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BELOW- AND ABOVE-GROUND TREE SPECIES DIVERSITY IN NATURAL FOREST AND MONOCULTURE TREE PLANTATIONS AT OMO BIOSPHERE RESERVE, NIGERIA

***Chima, U.D. and Alex A.**

Department of Forestry and Wildlife Management, University of Port Harcourt,
P.M.B. 5323, Port Harcourt, Rivers State, Nigeria
*Corresponding author's Email: *uzoma.chima@uniport.edu.ng*

ABSTRACT

The conversion of natural forests to monoculture tree plantations (MTPs) has been known to reduce above-ground tree diversity. However, information is lacking on the impact of MTPs on below-ground tree species diversity. This study evaluated below- and above-ground tree species diversity in a Strict Nature Reserve (SNR), a monoculture plantation of an indigenous tree species – Nauclea diderrichii (Nd), and four MTPs of exotic species – Gmelina arborea (Ga), Tectona grandis (Tg), Pinus caribaea (Pc) and Theobroma cacao (Tc) within Omo Biosphere Reserve in South-western Nigeria. Below-ground tree species was ascertained by evaluating the soil seed banks from the natural forest and the monoculture plantations using the seedling emergence method while tree species enumeration above-ground was done using the quadrat method. Below- and above-ground tree species diversity was higher in the SNR than in the MTPs and higher in the MTP of indigenous species (Nd) than in those of the exotic species. Below-ground tree species diversity was zero in both the SNR and MTPs below 0-5 cm soil depth. Similarity in tree species composition was also higher between the SNR and the indigenous species (Nd) plantation. The negative impact of natural forest conversion to MTPs on below- and above-ground tree species diversity was found to be lower in the indigenous species (Nd) plantation than in the exotic species (Ga, Tg, Pc & Tc) plantations. Consequently, plantation forestry may consider native species for biodiversity restoration.

Key words: Forest conversion, species origin, regeneration potential, tree diversity

INTRODUCTION

The pressure on forests to provide economic resources especially in the tropical world has been increasing rapidly as a result of burgeoning population in the region (Salami, 2006). The rate of deforestation and forest degradation in developing countries of the world is quite alarming in recent times, with about 13 million hectares of forest converted to other uses, largely agriculture, or lost through natural causes each year, in the last decade (FAO, 2010).

In Nigeria, forests provide invaluable services to the nation. But over the last half century, the Nigerian rainforest has experienced unprecedented reduction due to deforestation and degradation, which now pose intractable ecological, land use, biodiversity and sustainable management problem (Ikhuoria, *et al.*, 2006). Available records in the Federal Department of Forestry show that Nigeria has a total of 1,160 constituted forest reserves covering a total land area of 10,752,702 hectares, and this represents about 10% of the total land area (Salami, 2006). However, most of these reserves only exist on paper and the Federal Department of Forestry argues that deforestation in Nigeria is now progressing at the rate of 3.5% per annum.

The conservation of the tropical rainforest was central to the establishment of forest reserves in Southwestern Nigeria. However, different anthropogenic activities including farming and the establishment of monoculture tree plantations have either diminished their extent or degraded their abilities to play various ecological roles. Some research findings (Nwoboshi, 1970; Oyeniyi and Aweto, 1986) have shown that

certain cultural regimes for exotic hardwoods, do not maintain the hitherto soil and vegetation equilibrium.

A recent study by Chima and Adedire (2014) observed that the natural forest which covered 39.32% (58457 hectares) of Omo Biosphere Reserve in 1987 reduced to 32.05% (47654 hectares) in 2011. Taketay (1996) observed that the transformation of natural landscapes accelerates biodiversity losses indirectly through the anthropogenic activities that degrade the self-repairing capacity of an ecosystem including soil seed banks and soil fertility.

Soil seed banks play an important role in the natural forest. For example, the rapid re-vegetation of sites disturbed by wildfire, catastrophic weather, agricultural operations, and timber harvesting is largely due to the soil seed bank. A study into the natural process which influences forest dynamics has shown that soil seed bank is one of the principal sources of recruitment for new individuals in the initial stages of forest succession (Butler and Chazdon, 1998) and is partially responsible for dynamic changes that may occur during the development of vegetation (Lunt, 1997). The species richness and abundance in soil seed banks may provide information on the potential of a community for regeneration (William-Linera, 1993). Thus, the importance of soil seed bank in the restoration of plant communities after disturbance cannot be overemphasized. Establishment of vegetation from the seed bank may contribute to the long-term success of the recovering plant community.

Despite the rapid land use and land cover changes in Omo Biosphere Reserve including the Ogun State Plantation Project, no empirical study has been carried out to ascertain the impact of monoculture tree plantations (indigenous and/or exotic) and their associated management practices on the below- and above-ground tree species diversity. This study was carried out to fill this gap in knowledge.

MATERIALS AND METHODS

Above-Ground Tree Enumeration

Ten 35m × 35m quadrats were randomly distributed in each of the sites. This quadrat size falls within the range specified in the literature for ecological studies in the humid tropics (Salami, 2006). Narrow cut lines were made to demarcate the plot boundaries. All single-stem woody plants of erect posture with a minimum height of 5m and diameter at breast height (dbh) of 5cm were identified to species level and the number of individuals counted and recorded. Species identification was done with the aid of keys provided by Keay (1989). Specimens of species that could not be identified in the field were taken to the Forestry Research Institute of Nigeria (FRIN) Herbarium for identification.

Below-Ground Tree Species Enumeration

Data on below-ground tree species in the natural forest and the monoculture tree plantations were collected by evaluating the soil seed banks under them using the seedling emergence method. Five random plots, 2m x 2m, were marked out first at each site from five of the ten quadrats used for above-ground tree enumeration. Subsequently, three subplots, 20cm x 20cm, were marked out in a triangular shape, at the centre of each plot. Soil samples were removed from 0-5cm, 5-10cm and 10-15cm soil layers of each subplot. Soil samples were bulked for corresponding soil layers in each site and divided into six equal parts, four of which were randomly selected for germination trials at the Forestry Research Institute of Nigeria (FRIN) Experimental Nursery. The rationale for taking subplots was to capture the spatial heterogeneity of soil seed distribution.

Soil samples were spread to a thickness of 3cm on perforated plastic trays (diameter: 30cm and depth: 3cm) that were kept moist continuously. The seedling emergence method was used to assess the composition of the soil seed banks. Emerging tree species seedlings that are readily identifiable were counted, recorded and discarded on monthly basis until germination ceased.

Data Analyses

Measurement of Alpha Diversity

Simpson Index (Simpson, 1949) and Shannon-Wiener Index (Odum, 1971) were used to measure the below- and above-ground tree species diversity in each site.

Simpson's Index is expressed as:

$$D = \frac{\sum_{i=1}^{q} ni(ni-1)}{N(N-1)} \quad \text{------eqn. 1}$$

Where:
N = total number of individuals encountered
ni = number of individuals of ith species enumerated for i=1……q
q = number of different species enumerated.

Shannon-Wiener Index is expressed as:

$$H = -\sum_{i=1}^{s} pi \log pi \quad \text{----------eqn. 2}$$

Where:
pi = the proportion of individuals in the ith species
s = the total number of species

Both Simpson and Shannon-Wiener diversity indices were computed in this study using the PAleontological STatistics (PAST) Software.

Measurement of Similarity
A variety of indices are available for describing beta diversity, most of which are based on the use of presence-absence data, although quantitative abundance data can also be used (Newton, 2007). In this study, Sorensen's Similarity Index was used after Ogunleye *et al.* (2004), Ojo (2004) and Ihenyen *et al.* (2010), to determine the similarity in below-and above-ground tree species between each pair of the sites.
Sorensen's Similarity Index is expressed as:

$$SI = \frac{a}{a+b+c} * 100 \quad \text{------eqn.3}$$

Where:
a = number of species present in both sites under consideration
b = number of species present in Site 1 but absent in Site 2
c = number of species present in Site 2 but absent in Site 1.

RESULTS

Below- and Above-Ground Tree Species Richness in the Natural Forest and the Monoculture Tree Plantations
The below- and above-ground tree species richness in both the natural forest and the monoculture tree plantations at different soil depths is shown in Figure 1. The above ground tree species richness followed the order: SNR > Nd > Pc >Tg > Ga/Tc. At 0 -5 cm soil depth, tree species richness followed the order: SNR/Nd > Tg > Ga > Pc/Tc. Tree species richness at 5 – 10 cm and 10 -15 cm soil depths, was zero except in Nd where one tree seedling germinated at the 5 -10cm depth.

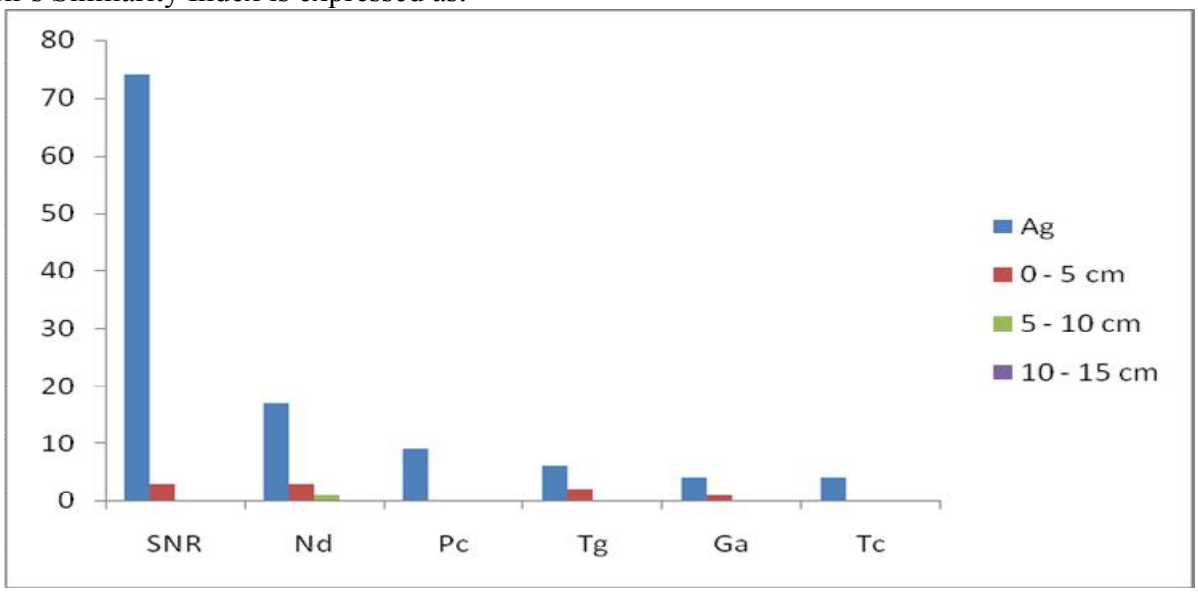

Figure 1: Below- and above-ground tree species richness in the natural forest and the monoculture tree plantations
Ag = above-ground; SNR = Strict Nature Reserve; Nd = *Nauclea diderrichii*; Pc = *Pinus caribaea*; Tg = *Tectona grandis*; Ga = *Gmelina arborea*; Tc = *Theobroma cacao*

Below–and Above-Ground Tree Species Diversity in the Natural Forest and the Monoculture Tree Plantations at Different Soil Depths

The below- and above-ground tree species diversity indices for both the natural forest and the monoculture tree plantations at different soil depths are shown in Table 1. Below and above-ground tree species diversity was higher in the natural forest than in both the indigenous and exotic tree plantations. Considering the monoculture tree plantations alone, below and above- ground tree species diversity was higher in the monoculture plantation of the indigenous species - *Nauclea diderrichii* than in the plantations of exotic species. Below ground tree species diversity was zero for both the natural forest and the monoculture plantations at 5 – 10 cm and 10 – 15 cm soil depths.

Table 1: Tree diversity indices at different land use types and soil depths

	SNR	Nd	Pc	Tg	Ga	Tc
Above-ground						
Shannon H	3.59	0.54	0.22	0.29	0.09	0.20
Simpson 1 – D	0.96	0.19	0.07	0.12	0.03	0.08
0 – 5 cm						
Shannon H	1.04	0.86	0.00	0.27	0.00	0.00
Simpson 1 – D	0.63	0.54	0.00	0.14	0.00	0.00
5 – 10 cm						
Shannon H	0.00	0.00	0.00	0.00	0.00	0.00
Simpson 1 – D	0.00	0.00	0.00	0.00	0.00	0.00
10 – 15 cm						
Shannon H	0.00	0.00	0.00	0.00	0.00	0.00
Simpson 1 – D	0.00	0.00	0.00	0.00	0.00	0.00

SNR = Strict Nature Reserve; Nd = *Nauclea diderrichii*; Pc = *Pinus caribaea*; Tg = *Tectona grandis*; Ga = *Gmelina arborea*; Tc = *Theobroma cacao*

Below– and Above-Ground Tree Species Similarity between the Natural Forest and the Monoculture Tree Plantations at Different Soil depths

The extent of similarity in tree species composition between the natural forest and the monoculture plantations and between the monoculture plantations below- and above-ground, is shown in Table 2. Similarity in tree species composition was higher between the natural forest (SNR) and the indigenous species plantation (Nd) both below- and above-ground. Monoculture tree plantations that were close to each other (e.g. Nd/Pc and Pc/Tg) were observed to have higher similarity in above-ground tree species composition.

Table 2: Sorensen's Similarity Indices for above-and below-ground tree species composition at the Natural Forest and the Monoculture Tree Plantations

	SNR	**Nd**	**Pc**	**Tg**	**Ga**	**Tc**
Above-ground						
SNR	*	5.88	2.50	1.27	2.63	1.30
Nd		*	44.44	27.78	10.53	10.53
Pc			*	50.00	8.33	8.33
Tg				*	25.00	11.11
Ga					*	0.00
Tc						*
0 – 5 cm						
	SNR	Nd	Pc	Tg	Ga	Tc
SNR	*	50.00	0.00	0.00	0.00	0.00
Nd		*	0.00	0.00	0.00	0.00
Pc			*	0.00	0.00	0.00
Tg				*	50.00	0.00
Ga					*	0.00
Tc						*
5 – 10 cm						
	SNR	Nd	Pc	Tg	Ga	Tc
SNR	*	0.00	0.00	0.00	0.00	0.00
Nd		*	0.00	0.00	0.00	0.00
Pc			*	0.00	0.00	0.00
Tg				*	0.00	0.00
Ga					*	0.00
Tc						*
10 – 15 cm						
	SNR	Nd	Pc	Tg	Ga	Tc
SNR	*	0.00	0.00	0.00	0.00	0.00
Nd		*	0.00	0.00	0.00	0.00
Pc			*	0.00	0.00	0.00
Tg				*	0.00	0.00
Ga					*	0.00
Tc						*

SNR = Strict Nature Reserve; Nd = *Nauclea diderrichii*; Pc = *Pinus caribaea*; Tg = *Tectona grandis*; Ga = *Gmelina arborea*; Tc = *Theobroma cacao*

DISCUSSION

Below- and above- ground tree species richness and diversity were higher in the SNR than in the MTPs probably due to the relatively undisturbed nature of the former. Several other studies (e.g. Williams-Linera, 1990; Harris and Silva-Lopez, 1992; Taketay, 1996; IUCN, 2002; Chima and Uwaegbulem, 2012) have shown that habitat destruction reduce biological diversity.

The higher species similarity between the SNR and the *Nauclea diderrichii* plantation and the higher species richness and diversity also in *Nauclea diderrichii* plantation than in the plantations of exotic species could be due to several reasons. *Nauclea diderrichii* is an indigenous species and recovery of native tree species diversity has been known to be supported better by indigenous species. Another possible reason could be that the *Nauclea diderrichii* plantation was the least disturbed of all the plantations, having not been logged since its establishment in 1975. The plantation acts as a

buffer to the staff residential quarters and the dispersal of eaten or used seeds and fruits by the residents may have equally enhanced the species diversity. The closer similarity between the SNR and the *Nauclea diderrichii* plantation in the above evaluated attributes both below- and above-ground underscores the resilience of disturbed and modified natural forest ecosystems when protected from further disturbances.

Higher similarity in above-ground tree species composition between neigbouring plantations could probably be as result of more exchange of seeds by agents of dispersal due to closer distances.

There was a wide gap between the above-ground and below-ground tree species diversity. The paucity of tree species below-ground was quite obvious. Several other studies (e.g. Kebrom and Tesfaye, 2000; Senbata and Teketay, 2002; De Villiers *et al*, 2003; Jalili *et al*, 2003; Wassie and Teketay, 2006; Oke *et al*., 2007) had also recorded few tree species in soil seed banks. Oke *et al*. (2007) in their study recorded only three woody species with herbaceous species accounting for 98% of the total seed density in all the plantations they considered. The paucity of woody species below-ground may be attributed to the short-lived nature of their seeds (Garwood, 1989; Wassie and Teketay 2006), and/or quick germination after dispersal or the effect of pathogens and predators (Teketay, 1997). Dike (1992) had observed that forest species within this study area often complete their germination processes within eighty-four days after dispersal, thus leaving few seeds to be deposited in the seed bank.

The zero diversity recorded below the 0-5 cm soil depth can be attributed to the reduction in the abundance of seeds from the forest floor to lower soil horizons. Senbeta and Teketay (2002) equally observed that the number of seeds in the soil decreased with increasing depth, with the highest number of species and densities of seeds recorded in the upper three centimeters of soil, in all the plantations they considered. This same fact could be the most probable reason for the zero similarity in tree species composition between sites below 5 cm soil depth.

CONCLUSION AND RECOMMENDATION

The negative impact of natural forest conversion to monoculture tree plantations on below- and above-ground tree species diversity was found to be lower in the indigenous species plantation than in the exotic species plantations. Consequently, plantation forestry should consider native species for biodiversity restoration.

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