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**Original Research Article**

# Evidence for Regeneration of the Bafut-Ngemba Forest Reserve, Northwest Cameroon, from A Probe Into Biodiversity of Disturbed and Undisturbed Sites

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**Abstract:** To evaluate the impact of human-induced disturbances on the biodiversity of the Bafut-Ngemba Forest Reserve, data on tree species, the identity and number of plants per species were collected from an undisturbed and a disturbed forest fragment using transects. A total of 78 individual trees of 20 species belonging to 17 families were recorded. The undisturbed site had 72.22% of the tree species and 70.51% of individual trees. The most common tree species were *Eucalyptus grandis*, *Pinus wallichiana*, and *Persea americana* while Rosaceae and Fabaceae were the dominant families. *Eucalyptus grandis*, which was the most abundant tree species with a relative density of 12.82%, was found exclusively in the disturbed fragment. Fifty-five percent (55%) of the tree species were categorized as either rare ($1.00 \leq$ Relative Density $\leq 2.99$) or occasional ($3.00 \leq$ Relative Density $\leq 3.99$). Margalef species richness index was 9.04 for the undisturbed site and 5.74 for the disturbed. While Shannon-Wiener diversity index was 2.65 and 1.13 for the respective sites, Sørensen's similarity coefficient indicates that the two fragments were only 20.69 % similar. It is hoped that the findings will prompt forest managers and decision makers to put in place mitigating measures and safeguards against a decline in flora of the ecosystem under imminent challenges associated with an expected increase in human population.

**Keywords:** Biodiversity, Dominance, Forest disturbance, Species richness, Species diversity, Tree flora, Tropical forest.



## INTRODUCTION

Second only to Democratic Republic of Congo in Africa [1], 46% of Cameroon's total land area of 47.56 million hectares is covered by forests [2]. The tropical forests offer many ecosystem services that are essential to human well-being such as carbon sequestration, drought and flood control, air and water quality improvement, soil enrichment and maintenance, biodiversity conservation as well as social and cultural benefits like recreation, traditional resource uses and spirituality. As documented in a 2005 report of Cameroon's Ministry of Environment and Nature Protection [3], there exist 9000 floral, 297 mammal, 849 bird, 373 reptile and amphibian, and 451 fish species in the country. Law No. 94-01 of 20 January 1994 to lay down forestry, wildlife and fisheries regulations in Cameroon partitions the forest area into a non-permanent and a permanent estate which covers a land area of 10.22 million and 11.78 million hectares, respectively. While the former constitute communal and community forests, the permanent forests include wildlife protected areas and forest reserves which are typically state owned.

The Bamenda Highlands lies within the chain of volcanic mountains that make up the western Cameroon highlands. It contains the largest remaining patches of afromontane forest in Central Africa. Three kinds of vegetation are present: lowland forest, mountain forest, and subalpine community. As a biodiversity hotspot of global significance, the area supports high levels of biodiversity and endemism [4]. Notable among the endemic species are the Bannerman's Turaco (*Tauraco bannermani*) and Banded Wattle-eye (*Platysteira laticincta*) that are threatened globally and which have the remaining largest populations in the Bamenda Highlands [5]. Also remarkable are hydrologic attributes of the landscape. It is endowed with a bounty of catchments, rivers and streams that are relied upon for drinking water, domestic chores, watering and cooling of wildlife, and irrigation among other uses. The area is characterized by fertile soils and adequate rainfall which have

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permitted a strong growth and high density of a predominantly agriculture dependent population. The human presence has subjected the landscape to different levels of disturbance including harvesting of firewood, debarking of trees for medicine as well as logging for charcoal, utility poles, furniture, and infrastructural development. As a consequence, there is a record of a decline in the forested area from 20,000 hectares in 1978 to circa 9,500 hectares in 2012 [6]. Other human driven occurrences in the area are cattle and goat grazing, bushfires, hunting, and clearing of woodlands for cultivation [7]. The consequences of forest disturbances on tree species diversity, abundance, and composition can be far-reaching [8].

The Bamenda Highlands is host to the Bafut-Ngemba Forest Reserve. It prides itself amongst the Kagwene Wildlife Sanctuary, Bali-Ngemba Forest Reserve, Mt Oku Plant life Sanctuary, Mbi Crater, Mbembe Forest Reserve, Nkom-Wum Forest Reserve, and Kimbi-Fungom National Park that constitute the protected area profile of northwest Cameroon. Given that the reserve is the most accessible site for some endemic species of the Bamenda Highlands [9], it was created to preserve the rich biological diversity of the area. As a start point to protect trees of the Bafut-Ngemba Forest Reserve from declining in the face of the human activities that characterize the Bamenda Highlands, it is essential to examine the current status of species diversity and abundance. This study was designed to meet such an end. The information will also provide guidance on suitable mitigative measures to restore the integrity of the ecosystem.

## MATERIALS AND METHODS

**Study area**

Cameroon's Bafut-Ngemba Forest Reserve is situated some 35km from Bamenda, the capital of the North West Region, and 3km from the Sub-divisional headquarter of Santa. With a surface area of 4218 hectares, it is found at altitudes ranging from 1800 to 2500 m and within the montane vegetation region of the Bamenda Highlands [1]. The reserve was classified by the Bafut-Ngemba Native Authority Forest Reserve Order in 1953 and registered as the Eastern Region Public Notice No. 140 of 1953 as a production forest reserve. The climate of the area is the subtropical highland oceanic type with mean annual rainfall of 2193 mm and temperature of 19.3°C [10]. The climate is characterized by two seasons; a wet season from April to October and dry season that commences in November and ends in March. The least precipitation falls in January with an average of 13 mm while September is the wettest month with 400 mm. March and July are the hottest and coldest months of the year with average temperatures of 20.8°C and 17.7°C, respectively [10].

## DATA COLLECTION

The study was comprised of two treatments represented by two forest fragments. One of them was characterized by different human-induced disturbances including but not limited to logging, clearing, farming, cattle rearing while the other was to a very large extent undisturbed. Ten 100 $m^2$ plots were mapped out from each site at regular intervals of 50 m along a diagonal-line transect. To eliminate edge effects, no plot was less than 100m away from the boundary of the treatment site. The tree species within each plot were recorded alongside their frequency of occurrence. Identification of the trees was accomplished with the aid of tree identification guide books. Only wild forest plants, and not cultivated fruit trees, encountered in the sampling plots were considered in the investigation. The data were collected in March 2019.

## DATA ANALYSIS

Margalef species richness index (d), Shannon-Wiener diversity index (H), Sørensen similarity coefficient ($C_s$), Relative Density (RD) and Relative Abundance ($P_i$) were determined from the data in accordance with Margalef [11], Shannon and Wiener [12], and Sørensen [13]:

$$d = \frac{(S-1)}{\ln N}; \quad H = -\Sigma P_i \ln P_i; \quad C_s = \frac{2a}{(2a+b+c)} \times 100; \quad RD = \frac{N_s}{N_T} \times 100; \quad P_i = \frac{RD}{100}$$

Where S = total number of species; N = total number of individuals in the site; 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; $N_s$ = number of individual species; $N_T$ = total number of trees and ln = natural logarithm.

The various species were categorized according to their relative densities (RD) as follows: abundant (RD ≥ 5.00), frequent (4.00 ≤ RD ≤ 4.99), occasional (3.00 ≤ RD ≤ 3.99), rare (1.00 ≤ RD ≤ 2.99), and endangered (0.00 < RD ≤1.00).

## RESULTS

A total of 20 tree species belonging to 17 families were identified in the study area (Table 1). Unlike rosaceae and then fagaceae that dominated, there was a single species in all families. A large majority of the trees were timber producing. Other uses attributed to the trees were aesthetic, nutritional, industrial, medicinal, biofuel providing, and regulatory (Table 1).

**Table-1: Importance of tree flora**

| Botanical name | Common name | Family | Importance |
|---|---|---|---|
| *Pinus wallichiana* | Bhutan pine | Pinaceae | Timber, ornamental |
| *Terminalia catappa* | Indian almond | Combretaceae | Timber, ornamentals, fruits, essential oils, medicinal plant |
| *Aralia spinosa* | Prickly elder | Araliaceae | Medicinal plant, food, furniture |
| *Quercus suber* | Cork oak | Fagaceae | Ornamental, produce insulation panels, cork |
| *Prunus serotina* | Mountain black cherry | Rosaceae | Medicinal plants, dye production, wood, timber, ornamentals |
| *Albizia julibrissin* | Silk tree | Fabaceae | Medicinal use, ornamental, furniture, firewood |
| *Eribotrya japonica* | Loquat | Rosaceae | Medicinal plant, wood, fruit |
| *Rhus typhina* | Staghorn sumac | Anacardiaceae | Honey, firewood, medicine, ornamental |
| *Moringa oleifera* | Drum stick | Moringaceae | Medicinal use, improves water quality, vegetables, wood, dye, oil production |
| *Spathadae companulata* | African tulip tree | Bignoniaceae | Ornamentals, fruits, medicine, timber |
| *Persea americana* | Aligator pear | Laucaceae | Medicinal, vegetable, oil production |
| *Quercus robur* | Penduculate oak | Fagaceae | Timber, furniture, construction, charcoal |
| *Prunus persica* | Peach | Rosaceae | Timber, ornamental |
| *Cornus sericea* | Red osier dogwood | Cornaceae | Revegetation, medicine, dye production |
| *Hura crepitans* | Sand-box tree | Euphorbiaceae | Timber, ornamental, medicine |
| *Phytolacca americana* | Pigeon berry | Phytolaccaceae | Dye production, timber, wood |
| *Kiggeleria africana* | Wild peach | Achariaceae | Timber, fiber, ornamental |
| *Coccoloba pubescens* | Platter Leaf | Polygonaceae | Timber, ornamental |
| *Roystonea regia* | Royal palm | Arecaceae | Thatching, timber, fiber, ornamental |
| *Eucalyptus grandis* | Red-river gum | Myrtaceae | Biofuel extraction, ornamental, timber, bee production |

With 70.51% of individual tree count, the undisturbed site had 13 more tree species than the disturbed (Table 2). *While Quercus suber, Eribotrya japonica* and *Moringa oleifera* showed the highest representation at the former, *Eucalyptus grandis* trees were the most frequent in the disturbed plots. In contrast, the least populated species at the respective sites were *Prunus serotina* /*Coccoloba pubescens* and *Albizia julibrissin* (Table 2). The number of individuals of the remaining species was either similar or differed by a unit of 3 at the undisturbed and 2 at the disturbed site (Table 2). Summing up the number of trees per species for the two sites *Eucalyptus grandis* ranked first from the top while *Prunus serotina* and *Coccoloba pubescens* ranked last with a single tree each. The frequency of trees for the other tree species ranged from 2 in *Prunus persica*, *Hura crepitans*, and *Kiggeleria africana* to 8 in *Pinus wallichiana* which had only 2 trees lower than *Eucalyptus grandis* (Table 2).

**Table-2: Count of tree flora**

| Species | Undisturbed | Disturbed | Total |
|---|---|---|---|
| *Pinus wallichiana* | 3 | 5 | 8 |
| *Terminalia catappa* | 3 | - | 3 |
| *Aralia spinosa* | 4 | - | 4 |
| *Quercus suber* | 5 | - | 5 |
| *Prunus serotina* | 1 | - | 1 |
| *Albizia julibrissin* | 3 | 2 | 5 |
| *Eribotrya japonica* | 5 | - | 5 |
| *Rhus typhina* | 3 | - | 3 |
| *Moringa oleifera* | 5 | - | 5 |
| *Spathadae companulata* | 3 | - | 3 |
| *Persea americana* | 3 | 3 | 6 |
| *Quercus robur* | 3 | - | 3 |
| *Prunus persica* | 2 | - | 2 |
| *Cornus sericea* | 3 | - | 3 |
| *Hura crepitans* | 2 | - | 2 |
| *Phytolacca americana* | 4 | - | 4 |
| *Kiggeleria africana* | 2 | - | 2 |
| *Coccoloba pubescens* | 1 | - | 1 |
| *Roystonea regia* | - | 3 | 3 |
| *Eucalyptus grandis* | - | 10 | 10 |
| **Total** | **55** | **23** | **78** |

Relative density, abundance, Margalef and Shannon-Wiener indices were highest for *Eucalyptus grandis* and lowest for Prunus serotina and *Coccoloba pubescens*. Values of the indices were the second highest in *Pinus wallichiana* (Table 3). Immediately beneath the bounds of the aforementioned species,

*Prunus persica*, *Hura crepitans* and *Kiggeleria africana* had comparable but lower values of the attributes than *Albizia julibrissin*, *Eribotrya japonica*, *Moringa oleifera* and *Quercus ruber* that lagged behind *Persea americana* (Table 3). For the ranking of the other species, *Aralia spinosa* and *Phytolacca americana* were greater than *Terminalia catappa*, *Rhus typhina*, *Spathadae companulata*, *Quercus robur*, *Cornus sericea* and *Roystonea regia (Table 3).*

**Table-3: Relative density (RD), relative abundance ($P_i$), Margalef species richness index (d), Shannon-Wiener diversity index (H) and density status of tree flora**

| Tree species | RD | $P_i$ | d | H | Status |
|---|---|---|---|---|---|
| *Pinus wallichiana* | 10.25641 | 0.102564 | 1.606717 | 0.233566 | Abundant |
| *Terminalia catappa* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Aralia spinosa* | 5.128205 | 0.051282 | 0.688593 | 0.123666 | Abundant |
| *Quercus suber* | 6.410256 | 0.064103 | 0.918124 | 0.144057 | Abundant |
| *Prunus serotina* | 1.282051 | 0.012821 | 0 | 0.043995 | Rare |
| *Albizia julibrissin* | 6.410256 | 0.064103 | 0.918124 | 0.144057 | Abundant |
| *Eribotrya japonica* | 6.410256 | 0.064103 | 0.918124 | 0.144057 | Abundant |
| *Rhus typhina* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Moringa oleifera* | 6.410256 | 0.064103 | 0.918124 | 0.144057 | Abundant |
| *Spathadae companulata* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Persea americana* | 7.692308 | 0.076923 | 1.147655 | 0.162548 | Abundant |
| *Quercus robur* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Prunus persica* | 2.564103 | 0.025641 | 0.229531 | 0.074911 | Rare |
| *Cornus sericea* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Hura crepitans* | 2.564103 | 0.025641 | 0.229531 | 0.074911 | Rare |
| *Phytolacca americana* | 5.128205 | 0.051282 | 0.688593 | 0.123666 | Abundant |
| *Kiggeleria africana* | 2.564103 | 0.025641 | 0.229531 | 0.074911 | Rare |
| *Coccoloba pubescens* | 1.282051 | 0.012821 | 0 | 0.043995 | Rare |
| *Roystonea regia* | 3.846154 | 0.038462 | 0.459062 | 0.100891 | Occasional |
| *Eucalyptus grandis* | 12.82051 | 0.128205 | 2.06578 | 0.222722 | Abundant |

The undisturbed site had higher values of both the Margalef species richness and Shannon-Wiener diversity indices than the disturbed. Sørensen's coefficient for comparing similarities between the two sites yielded a value of less than 50% (Table 4).

**Table-4: Margalef species richness (d), Shannon-Wiener diversity (H) and Sørensen similarity ($C_s$) indices of undisturbed and disturbed forest fragments**

| Site | d | H | $C_s$ (50%) |
|---|---|---|---|
| Undisturbed | 9.04 | 2.65 | |
| Disturbed | 5.74 | 1.13 | 20.69% |

# DISCUSSION

The two forest fragments examined differed in diversity and richness with the undisturbed treatment displaying greater values of the attributes. In fact, only a quarter of the tree species in the study area were represented in disturbed plots as opposed to 90% in the undisturbed. Since the trial explored two fragments of an ecosystem with uniform edaphic and weather conditions, the plausible explanation for the observation is the difference in the extent of anthropogenic disturbances between the sites. Apart from reducing the floral cover, the high human activity in the disturbed plots resulted in the modification of micro-climatic conditions which accentuated the impact of plant removal and or replacement on biodiversity indices. The findings of this study are in line with the negative correlations between density, basal area, diversity and disturbance reported by Shackleton et al. [14]. Furthermore, Chittibabu and Parthasarathy [15] have documented lower values of richness, diversity, and density in disturbed than undisturbed plots in a tropical evergreen forest in the Eastern Ghats of India [15]. Unlike is the case with forest communities, however, a detailed comparison of diversity and dominance indices with other studies must be handled with caution because of practical differences in sample size, standard girth parameters, and environmental conditions [16].

Sørensen similarity coefficient showed the two forest fragments to be strikingly different from one another. *Eucalyptus grandis*, which dominated the disturbed treatment, was completely absent in the undisturbed stand. The observation was not surprising as the planting of eucalyptus for short-term economic gain is common practice in the Bamenda Highlands. The tree is a source of fuelwood, charcoal, and utility poles. Its wood is also used for general construction, joinery, furniture, and plywood. The high density in the disturbed site was further aided by ecological release from the removal of competing species. Moreover, eucalypts have major competitive advantages over other tree species in terms of productivity, tolerance to biotic and abiotic stresses, and ability to regenerate by coppicing [17]. According to Torti et al. [18], monodominance in tropical forests is likely to be better

explained by a combination of environmental conditions and life history attributes than any trait alone.

Although none was categorized as endangered, the finding that over half of the tree species were either rare or occasional is a hint that the protection of the flora from further decline is crucial. This, in combination with an augmentation of the population of some species, could potentially mitigate the adverse impact of human activity on the Bafut-Ngemba Forest Reserve. In accomplishing the latter, it is important to bear in mind that where tree regeneration is limited, there is a danger of exposing forests to a threat of clearing for agricultural expansion [19, 20].

## CONCLUSION

This study has explored the state of biodiversity of the Bafut-Ngemba Forest Reserve that is under pressure from human-induced disturbances. An adverse impact of the disturbances on biodiversity was observed. As the population of Cameroon increases from the 26.55 million in 2020 to 50 million in 2050 [21], potential increases in need for arable land and intensification of land use are likely to have negative feedback effects on forests. It is hoped that the findings pertaining to the Bafut-Ngemba Forest Reserve documented here will prompt forest managers and decision makers to put in place mitigating measures and safeguards against a decline in flora of the ecosystem under imminent challenges associated with the population increase.

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