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Vegetation studies of Non-Timber Forest Products (NTFPs) at three sites with varying levels of anthropogenic disturbances in the Southern Bakundu Forest Reserve, Cameroon

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A study was carried out to evaluate the distribution, abundance and diversity of Non-Timber Forest Products (NTFPs) in the Southern Bakundu Forest Reserve at the northern (Diffa), western (Bai Manya) and eastern (Mbalangi) parts of the reserve. NTFPs can be used as source of food, medicine, fuel wood and other socio-economic and cultural uses. Six belt-transects were use at each site to assess the distribution, abundance and diversity of NTFPs in this Forest Reserve. The southern part of the reserve was not evaluated as it was heavily encroached with cocoa plantations. A total of 50 species in 40 genera and 27 families were identified. 28 species were most commonly distributed in the three sites. These include *Irvingia gabonensis*, *Trichoscypha abut* and *Cola lepidota*, while *Garcinia cola*, *Baillonella toxisperma* and *Tetracarpidium conophorum*, *Raphia* species and *Afromomum citratum* were restricted to one or two sites. The northern part of the forest had the highest number of useful plants (3119), followed by the eastern part (837) and lastly by the western part (774). Between sites, Bai Manya and Diffa were most similar (Jaccard Index = 0.65; Sorenson Coefficient = 0.79). The western part had the highest species diversity (D = 0.92), followed by the northern part (D = 0.85) and lastly by the eastern part (D = 0.8).The results are significant for better management and conservation of this forest reserve.

Key words: Non-timber Forest Products (NTFPs), species diversity, similarity indices, abundance, frequency, anthropogenic.

INTRODUCTION

The Southern Bakundu Forest Reserve (SBFR) was established in about 1939 by the British Colonial Authorities, mainly for selective exploitation of timber for domestic construction and export. In 1959, the reserve

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was passed on to the Cameroon Ministry of Forestry which initiated regeneration activities in a 160 ha compartment. In 1972, the “Fond Nationale de Development Forestiere et Piscicole” established an additional 312 ha. Human habitats surrounding the forest increased tremendously with time, resulting in encroachment into the forest for slash and burn agriculture and also harvest of Non-timber Forest Products (NTFPs) on which the local populations depend heavily for food, fuel wood, medicine and condiments (Banjade and Paudel, 2008; Focho et al., 2009; Hossanet al., 2010; Jiofac et al., 2009; Simbo, 2010; Egbe et al., 2012; Nang and Dioggban, 2015). The resulting decrease in forest area and quality negatively alters ecosystem functioning and services (Aerts and Honnay, 2011). In 1982, the “Office Nationale de Regeneration Forestiére” (ONADEF) countered this encroachment by establishing 258 more hectares. However, harvests of NTFPs and illegal logging in the forest reserve continued unabated, resulting in massive degradation of the forest. It became apparent that effective conservation has to take into consideration the needs of the forest users. It has been shown that forest management and rehabilitation depend greatly on the resources that are found in the forest and the strategic role the forest plays to the surrounding population and environment (Sunderland et al., 1999; Jewitt et al., 2014). In the SBFR, exploitation of NTFP which constitutes an important activity thus has to be considered alongside mainstream management of the reserve. Non-timber forest products have been shown to serve a dual role as a “possible” tool for the conservation of tropical forest through community participatory approach and as an economic cornerstone (Incentive Approach Theory) for the local population (Peters et al., 1989; Wong, 2000b). However, unchecked harvesting erodes biomass and degrades the forest, with the potential to influence species retention, abundance and diversity (Hughes, 2012). Efforts by the government, NGOs and donors to protect the SBFR and promote sustainable harvesting of the NTFPs from forest reserves have not been successful, as the level of deforestation and degradation of this forest and its NTFPs (e.g. depletion of *Gnetum africanum* Welw.stock) continue unabated. According to the Intermediate Disturbance Hypothesis, maximum species richness should be expected at sites with an intermediate level of disturbance (Bongers et al., 2009; Hughes, 2012). Thus, NTFPs harvesting and other ‘necessary’ disturbances should aim at not exploiting beyond this optimum level. Without dedicated studies however, it is unclear whether or not the present levels of exploitation and other anthropogenic disturbances in the SBFR are sustainable, and the effects on flora biodiversity are unknown. In addition, no studies of pristine conditions at this site exist for comparison. Thus, despite the high value of some of the NTFPs in and around the Southern Bakundu Forest Reserve (SBFR) and coupled with the high rates of exploitation, agricultural expansion, increased urbanisation and general deforestation of this important catchment over the past 33 years (Oyono et al., 1997) there is no available literature on the associated dynamics of NTFP species distribution, abundance and diversity at the different sites.

While studies on NTFPs mainly focuses on ethnobotany and domestication in Cameroon exist for *Irvingia* species, *Ricinodendron heudelotii* (Baill) Pierre ex Pax & Hoffm, *Prunus africanab* (Hook.f.) Kalkmanetc, with export potentials (Ayuk et al., 1999; Malleson, 2000; Awono et al., 2002; Ndoye, 2005; Focho et al., 2010; Egbe et al., 2012), research has mainly ignored studies on diversity and population structure of these species, which are key to the understanding of long-term species retention, and the general health of the forest. In Cameroon, there is very good legislation on forest management but the major constraint is its effective implementation in the field. Recent information indicates that the Cameroon Government is in the process of transferring the management of this forest reserve to the local communities, and so a baseline study of diversity and abundance of NTFPs is essential to understand the present dynamics and comparisons with future studies. The aim of this study was to identify NTFPs and evaluate their diversity and abundance across sites in the SBFR. This work goes a long way in contributing to the baseline data bank of NTFPs in the SBFR, which is needed for the rehabilitation of this forest.

MATERIALS AND METHODS

The study area

This study was carried out in the Southern Bakundu Forest Reserve (SBFR). This reserve is found in Mbonge Subdivision, Meme Division, Southwestern Cameroon (Figure 1). The SBFR is located in the belt of the Gulf of Guinea (Biafra), between latitudes 4°20′ and 4°50′ north of the equator, 9°0′ and 9°30′ east and north of Mount Cameroon (Mekou, 2003). The forest covers an area of 18100 ha and is surrounded by 22 villages. It is bounded to the north by the Kumba-Mbonge road, to the south by the Cameroon Development Cooperation CDC rubber and palm plantations, to the east by the Kumba-Buea road and to the west by the Kumba metropolis.

The climate is humid and tropical, characterized by a long rainy season from March to October and the short dry season from November to January. The mean annual rainfall and temperature of the SBFR are 2200 mm and 29.01°C, respectively. The average relative humidity is constantly higher than 86%, with an average sunshine period of about 260 days. The climate does not vary greatly between villages around the forest. Two major soil types are found in the Sothern Bakundu Forest Area (SBFA); the deep well drained yellowish brown sandy clay soils developed from old sedimentary deposits and the deep brown clay soils developed from volcanic materials (Ngole, 2005). The topography is irregular, with flats and gentle slopes of between 5 and 8%, although slopes of more than 25% can be seen near waterfalls (Ngole, 2005). An

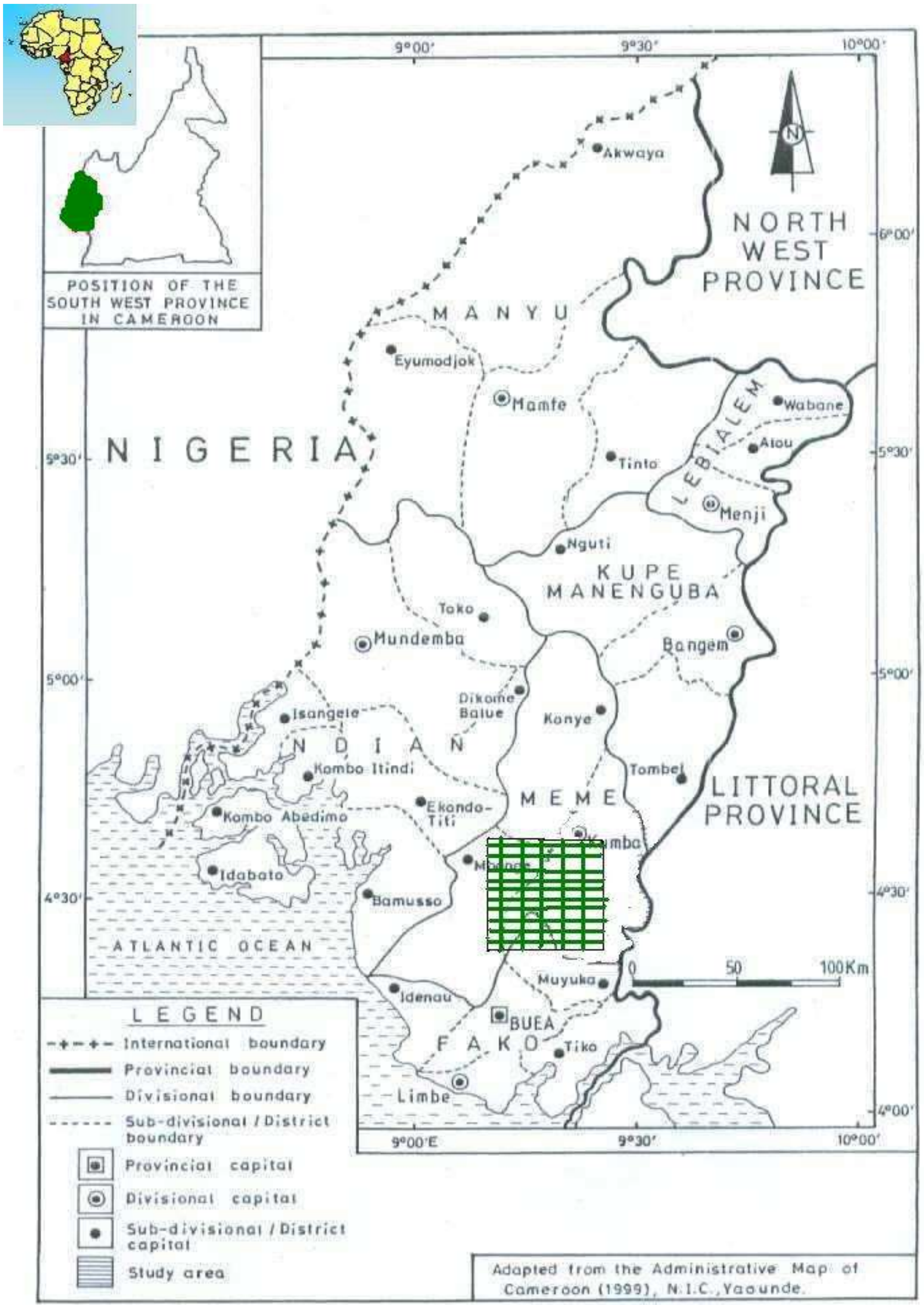

Figure 1. Map of the South West Region showing the location of the study site.

average altitude of about 200 m dominates the forest, with the lowest of about 30 m found in the southwestern part and the

Table 1. Vegetation classification of the Southern Bakundu Forest Reserve.

Type of forest	Area covered (ha)	Percentage
Primary forest	7052	39
Secondary young forest	936	5.17
Secondary old forest	9160	50.6
Plantation and agroforestry	952	5.27
Total	18100	100

This classification has changed drastically ever since, as more farms have been established in the area.
Source: Southern Bakundu Project (1994).

Table 2. Location of study sites.

Village	Approximate distance from village (km)	Geographical orientation
Mbalangi	12	East
Diffa	7-8.5	North
Bai Manya	15	West
Muyenge, Mussone, Lykoko	>20*	South (Intensive encroachment into the reserve land)

*Heavily degraded areas in the southern villages.

highest of 300 m, occurring on hills of the western parts of the forest (Ngole, 2005).

The vegetation is dense evergreen tropical rainforest. This reserve is classed mainly in the lowland range (0 to 800 m), within the Biafrean Atlantic district, dominated by mainly the Caesalpinaceae (Mekou, 2003). The lowland rainforest in which the SBFR is found accounts for the most important vegetation type with very high species diversity (Mekou, 2003). The Southern Bakundu Project classified the vegetation of the SBFR into four major forest types: primary, secondary old forest, secondary young forest, plantation and Agroforestry (Table 1). These area cover and forest type are not what is obtain today as there have been a lot of encroachments after 1994.

Ecological survey

A reconnaissance survey was carried out to select study sites and sampling points in the field. Four villages surrounding the SBFR, representing the cardinal coordinates were chosen and six transects per village were selected for more detailed study. One village was selected each to represent the north, south, east and west of the reserve, respectively (Table 2). This was aimed at reducing bias and improving on full coverage of the reserve.

Sampling design

Baselines were chosen in the reserve at about 100 m from the limits of encroachment into the forest reserve. This was to reduce the influence of direct and visible human activities on the results. Sampling was based on the methods of Hall and Bawa (1993). Six belt transects of 500 ×10 m were set up at each site. These transects were set up in parallel series separated by 200 m gaps. This was to ensure that the presence or absence of a targeted species in one transect does not influenice the probability of the species occurring in any other transect (Wong, 2000a). Each transects was evaluated as a replicate to reduce the sampling error margin (Wong, 2000a). Quadrats of 20 × 10 m were randomly created in each transect to sample smaller NTFPs such as *Gnetum* species. Sampling was done within each transect, with a researcher on either side of each transect carefully searching for, and recording the NTFP species (Peters, 1994, 1996). Parameters recorded included presence/absence, abundance, and some NTFPs were only counted e.g. rattans, *Gnetum* (in the 20 × 10 m quadrats), while others such as *Afromomum* and *Thaumatococus* species were counted by stands.

Voucher specimens were collected in cases where species could not be well identified; these were tagged, oven-dried and identified post-collection at the Limbe Botanic Garden Herbarium (SCA).

Data analyses

Species diversity and similarity between sites

Simpson diversity index, Jaccard's coefficient and Sorenson similarity index were calculated for the different sites, according to the equations outlined:

$$Simpson\ Index\ \lambda = \sum_{i=1}^{R} pi2 \quad (1)$$

where pi = proportional abundance of the ith species, R = maximum number of species.

Similarity indices were calculated using Jaccard's and Sorensen's coefficients:

$$Jaccard's\ Coefficient = \frac{|Q \cap D|}{|Q \cup D|} = \frac{p}{p+q+d} \quad (2)$$

where p = number of species present in both sites; q = number of species present in Q but not in D; d = number of species present in D but not in Q.

$$Sorensen's\ Coefficient\ Cn = \frac{2c}{a+b} \quad (3)$$

where Cn = Sorensen similarity coefficient; c = number of species common to samples A and sample B; b = number of species in sample B, and a = number of species in sample A.

Frequency and abundance of species within the different sites

The frequency of occurrence of each species was calculated for the different sites using the formula:

$$Frequency = \frac{Y}{Z} * 100 \quad (4)$$

where Y = Number of transects in which species is present; Z = total number of transects in each site.

In terms of presence or absence of species, the evaluation of each species in each site was conducted using the Braun-Blanquet Rating scheme, plant cover rating as follows:

(1) Species present in 75-100% transect, meant that the species was highly abundant.
(2) Species present in 50-74% transect, meant that the species was moderately abundant.
(3) Species present in 25-49% transect, meant that the species was sparsely abundant.
(4) Species present in <25% transect, meant that the species was rare.

These results were further refined through Simple Correspondence Analyses of species incidence and abundance across sites, respectively. These analyses were carried out in the Minitab Version 16 statistical package (Minitab Inc., USA).

RESULTS

Distribution and abundance of NTFP species found

The 24 transects sampled from the four sites, results from the southern site were not evaluated due to intensive encroachment. Fifty NTFP species in 40 genera and 27 families were identified (Table 3). From these, 28 species most frequent are presented in Table 4. The distribution of the different NTFPs was assessed in terms of presence or absence of species at the different sites. Species such as *Irvingia gabonensis* Baill. Ex Lanen, *Trichoscypha abut* Engl & Brehmer, *Cola lepidota* K.Schum, etc., were present in all the sites while *Garcinia kola* Heckel, *Baillonella toxisperma* Pierre, and *Tetracarpidium conophorum* (Müll.Arg.) Hutch. & Dalziel were restricted to either one or two sites. Correspondence analyses showed that the observed species distribution can be explained by two main components; analysis of the contingency table indicated that Components 1 and 2 contributed 53.2 and 46.7%, respectively of the total inertia (Table 5). The two components effectively explain the distribution of species across all sites (Qual = 1). Component 1 best explains distribution of species at the North site (Diffa) (Corr = 0.95). Diffa was highly associated with *G. kola, T. conophorum*, and *Omphalocarpum procerum* P. Beauv. not found in the other sites. The west site (Bai Manya) and the east site (Mbalangi) are best explained by Component 2 (Corr = 0.836 and 0.543, respectively) (Table 5). *Nephthytis poissonii* and *B. toxisperma* were only found in Bai Manya, distinguishing it from Mbalangi where no species existed exclusively; the rest of species observed were cosmopolitan across sites (Figure 2). The detailed frequencies of the different species are presented in Table 4. *Coula edulis* Baill., *C. lepidota*, and *G. africanum* were present in all the sites (100%). Raphia palm (*Raphia* species), *G. kola* and a few other species, were rare in the wild (<25%).

Abundance

Correspondence analysis of the pattern of species abundance across sites is presented in Table 6. The first two components explained most of the spatial abundance of species, contributing 52.5 and 47.5%, respectively of the total inertia (Table 6). The two components effectively explain the spatial species abundance across all sites (Qual = 1). Component 1 explains abundance of species at the North site (Diffa) (Corr = 0.616) and Bai Manya (Corr = 0.98). *G. kola, Tetrapluera tetraptera, O. procerum, T. conophorum* and *Piper guineensis* L. have the highest abundance in Diffa, and occur at very low numbers in other sites. Similarly, *N. poissonii* (183), *B. toxisperma* (10) and *Afromomun citratum* (Pereira) K.Schum (9) have the highest abundance in Bai Manya, occurring in very low numbers across the other sites. Mbalangi was the best described by Component 2 (corr = 0.821). *Phyllanthus meullerianus* (Kuntze) Exell. has the highest abundance in Mbalangi (Table 6 and Figure 3).

Similarity and diversity indices

Bai Manya and Diffa were the most plants similar sites with Jaccard's Coefficient (C_j) of 0.65 and Sorensen's coefficient (C_n) of 0.79. Plants in Diffa and Mbalangi were the least similar sites with Jaccard's Coefficient (C_j) of 0.52 (Table 7).

Table 8 shows plant diversity indices of the different sites with respect to plant species assessed. Bai Manya was the most diverse site (D = 0.92) and Mbalangi was the least (D = 0.8) with respect to NTFPs. In terms of magnitude however all sites could be considered to be highly diverse.

Table 3. Species identified in field surveys in the SBFR.

Scientific name	Common names	Family	Habit
Afromomum citratum (Pereira) K.Schum.	Mbongo	Zingiberaceae	Herb
Afromomum sp	Alligator pepper	Zingiberaceae	Herb
Afrostyrax lepidophyllus Mildbr.	Bush onion	Styracaceae	Tree
Angylocalyx talbotii Baker	Strong cough medicine	Sterculiaceae	Tree
Arthocarpus heterophyla Lam.	Pembe	Moraceae	Tree
Baillonella toxisperma Pierre	Njambe/moabi	Sapotaceae	Tree
Canariums cheinfurthii Engl.	Bush plums/ aiele	Burseraceae	Tree
Cassia alata L.	Fish poison	Fabaceae	Shrub
Cinchona officinalis L.	Quinine plant	Rubiaceae	Tree
Cola lepidota K. Schum.	Monkey cola	Sterculiaceae	Tree
Cola nitida (Vent.) Schott &Endl.	Country kola nut	Sterculiaceae	Tree
Cola verticilata (Thonn) Stapf ex A.Chev	Two halves kola nut	Sterculiaceae	Tree
*Coula edulis*Baill	Koma	Olacaceae	Tree
Dacryodes edulis (G. Don.) H.J. Lam	Plum	Burseraceae	Tree
Dichapetalum sp	Bush water rope	Dichapetalaceae	Liana
Enantia chlorantha (Oliv)	Yellow bark	Annonaceae	Tree
Entandrophragma cylindricum (Sprague) Sprague	Sapelli	Meliaceae	Tree
Eremospatha sp	Small cane	Arecaceae	Palm
Erythrophleum ivorensis (Guill. & Perr.)	Tali	Caesalpiniaceae	Tree
Fagara sp.	Belly medicine	Rutaceae	Tree
Garcinia kola Heckel. Engl	Bitter kola	Clusiaceae	Tree
Garcinia mannii Oliv.	Chewing stick	Clusiaceae	Tree
Gnetum africana Welw.	Eru	Gnetaceae	Vine
Irvingia gabonensis (Aubry. Lecomte ex O'Rorke) *& I . wombolu*	Bush mango	Irvingiaceae	Tree
Maranthochloa holostachya (Bak.)	Mbombolo leaf	Marantaceae	Herb
Massularia acuminate (G. Don) Bullock ex Hoyle		Rubiaceae	
Megaphrynium macrostachium(Benth.) Milne-Redh	Big leafs	Marantaceae	Herb
Milicia excelsa Welw.	Iroko	Moraceae	Tree
Myrianthus arboreas (L.) Sleum.	Bush pineapple	Moraceae	Tree
Nephthytis poissonii (Engl.)N.E.Br	Mebe	Araceae	Epiphyte
Omphalocarpum procerum P. Beaux.	Dancing beads plant	Sapotaceae	Tree
Oncocalamus sp	Large cane	Arecaceae	Palm
Pentaclethra macrophylla Benth.	Botton	Fabaceae	Tree
Phyllanthus meullerianus (O.Ktze.) Exell.	White Mahum	Euphorbiaceae	Vine
Phyllanthus reticulates Poir	Red Mahum	Euphorbiaceae	Vine
Piper guineensis Schum. and Thorn	Bush pepper	Piperaceae	Vine
Pterocarpus soyauxii Taub	Camwood/Padouk	Papilionaceae	Tree
Raphia spp.	Raphia palm/ Matutu	Arecaceae	Palm
Ricinodendron heudelotii (Baill.) Pierre ex Pax &Hoffm.	Njansang	Euphorbiaceae	Tree
Sarcophrynium prionogonum (K.Schum.)	Small leaf	Marantaceae	Herb
Terapleura tetraptera (Schumach. &Thonn) Taub.	Black spice	Mimosaceae	Tree
Tetracarpidium conophorum (Mull. Arg) Hutch. & Dalziel	Africa Cashew nut	Euphorbiaceae	Vine
Tetracera alnifolia Willd.	Bush water rope	Dilleniaceae	
Thaumatococcus spp.	Fat leaf	Marantaceae	Herb
Trichoscypha abut Engl. &Brehmer	Sweet changing blood	Anacardiaceae	Tree
Trichoscypha arborea (A. Chev) A.Chev	Sour changing blood	Anacardiaceae	
Xylopia aethiopica (Dunal) A. Rich.	Achu spice	Annonaceae	Tree

Table 4. Frequency of occurrence of each species at different sites.

Species	Mbalangi			Diffa			Bai Manya		
	No. present	No. of transects out of 6 with species	Frequency (Y/Z) ×100	No. present	No. of transects out of 6 with species	Frequency (Y/Z) ×100	No. present	No. of transects out of 6 with species	Frequency (Y/Z) ×100
Irvingia gabonensis	15	5	83.3	13	6	100	16	6	100
Trichoscypha spp.	9	4	66.7	45	6	100	10	6	100
Garcinia spp.	59	6	100	62	6	100	0	0	0
Mussularia acuminata									
Coula edulis	41	6	100	18	6	100	20	6	100
Cola lepidota	28	6	100	160	6	100	37	6	100
Dacryodes edulis	0	0	0	7	4	66.7	6	3	50
R. heudelotii	0	0	0	13	6	100	12	4	66.7
Fagara spp.	11	3	50	22	2	33.3	16	5	83.3
Cinchona officinalis	0	0	0	13	4	66.7	16	5	83.3
Tetrapleura. Tetraptera	0	0	0	7	6	100	1	1	16.7
Cola grasilensis	10	4	66.7	0	0	0	16	5	83.3
Garcinia kola	0	0	0	5	2	33.3	0	0	0
Baillonella toxisperma	0	0	0	0	0	0	10	4	66.7
Omphalocarpum procerum	0	0	0	6	4	66.7	0	0	0
Gnetum africana	124	6	100	159	6	100	126	6	100
Piper guineensis	0	0	0	570	6	100	103	6	100
Oncocalamus spp.	72	6	100	147	6	100	73	6	100
Eremospatha spp.	398	6	100	1861	6	100	510	6	100
*Afromomum. Citratum (*Stands)	0	0	0	2	1	16.7	9	2	33.3
Maranthochloa spp.	2	2	33.3	3	3	50	4	2	33.3
Megaphrynium spp.	2	2	33.3	0	0	0	7	2	33.3
Thaumatococcus spp.	0	0	0	3	3	50	6	4	66.7
Sarcophrynium spp.	0	0	0	2	1	16.7	6	5	83.3
Phllanthus meullerianus	67	2	33.3	0	0	0	5	2	33.3
Tetracarpidium conophorum	0	0	0	3	2	33.3	0	0	0
Nephthytis poissonii	0	0	0	0	0	0	183	4	66.7
Raphia spp.	1	1	16.7	3	2	33.3	1	1	16.7

DISCUSSION

The aim of this study was to identify NTFPs and evaluate their distribution, diversity and abundance across sites in the SBFR. Research on species distribution, diversity and abundance patterns in forest ecosystems is essential to inform better conservation and management policy(Kanagaraj et al., 2016). This is especially true of forest ecosystems under various forms of anthropogenic disturbances. A total of 50 species in 40 genera and 27 families were observed. The patterns observed in this study are consistent with policy(Kanagaraj et al., 2016). combined effects of harvesting patterns and other anthropogenic

Table 5. Simple Correspondence Analysis of species occurrence across sites.

Axis	Analysis of the contingency table		
	Inertia	Proportion	Cumulative
1	0.1565	0.5322	0.5322
2	0.1375	0.4678	1
Total	0.294		

Sites	Row contributions				
	Qual	Component 1		Component 2	
		Corr	Contr	Corr	Contr
Mbalangi (East)	1	0.457	0.312	**0.543**	0.422
Diffa (North)	1	**0.956**	0.594	0.044	0.031
Bai Manya (West)	1	0.164	0.094	**0.836**	0.546

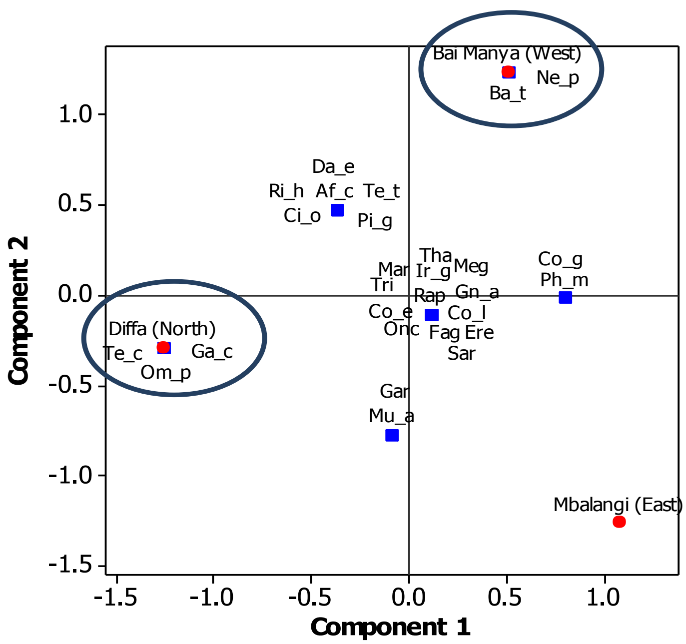

Figure 2. Distribution patterns of NTFP species across sites**.** Ba_t: *Baillonella toxisperma*, Ci_o: *Cinchona officinalis*, Co_g: *Cola grasilensis*, Co_l: *Cola lepidota*, Co_e: *Coula edulis*, Da_e: *Dacryodes edulis*, Fag: *Fagara* spp., Ga_c: *Garcinia cola*, Gar: *Garcinia sp*, Mu_a: *Mussularia acuminata*, Ir_g: *Irvingia gabonensis*, Ri_h: *Ricinodendron heudelotii*, Te_t: *Tetrapleura tetraptera*, Tr_a: *Trichoscypha abut*, Af_c: *Afromomum citratum*, Ne_p: *Nephthytis poissonii*, Ere: *Eremospatha* spp., Gn_a: *Gnetum africanum*, Mar: *Maranthochloa* spp., Meg: *Megaphrynium* spp., Sar: *Sarcophrynium*, Tha: *Thaumatococcus* spp., Om_p: *Omphalocarpum procerum*, Onc: *Oncocalamus* spp., Ph_m: *Phllanthus meullerianus*, Pi_g: *Piper guineensis*, Rap: *Raphia* spp, Te_c: *Tetracarpidium conophorum.*

impacts.However, the results are lower than those reported by Nnanga et al. (2017) at the coastal forest area of Cameroon which might be due to very low disturbances in their study areas though both of them are

Table 6. Simple correspondence analysis of species abundance across sites.

Axis	Analysis of the contingency table		
	Inertia	Proportion	Cumulative
1	0.1737	0.5248	0.5248
2	0.1573	0.4752	1
Total	0.3309		

Name	Row contributions				
	Qual	Component 1		Component 2	
		Corr	Contr	Corr	Contr
Mbalangi	1	0.01	0.008	0.99	0.821
Diffa	1	0.616	0.234	0.384	0.161
Bai Manya	1	0.98	0.758	0.02	0.017

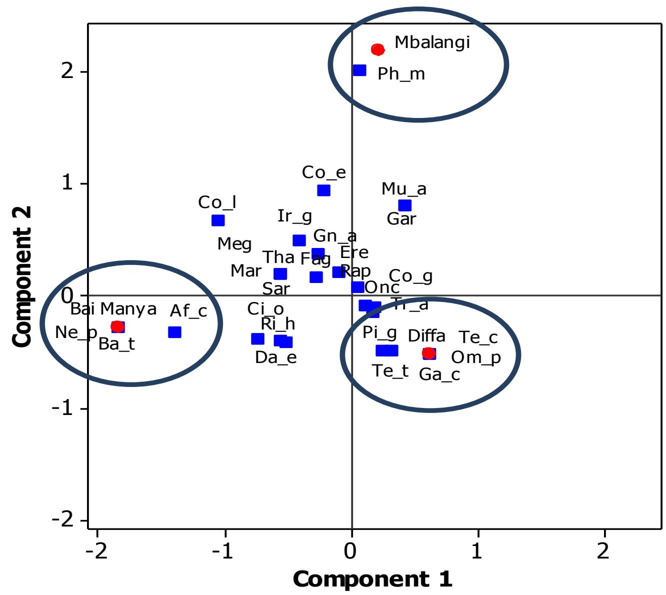

Figure 3. Abundance patterns of NTFP species across the different sites. Ba_t: *Baillonella toxisperma*, Ci_o: *Cinchona officinalis*, Co_g: *Cola grasilensis*, Co_l: *Cola lepidota*, Co_e: *Coula edulis*, Da_e: *Dacryodes edulis*, Fag: *Fagara* spp., Ga_c: *Garcinia cola*, Gar: *Garcinia sp*, Mu_a: *Mussularia acuminata*, Ir_g: *Irvingia gabonensis*, Ri_h: *Ricinodendron heudelotii*, Te_t: *Tetrapleura tetraptera*, Tr_a: *Trichoscypha abut*, Af_c: *Afromomum citratum*, Ne_p: *Nephthytis poissonii*, Ere: *Eremospatha* spp., Gn_a: *Gnetum africanum*, Mar: *Maranthochloa* spp., Meg: *Megaphrynium* spp., Sar: *Sarcophrynium*, Tha: *Thaumatococcus* spp., Om_p: *Omphalocarpum procerum*, Onc: *Oncocalamus* spp., Ph_m: *Phllanthus meullerianus*, Pi_g: *Piper guineensis*, Rap: *Raphia* spp, Te_c: *Tetracarpidium conophorum.*

within the same agro-ecological zone in Cameroon. Species with high economic value that are also the most (*Dacryodes* harvested *edulis, R. heudelotii*) were present across all sites suggesting that harvesting alone could

Table 7. Similarity measures across sites.

Site	Jaccard's Coefficient		Sorensen Coefficient	
	Bai Manya	Diffa	Bai Manya	Diffa
Bai Manya	-	-	-	-
Diffa	0.65	-	0.79	-
Mbalangi	0.60	0.52	0.75	0.69

Table 8. Species diversity across sites measured by Simpson's index**.**

Variable	Bai Manya	Diffa	Mbalangi
Simpson's index (D)	0.92	0.85	0.8
Reverse of Simpson' index (1/D)	12.6	6.59	7.85

not explain species distribution patterns in the SBFR. Since the fruits of these species are eating by animals, they in the dispersal of the seeds in the forest. In fact, some cosmopolitan species identified such as *R. heudelotii* and *Tetrapleura tetraptera* are indicators of fragmentation of forest stand and secondary forest (Moris, 2010; Reyes et al., 2014). *T. tetraptera* and *R. heudelotii* were abundant in the northern part of the forest. The northern part of the forest, classified as being mainly primary forest type has over the years witnessed an increase in illegal logging activities which led to the creation of gaps, an environment favourable to these species. *Irvingia gabonensis, C. edulis, C. lepidota, G. africanum, Eremospatha* species, *Laccosperma* species and *Trichoscypha* species were other cosmopolitan species found to be the most frequent at all the sites. They were present in more than 75% of transects. However, the very low volumes of *G. africanum* observed, demonstrate resource depletion since the species is a vine and needs trees for support and shade for effective growth. On the other hand, species unique to particular sites e.g. *G. kola, T. conophorum*, and *O. procerum* in Diffa, or *N. poissonii* and *B. toxisperma* in Bai Manya suggest that habitats have been altered such that their range is reduced. There is fragmentation which prevents gene flow, or overexploitation at different sites leading to local extinction (Morris, 2010). The three sites whose data were considered, Diffa is the most remote, and almost wholly dependent on the forest than the other sites in spite of sparse population. There has been serious degradation at Bai Manya, with extensive harvest of *G. africanum* and *R. heudelotii.* From Bai Manya westward, intensity of encroachment increases; Munyenge, the fourth site excluded from these analyses almost had no forest left as it has been replaced with cocoa plantations. This observation corroborates that of Zhu et al. (2015) who noted that, the southern portion of Yunnan tropical rainforest of south-western China was transformed into monoculture rubber plantation. The high abundance of some species at particular sites may suggest more restrained harvesting or thriving populations. This is difficult to compare given that no baseline or pristine conditions studies exist. Bai Manya and Diffa which are the least disturbed sites were the most similar, as a result of a large number of common species across sites. At Mbalangi, there has been active reforestation over the years, so the forest is actually artificial, and hence markedly different from the other sites. NTFPs that have survived across sites are resilient species that are also amendable to domestication, and hence similar to the planted forest in many ways. However, all sites had high species diversity (0.8 to 0.97). It has however been shown that functional diversity that takes into consideration linkages between species assemblages is more important in biodiversity conservation than simple taxonomic diversity (Moris, 2010; Aerts and Honnay, 2011). Hence, although highly diverse, the modified Mbalangi site is less representative of the SBFR than the other two sites, and this is shown by the similarity indices that actually take species composition into consideration. The least disturbed sites (Diffa and Bai Manya) are richer in species than Mbalangi. This is consistent with findings that tropical forests with minimal anthropogenic disturbances are centres of undescribed species richness (Giam et al., 2012; Gandhi and Sundarapandian, 2014).

According to the Intermediate Disturbance Hypothesis, moderate disturbances could be expected to have positive effects on species richness (Bongers et al., 2009). Harvests of NTFPs result directly in two types of disturbances, namely, shifts in mortality rate and shifts in reproductive rates; while direct deforestation for agriculture and building materials result in shifts in carrying capacity (Dornelas, 2010). All these forms of disturbances are present to varying degrees in the SBFR, with the result that at the more degraded sites like Mbalangi, NTFP species richness is highly affected negatively suggesting that the site is functionally isolated from the rest, and this isolation hinders any positive effects of disturbances (Bobo et al., 2006; Dornelas, 2010).

Conclusion

Species diversity and abundance was high in the forest sites of Bai Manya and Diffa as a result of moderate disturbances when compared with the site at Mbalangi which had greater disturbances. The results are significant for better management of the SBFR. The present rate of degradation is unsustainable whilst the forest is still under state protection; it will be more so under communal control. A more integrated approach that creates exploitation quotas for the different NTFPs could allow for natural regeneration to occur, under which more diverse species can result in improved functional relationships. More detailed studies are essential to better inform government conservation policy at this site, as a way forward.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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