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Assessment of tree species diversity and abundance as a diagnostic tool for regeneration of the Bali-Ngemba forest reserve, north west region, Cameroon

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Abstract

Human encroachment and activities in protected areas has continued to pose a serious threat to biodiversity around the world. This study assessed tree species diversity and abundance in the Bali-Ngemba Forest Reserve (BNFR) in the Bamenda Highlands of Cameroon, in a bid to obtain baseline data that can guide conservation initiatives. Data were collected through an inventory of tree species in disturbed and undisturbed portions of the reserve and indices including the Sørensen similarity coefficient (Cs), Shannon Wiener diversity index (H) and the Margalef species richness index (d) were calculated. Based on the study's findings, there were 13 tree species in the BNFR belonging to 10 families, with the most common uses being timber, fuelwood, food, medicine, and fodder. Of the species encountered, 61.5% were abundant (*Kigelia africana, Canarium indicum, Triplochiton scleroxylon, Cola nitida, Terminalia catappa, Eucalyptus grandis, Manilkara chicle, Eucalyptus globulus*), 15.4% were rare (*Rapanea melanophloeos, Pinus serotina*) while the frequent (*Pinus walliciana*), occasional (*Podocarpus latifolius*), and endangered (*Sizygium guineense*) biodiversity categories were each represented by 7.7% corresponding to a species. Malvaceae and Myrtaceae were the most abundant families with d = 0.389871 and 0.779742, respectively. The undisturbed site was more diverse than the disturbed. Comparing the levels of diversity using Sørensen's similarity coefficient, both sites were found to be only 21% similar. It was concluded that anthropogenic disturbances are responsible for the decline in the diversity and abundance of indigenous tree species in the BNFR, thus calling for better conservation measures that limit human encroachment.

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Introduction

Tropical forests occupy a little below 10% of the Earth's total land surface (Bradshaw *et al.,* 2009) while constituting 45% of the world's forests (FAO, 2020). They contribute to biodiversity conservation, drought and flood control, carbon sequestration, soil enrichment and maintenance, air and water quality improvement, as well as cultural and social benefits such as spirituality, traditional resource uses and recreation (Ambebe *et al*., 2021). As time goes on, this forest continues to witness untold levels of manipulation. The manipulation has been attributed to poverty and the increasing human population which needs to fell trees to create space for agricultural land and infrastructural development, gather fire wood and timber, produce charcoal, hunt as well as collect other non-timber forest products (D´avalos *et al.,* 2016). This practice may undermine species composition, diversity, abundance, conservation tree species (Ogwu *et al*., 2016). Despite being one of the most diverse ecosystems on earth, tropical forests are witnessing spiking rates of biodiversity loss (Alroy, 2017).

Cameroon's forests are administered in line with Law n ° 94/01 which lays out the forestry, wildlife and fishing regime of the country. The New Forestry Policy (NFP) was guided by the 1992 Rio principles of sustainable management and protection of global forests. According to the NFP, there exist two categories of forests in Cameroon i.e., Non-Permanent and Permanent Forests. The permanent forests are state owned and include National parks, Production forests, State zoological gardens, Protection forests, Game reserves, Forest plantations, Buffer zones, Recreation forests, State game ranches, Plant life sanctuaries, Integral ecological reserves, Hunting areas, Wildlife sanctuaries, Botanical gardens, and Teaching and research forests. Non-permanent forests are owned by individuals and communities such as Private tree plantations as well as Community forests.

In the wake Cameroon's NFP, the North West region of Cameroon has seen the creation of numerous reserves on which the adjacent populations depend for diverse livelihood purposes. These reserves include the Bali-Ngemba Forest Reserve, Kilum-Ijim Forest Reserve, Mbei and Mbiame Forest Reserve, Mendankwe Communal Forest Reserve, Mbessa Forest Reserve, Kimbi Game Reserve, and Bafut-Ngemba Forest Reserve (Samba *et al*., 2020). Of these, six are flora reserves among which is the Bali-Ngemba that is a plantation forest. Civilization and its accompanying population pressure through activities like agriculture and infrastructural development have gradually and steadily converted the region which was previously covered with montane forest to degraded patches. Like the other reserves in the North West Region, the Bali-Ngemba Forest Reserve (BNFR) is experiencing similar challenges. As a consequence of the increase in population and quest for basic commodities, different land uses are emerging in and around the reserve, which are likely to impact tree species diversity and abundance. This investigated the effect of disturbance on biodiversity traits of the BNFR. The findings of the study should provide indicators for sustainable management of the ecosystem.

Materials and methods

Description of the study area

This study was carried out in the Bali-Ngemba Forest Reserve (BNFR) located in Santa Subdivision, Mezam Division of the North West Region. The Subdivision that is found between longitudes 9°58 ´ and 10°18 ´ east of the Greenwich Meridian and latitudes 5°42 ´and 5°53 ´ north of the equator covers an area of 532.67 km² *(*Konje *et al.,* 2019). The BNFR is one of the over 07 reserves found in the North West Region of Cameroon and was Classified on 21st of July 1934 as a Native Authority reserve. Like most forest reserves in the North West Region, it is located on a high land at altitude ranging from 1350 to 2100m (Cheek *et al.,* 2018), with a surface area of 905 ha (Key Biodiversity Areas Partnership, 2022). It is a key biodiversity area that is located in the valley of the Alatening stream, south west of Bamenda, and also a catchment area for the water that is used by the population of Pinyin, Mantum, Baforchu and Baba II.

The climate of the BNFR is equatorial type (Kottek *et al.,* 2006). It is characterized by an abundance of rain which falls in a single annual season from mid-March to mid-November receiving 2,000-3,000mm of rainfall per year and a dry season from November to March with temperatures oscillating between 12°C and 23°C. The climates are both humid and cool (Cheek *et al.,* 2018; 2022).

Data collection

The study area was zoned into two fragments based on the degree of anthropogenic disturbance or degradation following the methods of Bentsi-Enchilla *et al.* (2022). Fragment 1: undegraded fragment, entailed areas with no or limited anthropogenic disturbance and good canopy cover, lianas and visible presence of wildlife. Fragment 2: highly degraded, are areas characterized by high levels of anthropogenic disturbance and little or no canopy cover, and presence of anthropogenic activities like farmland and cattle rearing. Same as with Bentsi-Enchilla *et al.* (2022), the undegraded fragments were found at a high elevation and were void of anthropogenic activities as against the degraded fragments that were found at lower elevations and close to communities such as the Dwenase Apinaman where anthropogenic activities like the collection of non-timber forest products and farming are pronounced.

Quantitative data was collected from the two fragments, hereafter referred to as disturbed and undisturbed. The disturbed fragment was highly degraded and had of human activities like farming, logging, and clearing, cattle rearing especially at the fringes of the reserve while the undisturbed were found at the interior or somewhat inaccessible part of the forest. In each of the fragments three 10 m × 10 m plots were carved out at regular intervals of 50 m along a transect line. Forest tree species within each plot were identified with the aid of a botanist and their frequency of occurrence noted. The uses of the trees were obtained from expert knowledge, corroborated by internet sources. The data collection was done in March 2023.

Data analysis

Margalef species richness index (d), Shannon Wiener diversity index (H), and Sørensen similarity coefficient (Cs) were computed from the data as per the models below, after which the effect of disturbance on d and H were tested with t-test at p = 0.05. Relative Density (RD) was also calculated in accordance with Mueller-Dombois and Ellenberge (1974). All the analyses were conducted in Microsoft Excel 2013.

i. Margalef species richness index (d)

$$d = \frac{S-1}{In\ N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where S = total number of species; N = total number of individuals in the site; In = natural logarithm (Margalef, 1958).

ii. Shannon-Wiener diversity index (H)

$$H = -\sum P_i\ In\ P_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where; Pi = proportion of individuals found in the species i; In = natural logarithm (Shannon and Wiener, 1949).

iii. Sørensen's similarity coefficient (Cs)

$$Cs = \frac{2a}{(2a+b+c)} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where a = number of species found in both sites; b = number of species found only in disturbed site; c = number of species found only in undisturbed site (Sørensen, 1948).

iv. Relative Density (RD)

$$RD = \frac{Ns}{Nt} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where N_s = number of individuals of genus / species i; N_T = total number of individuals of all genera / species.

The biodiversity status of each species was determined from its RD as follows (Ogwu *et al.*, 2016): abundant (RD ≥ 5.00), frequent (4.00 ≤ RD ≤ 4.99), occasional (3.00 ≤ RD ≤ 3.99), rare (1.00 ≤ RD ≤ 2.99) and threatened/endangered (0.00 < RD ≤ 1.00).

Results

Some thirteen (13) tree species belonging to diverse families and having different uses comprising timber, fuel wood, food, medicine and among others were recorded (Table 1).

Table 1. List and economic value of trees in the Bali-Ngemba Forest Reserve

Botanical name	Family	Common name	Uses
Podocarpus latifolius	Podocarpaceae	Broad-leaved Yellow wood	Furniture, construction, fuel wood, matches, carving, food
Pinus wallichiana	Pinaceae	Bhutan pine	Fuel, aesthetics
Kigelia africana	Bignonaceae	Sausage tree	Fuel, medicine, carving, plank, fence posts
Canarium indicum	Burseraceae	Canarium nut	Food, construction, fuel, agroforestry
Triplochiton scleroxylon	Malvaceae	African maple	Food, construction, furniture, medicine, food
Sizygium guineense	Myrtaceae	Water berry	Construction, furniture, fruit, fodder, nectar, shade
Rapanea melanophloeos	Myrsinaceae	Cape beech	Furniture, medicine
Manilkara chicle	Sapotaceae	Sapodilla	Fruit, latex, construction
Prunus serotina	Rosaceae	Black cherry	Fruit, timber, medicine
Cola nitida	Malvaceae	Cola nut	Stimulant, medicine, food, shade
Terminalia catappa	Combretaceae	Indian almond	Food, shade, aesthetics, wood, medicine
Eucalyptus grandis	Myrtaceae	Flooded gum	Medicine, windbreaks, oil, timber, utility poles, charcoal, pulp
Eucalyptus globulus	Myrtaceae	Blue gum	Fuel wood, charcoal, timber, utility poles, dye, oil, medicine

A total of 13 tree species were recorded in the BNFR. Even though the species are dominated by timber producing trees some still offer supplementary roles such as medicinal, food, vegetables, fruits, edible oils, dye, fodder, and stimulants. Others are used to beautify the environment like *Pinus wallichiana and Terminalia catappa*.

Table 2. Families of trees in the Bali-Ngemba Forest Reserve

Family	Number of tree species
Podocarpaceae	1
Pinaceae	1
Bignonaceae	1
Burseraceae	1
Malvaceae	2
Myrtaceae	3
Myrsinaceae	1
Sapotaceae	1
Rosaceae	1
Combretaceae	1

Table 3. Tree counts per species in the Bali-Ngemba Forest Reserve

Tree species	Undisturbed	Disturbed	Total
Podocarpus latifolius	10	-	10
Pinus wallichiana	13	-	13
Kigelia africana	19	-	19
Canarium indicum	37	3	40
Triplochiton scleroxylon	43	6	49
Sizygium guineense	3	-	3
Rapanea melanophloeos	6	-	6
Manilkara chicle	39	-	39
Prunus serotina	9	-	9
Cola nitida	34	-	34
Terminalia catappa	22	-	22
Eucalyptus grandis	-	51	51
Eucalyptus globulus	-	28	28
Total tree count	235	88	323

The tree species encountered belonged to 10 families with all families occurring in both treatment sites. Eighty percent (80%) of the families had just one tree species whereas, 20% of them had two (Malvaceae) and three (Myrtaceae) tree species (Table 2). Of the 10 encountered families, all 10 occurred in the undisturbed site while the disturbed site registered just 3 families (Tables 2 and 3).

The number of trees of each species varied greatly. The study registered a total of 323 individual trees, and 13 species belonging to 10 families. There was a greater representation of species in the undisturbed than disturbed site. The undisturbed part had 235 individual trees with 11 of the 13 tree species registered in the study area. *Triplochiton scleroxylon* was the most abundant tree species in the undisturbed site with a total of 49 individual trees while *Eucalyptus grandis* and *Eucalyptus globulus* were completely absent. On the other hand, the disturbed part had 88 individual tree species belonging to 4 species *(Canarium indicum, Triplochiton scleroxylon, Eucalyptus grandis* and *Eucalyptus* globulus). Of the four, *Eucalyptus grandis* was the most abundant species in the disturbed site with a total of 51 individual trees.

Of the 13 identified tree species, 61.5% were classified as abundant comprising of *Kigelia Africana, Canarium indicum, Triplochiton scleroxylon, Cola nitida, Terminalia catappa, Eucalyptus grandis,*

Manilkara chicle and *Eucalyptus globulus*. 15.5% as rare, 7.7% as frequent, 7.7% as occasional and *Sizygium guineense* contributing *a* 7.7% was classified as endangerd (Table 4).

Malvaceae and Myrtaceae families were the most abundant with a Margalef species richness index (d) of 0.389871 and 0.779742, respectively as against a zero value for the rest of the 8 families (Table 5).

Table 4. Relative Density (RD), Relative Abundance (P_i), Margalef specie richness index (d), Shannon Wienner diversity index (H), and biodiversity status of tree species in the Bali-Ngemba Forest Reserve

Tree species	RD	P_i	d	H	Status
Podocarpus latifolius	3.154574	0.031546	1.562798	0.109032	Occasional
Pinus wallichiana	4.100946	0.041009	2.083731	0.130982	Frequent
Kigelia africana	5.993691	0.059937	3.125596	0.16869	Abundant
Canarium indicum	12.6183	0.126183	6.772125	0.261202	Abundant
Triplochiton scleroxylon	13.56467	0.135647	7.293057	0.270982	Abundant
Sizygium guineense	0.946372	0.009464	0.347288	0.044104	Endangered
Rapanea melanophloeos	1.892744	0.018927	0.868221	0.075088	Rare
Manilkara chicle	12.30284	0.123028	6.59848	0.257786	Abundant
Prunus serotina	2.839117	0.028391	1.389154	0.10112	Rare
Cola nitida	10.72555	0.107256	5.730259	0.239452	Abundant
Terminalia catappa	6.940063	0.069401	3.646529	0.185151	Abundant
Eucalyptus grandis	16.08833	0.160883	8.682211	0.293946	Abundant
Eucalyptus globulus	8.832808	0.088328	4.688394	0.214345	Abundant

Table 5. Relative Density (RD), Relative Abundance (P_i), Margalef specie richness index (d), and Shannon Wienner diversity index (H) of families in the Bali-Ngemba Forest Reserve

Family	RD	Pi	d	H
Podocarpaceae	7.692308	0.076923	0	0.197304
Pinaceae	7.692308	0.076923	0	0.197304
Bignonaceae	7.692308	0.076923	0	0.197304
Burseraceae	7.692308	0.076923	0	0.197304
Malvaceae	15.38462	0.153846	0.389871	0.28797
Myrtaceae	23.07692	0.230769	0.779742	0.338385
Myrsinaceae	7.692308	0.076923	0	0.197304
Sapotaceae	7.692308	0.076923	0	0.197304
Rosaceae	7.692308	0.076923	0	0.197304
Combretaceae	7.692308	0.076923	0	0.197304

Table 6. Higher plant class of tree species in the Bali-Ngemba Forest Reserve

Tree species	Higher plant category
Podocarpus latifolius	Gymnosperm
Pinus wallichiana	Gymnosperm
Kigelia africana	Angiosperm
Canarium indicum	Angiosperm
Triplochiton scleroxylon	Angiosperm
Sizygium guineense	Angiosperm
Rapanea melanophloeos	Angiosperm
Manilkara chicle	Angiosperm
Prunus serotina	Angiosperm
Cola nitida	Angiosperm
Terminalia catappa	Angiosperm
Eucalyptus grandis	Angiosperm
Eucalyptus globulus	Angiosperm

Table 6 presents the different categories of tree species in the BNFR. The most abundant were Angiosperms with a total of 11 individual trees (84.6%) while Gymnosperms had 2 individual trees (15.4%). This trend was expected because the BNFR is made of mostly broad leaf trees.

Table 7. Margalef specie richness (d) and Shanon-Wiener diversity (H) indices for two sites in the Bali-Ngemba Forest Reserve.

Site	d	H	Cs
Undisturbed	39.66^a	2.19^a	21.00%
Disturbed	18.76^b	0.98^b	
p-value	0.0018	0.0002	

Values carrying different letters are significantly different from each other as per t-test.

Disturbance had a significant effect on the Margalef species richness and Shannon-Wiener diversity indices as values of were significantly higher in the undisturbed than disturbed sites. According to the Sørensen similarity coefficient the sites are extremely

different from one another in terms of specie richness and abundance (Table 7).

Discussion

The study assessed the abundance and diversity of tree species in the BNFR. Fringe population's living adjacent tropical forests like the BNFR have been known to depend highly on the forest. These forests and their trees in return provide these communities boundless economic, social, psychological and environmental benefits. The results of this study indicates that there are diverse trees in the BNFR that are of varied relevance to fringe communities like fuel wood, timber, shade, wind breaks, utility poles, dye, oil, fibre, fodder, nectar, latex, ornamentals and medicine. Thirty eight percent (38%) of tree species occurring in the BNFR were also documented by Ambebe *et al.* (2021) in the nearby Bafut-Ngemba Forest Reserve. They include *Pinus wallichiana, Terminalia catappa, Prunus serotina, Kigelia africana and Eucalyptus grandis. Of these species, Eucalyptus grandis* and *Pinus wallichiana* are both frequent, *Prunus serotina* is rare in both reserves, *Eucalyptus grandis* is abundant in both while *Terminalia catappa* is occasional in Bafut and abundant in Bali.

Despite the myriad of benefits that the fringe communities gain from the BNFR and governments conservation efforts, the ecosystem and its trees are being threatened as the undisturbed site was richer and more diverse in species and family than the disturbed. The low representation of some species and families in the disturbed site could be attributed to anthropogenic activities. This trend is in line with Wardle *et al.* (2004), Ambebe *et al.* (2021) in the Bafut-Ngemba Forest Reserve, Ogwu *et al.* (2016) in the Ugbowo Campus of the University of Benin, and Bentsi-Enchilla *et al.* (2022) in the Atewa Range Forest Reserve who all recorded a negative correlation between anthropogenic activities and tree species abundance as a result of a high dependence of adjacent populations on the forests for livelihood. As was also the case in the Atewa Range Forest Reserve (Bentsi-Enchilla *et al.*, 2022), there was a high representation of exotic species in the disturbed fragment of the BNFR. They are valued for their fast-growing habit and high economic returns.

According to the Sørensen similarity coefficient the two sites are only 21% similar. The result was anticipated as some only two of the eleven species found in the undisturbed fragment were encountered in the disturbed. Furthermore, *Eucalyptus grandis* and *Eucalyptus globulus* which were completely absent from the undisturbed site were the most abundant species in the disturbed fragment owing to their use by the National Forestry Development Agency to regenerate the reserve. Eucalypts have a high tolerance to biotic and abiotic stress, a capability to rejuvenate by coppicing and high productivity, giving them a good regeneration potential (CIRAD *et al.*, 2018).

In a dry forest in the Central Part of the Tumbesian Region (Ecuador-Peru), the Malvaceae family was recorded as the second most diverse family with six (6) species (Ortiz *et al.*, 2019). Same was the situation in the BNFR where it was the second most abundant family. Even though the Malvaceae family occurred in both forests, they did not have similar species. Also, in another dry forest in East Nusa Tenggara, Indonesia (Aah, 2017) the families Burseraceae, Malvaceae and Myrtaceae recorded the same trend as in the BNFR.

The Shanon-Weinner diversity index showed that the disturbed fragment of the BNFR is more diverse than the disturbed fragment implying the disturbed fragment had suffered manipulation and consequent damage from anthropogenic activities. In contrast, however, the species diversity index remained relatively unchanged in the Momiwaren Forest Reserve in Indonesia in the face of yet minimal damages (Hasibuan *et al.*, 2018).

Conclusion

Trees of the BNFR have provided several environmental, economic, social and psychological benefits to the adjacent populations for ages. This study examined the biodiversity of trees in the BNFR. Findings revealed that tree species and families are

diverse in the BNFR and provide essential services to the adjacent inhabitants whose expoitation has put the flora under threat from anthropogenic activities, leading to biodiversity decline. Thus, conservation measures that limit encroachment into the reserve are encouraged.

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