project. Although biodiversity and nutrient pool within the cashew plantation can be improved by partial or total introduction of new and adaptable species in the area, there are opportunities for introduction of agroforestry practices within the area to enhance livelihood and broaden management objective.

Resumen: Se compararon la riqueza y la composición de especies vegetales, y el estatus de los nutrientes del suelo entre una plantación de marañón de 35 años de edad y un bosque natural en el área Isuochi del sur de Nigeria. Se muestrearon seis sitios tanto en la plantación de marañón como en el bosque natural. Se usaron transectos de banda para muestrear la vegetación y el análisis de los suelos involucró la recolección aleatoria de muestras usando una barrena a dos profundidades (0 - 15 cm, 15 - 30 cm); se determinaron los niveles de N, P, K, materia orgánica (MO) y pH. Se establecieron aleatoriamente cuadros de 1 m^2 para la recolección of hojarasca foliar a fin de determinar los contenidos de nutrientes tales como N, P, K, MO y pH. El Índice de Riqueza de Especies (SRI, siglas en inglés) fue de 0.415 en la plantación de marañón y de 1.073 en el sitio control. En la plantación, los nutrientes en el suelo fueron en general más altos que en la hojarasca, lo cual indica una mineralización disminuida en el piso. Sin embargo, el índice de fertilidad por producción de la cosecha fue más alto en la plantación de marañón que en el área control, lo que indica la posibilidad de un crecimiento rápido y oportunidades para un desempeño comparativamente mejor de las plantas cultivadas en los suelos de la plantación. Esto puede servir como un prueba preliminar en las tierras para la selección de cultivos en un proyecto de reconversión del suelo. Si bien la biodiversidad y los almacenes de nutrientes en la plantación de marañón puedan mejorarse por medio de la introducción parcial o total de especies nuevas y adaptables en el área, hay oportunidades para la introducción de prácticas agroforestales en el área para mejorar el sustento y ampliar el

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objetivo del manejo.

Resumo: A riqueza específica em plantas, composição e estado dos nutrientes do solo foram comparadas numa plantação de cajueiros de 35 anos na área de Isuochi no sul da Nigéria. Amostraram-se seis estações cada uma numa plantação de cajueiro e na floresta natural. A amostragem da vegetação foi feita usando transeptos em faixa e a análise de solo envolveu a colheita do mesmo às profundidades de (0 - 15 cm, 15 - 30cm) usando uma broca no qual foram determinados os teores de N, P, K, matéria orgânica (OM) e pH. Para colecta da folhada implantaram-se de forma casual quadrados de um metro quadrado para estudar os teores de N, P, K, OM e pH. O índice de riqueza específica (SRI) foi de 0,415 na plantação de cajueiro e de 1,073 na estação controlo. Na plantação de cajueiro, os nutrientes no solo eram geralmente mais elevados do que na folhada indicando um decréscimo da mineralização no solo. Contudo, o índice de fertilidade para a produção agrícola era maior na plantação de caju do que na área de controlo, indicativo de possibilidades para o crescimento rápido e melhores oportunidades comparativas de performance para a produção agrícola nos solos da plantação. Isto pode servir de pré-teste na escolha de solos para a produção agrícola em projetos de reconversão de solos. Embora o conjunto da biodiversidade e dos nutrientes na plantação de cajueiro possam ser melhorados pela introdução parcial ou total de espécies novas ou adaptadas na área, há oportunidades para a introdução de práticas agroflorestais na área para melhorar o modo de vida e alargar os objetivos da gestão.

Key words: Agroforestry practice, biodiversity, community composition, fertility index, mineralization.

Introduction

Periodic assessment of ecological conditions in the natural as well as managed forests are fundamental to sustainable forest resource management. Forests and plantations in Africa, and Nigeria in particular, have not been managed effectively (Abbas 2009; Kowero 2008). This situation has, over the time, resulted in low productivity of natural resources, poor land use and unregulated entrants by communities residing around such vegetation areas for farming activities and for several other livelihood enhancement opportunities. In Nigeria, newly established plantations by the government appear to attract some levels of management attention than older ones perhaps because successive governments tend to emphasize more on projects they initiate than those initiated by earlier administration.

Cashew (*Anacardium occidentale* L.) is a tree of forestry as well as horticultural significance grown in different parts of the world (FAO 2000). In Nigeria, cashew was introduced by the Portuguese explorers between 15th and 16th century (Togun & Igbokwe 1985). Given the poor land conservation practices prevalent during this period and the increasing menace of erosion, cashew plantations were purposefully established for erosion control and afforestation schemes across Nigeria. It became a popular crop during 1950s when more plantations were established for the nuts and also for the purpose of afforestation and erosion prevention programmes in areas such as Udi, Mbala, Isuochi and Kingie regions in eastern Nigeria (Akinwale & Esan 1989). About 100,000 hectares of land have been put under cashew in Nigeria by 2000 and the annual production stands at 70,000 metric tonnes and the tree crop contributes over $1,045,000 to the GDP (Ayodele *et al.* 2001). Cashew nuts are harvested for confectioneries and other purposes. The plants perform well on soils with minimal fertility as well as on a range of climates. Over a period of time, in Nigeria, research outputs have given rise to the development of jumbo nut-size cashew biotypes by the Cocoa Research Institute of Nigeria, CRIN. Report submitted by Falade (1978) shows that its cultivation has spread to other agro-ecological zones of Nigeria. Among the notable characteristic features of cashew are the high quantities of litter output per unit area (Schaper & Chacko 1993).

Long period of neglect and poor management of cashew plantations in South-eastern Nigeria

have resulted in declining productivity particularly in their fruiting densities. In the past, sales of the cashew nuts were made by the households to sustain their families. The neglect and decline in productivity have given room for the communities around the area to engage in illegal felling of the cashew trees for fuel wood and other end uses. It is projected that with this rate of removal and conversion, over 50 % of the originally established cashew plantations may be lost in the next 5 years. In advanced societies, the fertility margins of forest lands or agricultural lands are periodically evaluated as a management practice. This is not so in most developing countries (Parsons & Congdon 2008). In locations where resource evaluation activities are effectively conducted, certain plantations have over the time become inimical to the sustainability of important ecological resources around their areas of establishment, thus, necessitating either their outright conversion or incorporation of other species within the same area (Biervliet *et al.* 2009; Newmark 1991).

It has, therefore, become necessary to assess the status of the plantations. Studies within the cashew plantation were conducted to estimate the above-ground plant composition, levels of soil and litter characteristics with a view to proffering adaptable management alternatives/options to achieve broader objective of ecological sustainability, erosion control, afforestation as well as meeting the growing livelihood demands and challenges from the communities. These parameters have been used by several researchers to assess the conditions of natural resources of an area which has helped in better resource management (Karlen *et al.* 1997; Schoenholtz *et al.* 2000; Wilson *et al.* 2001).

Materials and methods

Experimental site

Isuochi is a community in Umunneochi Local Government Area of Abia State in southeastern Nigeria (5° 38 N and 7° 20 E). The soil temperature of the area ranges between 17 °C and 25 °C and annual rainfall between 1500 mm and 3000 mm (Chukwu & Mbanaso 1999). The soil type is predominantly acrisols and the vegetation of the area is dominated by forest species, located within the humid tropical rainforest zone of Nigeria. Farming is the major socio-economic activity in the area (Igbozurike 1975). The cashew plantation located in Isuochi is among several cashew plantations originally established by the government of the defunct eastern Nigeria. This plantation originally measured about 2.5 ha in size, even-aged and established with about 7 m by 5 m spacing. Given the above, about 31 cashew trees ought to be contained within an area of 0.1 ha. Reconnaissance visits to the plantation revealed rapidly increasing encroachment activities in the plantation which have fast extended into the interior of the plantation with the creation of different pathways. Random estimation of the stand density over a 0.002 ha (5 m x 4 m) which upon extrapolation over a 0.1 ha area showed a reduction in the stand density from an estimated initial density of about 31 to an actual value of about 17 trees per 0.1 ha area.

Methods

Illegal encroachment for agricultural activities was the major cause of disturbance in the vegetation lots across rural societies which is more visible around the boundaries of vegetation areas. These activities cause variations in species density and productivity. Considering this, the cashew plantation area was divided into two categories, viz., the inner region and the outer region. The inner region represented area of minimal encroachment and less disturbance while the outer region represented the disturbed and encroached site. Each region measured 0.15 ha (50 m x 30 m) in size thus giving a total of 0.3 ha of the plantation surveyed. The inner region was divided into three equal units or sub-plots (I, II, III) measuring 50 m x 10 m each. The outer region correspondingly had IV, V, VI as equal sub-plots. Within these regions (inner and outer regions), sampling for soil, litter and vegetation was accomplished.

A 50 m transect was cut in each of the above sub - plots. Identification and enumeration of the plant species which occurred within the area were carried out. The species were then classified into indigenous and non-indigenous species by comparing the identified species within the site with documented list of indigenous species of Nigeria contained in FAO (1995) and Etukudo (2000). Species' Richness Index (SRI) was also calculated using Menhinick's (1964) formula:

$$SRI = S/\sqrt{N},$$

where, S = number of species per unit area and N = total number of individuals that occurred.

Soil and leaf litter analyses

Within the different regions in the plantation, soil samples were collected at three random points

Table 1. A comparison of plant species abundance and richness in Cashew Plantation and Natural Forest, Southern Nigeria.

Vegetation Parameters	Cashew Plantation	Natural Forest
Total number of plants	284	1682
Indigenous species (and abundance)	7 (284)	36 (1333)
Exotic species (and abundance)	0 (0)	8 (349)
Total number of species	7	44
Species Richness Index (SRI)	0.415	1.073

from two soil depths (0 - 15 cm and 15 - 30 cm) using soil auger. These were labelled and taken to the laboratory for analysis for pH, total N, available P, K and organic matter using standard methods (AOAC 1995). Soil pH was determined with pH meter using soil : water ratio of 1 : 2.5; organic matter by Walkley and Black oxidation method; N by Kjeldahl method; P by Atomic Absorption Spectrophotometer (AAS) and K by Flame Photometry.

Leaf litter on the floor of the cashew plantation was also collected at 3 random points from each region using a 2 m x 2 m quadrat. These were dried at 60 °C, ground and analysed for nitrogen, organic matter and lignin contents. Lignin was determined by the method of Van-Soest (1963) while nitrogen and organic matter were analysed using similar methods as described above. A natural (managed) forest at Umudike also in Southern Nigeria was identified and used as control. This is located at about 12 km distance from the cashew plantation. Ecological, locational as well as age differences justify the choice of the control area. Analyses of plant community composition, soil and litter were accomplished for the control area following the procedures and methods described above. The results of soil analyses obtained in the different vegetation areas were used to provide estimate of the level of fertility status in the areas. Based on the assumption that soil quality and soil fertility are interchangeably used, the results of the soil analyses were adapted into the formula provided by Adejuwon & Ekanade (1988) for calculating Quality Index for lands.

$$LQI = [(P_1-P^1_1)/P^1_1 + (P_2-P^1_2)/P^1_2 +...+ (P_n-P^1_n)/P^1_n] \text{ X } n/100\ \%,$$

where, LQI = Land Quality Index (Soil Fertility Index), P_1, P_2 and ...P_n represent standard reference values for the measured parameters approved for agricultural lands. These were obtained from documented soil fertility index values from Federal Fertilizer Department (FFD) of the Ministry of Agriculture, Nigeria as contained in Chude *et al*. 2004. P^1_1, P^1_2 and ...P^1_n represent corresponding values for the measured parameter and n represents the number of vegetation area of a given type (site) considered in each case. Five choice parameters were taken and fitted into the above formula. These parameters are soil N, P, K, OM and pH.

Results and discussion

Only seven species of vascular plants, besides cashew, were recorded in the plantation having a total abundance of 284 plants. These were all indigenous species, viz., *Abrus precatorius, Alchornia cordifolia, Amorphophallus abyssinicus, Commelina benghalensis, Manniophytum fulvum, Pouzolzia guineense* and *Solanum fulvum* (Table 1). Their low abundance could be attributed to the character of the plantation canopy which tended to suppress the undergrowth from obtaining sufficient sunlight to support their growth on the plantation soil. This makes the plantation site a somewhat 'closed system', which allowed limited germination, growth and development of new individuals. The species observed in this area were those that showed adaptation to minimal illumination. *Amorphophallus abyssinicus* and *Abrus precatorius* have been cited as low light and nutrient demanders (Akobundu & Agyakwa 1988). Presence of a few exotic species at plantation site, e.g., *Tectona grandis, Ceiba pentandra, Cissus arguata, Dactylandaenia barteri, Erythrophleum suaveolens* could be due to past forestry operations or intentional introduction.

The Species Richness Index (SRI) in the cashew plantation was 0.415 (Table 1). In the forest area, on the other hand 44 plant species with total abundance of 1682 plants per 0.3 ha were recorded. Of these, 82 % constituted indigenous species. The SRI in the forest area was 1.073 showing a comparatively higher floral presence than in the cashew plantation. The abundance and diversity of the species are characteristic of advancing communities with flora of varying taxonomic groups exhibiting ability to survive amidst diverse and competing individual. The flow of nutrients/minerals into and from the site indicates unrestricted interception by the various community members which assume different ecological niches and stratification. Plant

Table 2. Nutrient composition in the cashew plantation and natural forest soils. Values on top are for 0 - 15 cm soil depth while bracketed values below are for 15 - 30 cm soil depth.

PLOTS	N(%)	P (mg kg^{-1})	K (mol kg^{-1})	pH (1:2.5H_2O)	OM (%)
CASHEW PLANTATION					
I	0.09	2.40	0.91	4.41	1.46
	(0.07)	(1.84)	(0.84)	(4.81)	(0.82)
II	0.05	2.56	0.78	5.01	1.40
	(0.09)	(1.71)	(0.70)	(4.53)	(0.81)
III	0.09	3.25	0.74	6.62	1.30
	(0.09)	(1.02)	(0.73)	(6.50)	(1.01)
IV	0.03	1.35	0.87	4.41	0.99
	(0.04)	(1.12)	(0.67)	(4.60)	(0.62)
V	0.05	1.90	0.45	4.63	1.47
	(0.04)	(1.05)	(0.72)	(4.80)	(0.59)
VI	0.02	1.50	0.59	4.40	1.30
	(0.03)	(1.07)	(0.61)	(4.43)	(0.43)
Mean	0.056	2.16	0.73	4.91	1.32
	(0.06)	(1.30)	(0.71)	(4.95)	(0.71)
S.D.	0.03	0.717	0.176	0.870	0.211
	(0.026)	(0.370)	(0.077)	(0.780)	(0.210)
NATURAL FOREST					
I	0.21	26.25	0.02	5.83	1.18
	(0.48)	(28.77)	(0.02)	(5.48)	(1.88)
II	0.26	34.37	0.02	5.83	1.18
	(0.15)	(25.41)	(0.04)	(5.48)	(1.88)
III	0.27	21.00	0.04	6.67	1.99
	(0.06)	(27.09)	(0.03)	(5.41)	(2.16)
IV	0.06	2.18	1.15	5.73	3.67
	(0.02)	(2.36)	(1.44)	(5.73)	(2.39)
V	0.09	2.29	0.87	5.62	3.48
	(0.02)	(2.70)	(1.09)	(5.74)	(2.36)
VI	0.30	6.03	0.74	5.73	3.16
	(0.25)	(2.67)	(0.90)	(5.78)	(1.44)
Mean	0.20	15.35	0.47	5.79	2.57
	(0.16)	(14.83)	(0.54)	(5.83)	(1.90)
S.D.	0.10	13.74	0.507	0.484	1.003
	(0.179)	(13.47)	(0.561)	(0.510)	(0.506)

growth and emergence within the cashew plantation area are more of an expression of adaptive capacity than that of competitive ability as is the case in the forest area. Plants nourish the soil through nutrient release. The plant species that occurred in the cashew plantation were relatively shallow feeders which are confined within the soil surface layers. Gaps (open areas) that exist as a result of tree felling activities could support closely related or physiologically similar species which can opportunistically exploit nutrients contained therein.

Status of soil nutrients

Soil pH in both the cashew plantation area at the two depths (4.91 and 4.95) and that in the control plot (5.79 and 5.83) was acidic (Table 2). Essential soil minerals (N, P, K among others) were lower in the soils of the cashew plantation and significantly different from that in the control. The level of N in the cashew plantation (0.056 %) is lower than 0.1 % for N recorded within cashew established area as observed by Aikpokpodion *et al.* (2010). In spite of the above, the soils of the cashew plantation showed comparatively higher soil fertility index for agricultural crop production (Fig. 1). It is apparent that from the result of the fertility index, agricultural crops particularly those that adapt to shade (for instance cocoyam) could be successfully grown under this environment. Except

Table 3. Nutrient concentration of leaf litter in cashew plantation and natural forest.
Values in parantheses are for 15 - 30 cm depth, rest are for 0 - 15 cm depth. S.E. represents Standard Error.

PLOTS	N(%)	P(%)	K(%)	Ca (cmol kg^{-1})	Lignin (%)	OM (%)
CASHEW PLANTATION						
I	1.23	0.19	0.58	0.53	19.42	0.03
II	1.36	0.19	0.47	0.62	18.42	0.04
III	0.83	0.12	0.42	0.53	16.88	0.04
IV	1.43	1.34	0.77	0.72	15.48	0.03
V	2.33	1.23	0.81	0.63	14.27	0.06
VI	1.63	1.26	0.49	0.36	10.68	0.10
Mean	1.47	0.72	0.59	0.57	15.82	0.05
S.D.	0.498	0.610	0.163	0.123	3.121	0.026
NATURAL FOREST						
I	1.95	0.14	0.83	1.32	6.86	3.39
II	1.66	0.26	0.63	1.61	4.89	2.36
III	1.47	0.18	0.54	1.24	3.29	1.44
IV	1.62	0.25	0.61	0.64	4.82	1.63
V	1.43	0.23	0.53	1.52	2.47	2.45
VI	1.33	0.18	0.24	1.09	3.50	2.65
Mean	1.58	0.20	0.57	1.24	4.30	2.32
S.D.	0.220	0.048	0.192	0.347	1.562	0.712

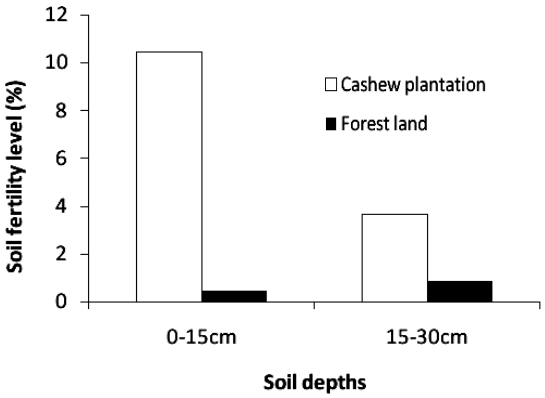

Fig. 1. Comparison of soil fertility level between the cashew plantation and forest land.

for N, results of soil analysis on arable croplands conducted within similar geographical locality by Nzegbule & Onyema (2006) were higher in all the measured soil parameters. Given the land hunger being experienced within the study area and indeed across the third world countries, this result could justify the preference people have for the choice of agricultural farming within forest plantation areas than in natural forest areas.

The leaf litter analysis for the measured nutrient elements (N, P, K, Ca) showed that there is a low rate of decomposition and mineralization of litter in the cashew plantation. Statistical analysis showed significant differences in the results obtained in the vegetation areas except for N. This situation can easily be traced to the peculiar character of N to easy volatilization in vegetation areas. In the control location, there were higher nutrient levels in the litter indicating accelerated nutrient recycling and decomposition (Table 3). Undisturbed tropical forest areas have been reported to have high levels of organic matter build-up as well as fast decomposition rates (Okeke & Omaliko 1992). Lignin is one of the chemical substances in plants and is essential in maintaining a complete plant litter bank. Its proportion in the cashew litter was 15.82 %, an amount that is more than the optimum tolerable amount for effective biochemical decomposition and nutrient mineralization (Reversat & Schwartz 1997). The high build-up and associated perceived slow rate of conversion of the above ground biomass of cashew plant through decomposition may have been hampered by the high lignin content. This chemical has also been richly found in other cashew parts as nuts and bark and this soluble liquid (lignin) accounts for the high rate of inflammability of cashew plant (Schaper & Chacko 1993).

Based on agricultural importance, the soil fertility index in the two locations varied considerably; for cashew plantation it was 10.48 % at the upper soil layer while it was 0.47 % in the control plot. The character of vegetation area and the age of such vegetation areas influence species composition and rate of decomposition but their soil nutrient stock or composition is inversely related to the soil fertility level for arable crop production purposes. This result is not at variance with the submission of Aweto & Ishola (1993) in which no significant variation occurred in the soil fertility levels of cashew plantation and that of adjoining bush thicket and croplands located within the neighbourhood of the plantation.

Conclusions

Age of plantation and character of dominant understorey vegetation determine the standing state of soil nutrients at any site. This study reveals that the gaps that exist within the cashew plantation can be utilized for replanting with new but adaptable species to enhance biodiversity conservation particularly as a corrective and ameliorative option for future land uses of non-agricultural purposes. More importantly, communities living around the cashew plantation should be encouraged to practice agro-forestry within the plantation in the form of corridor farming through collaborative partnership with the plantation owners.

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