The interactions of human mobility and farming systems and impacts on biodiversity and soil quality in the Western Highlands of Cameroon

Tankou, C.M.

Author: Tankou, Christopher Mubeteneh
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4 Variation of Biodiversity in Sacred Groves and Fallows in the Western Highlands of Cameroon

C.M. Tankou[1], G.R. de Snoo[2], G. Persoon[3] and H.H. de Iongh[2]*

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1 Faculty of Agronomy and Agricultural Sciences, University of Dschang, P.O. Box 222 Dschang, Cameroon.
2 Institute of Environmental Sciences, Leiden University, P.O. Box 9518, 2300 RA Leiden, The Netherlands
3 Department of Anthropology, Leiden University, P.O. Box 9518, 2300 RA Leiden, The Netherlands.
* Corresponding author. cmtankou@yahoo.com; tel: (237) 77 66 03 04; fax: (237) 33 45 15 66

Abstract

This study was conducted in order to estimate species richness and diversity in different ecosystems and understand the floristic changes resulting from variation in abiotic factors in sacred groves. Vegetative assessment in quadrats revealed that the sacred groves were rich in plant genetic diversity composed of a total of 42, 65 and 82 ethno-botanical species of herbs, shrubs and trees respectively, of varied ecological and economic importance. The herbaceous α-diversity was significantly higher in the fallows than the sacred groves at low altitudes. The tree species richness was higher at low altitudes compared to high altitudes with tree ß-diversity increasing with altitude. Varying combinations of soil pH, total P, total K, CEC and slope percent were related to herbaceous species richness, herbaceous Shannon index and shrub species richness. Intensive land-use has completely changed the structure of the native vegetation and caused severe plant diversity losses, though some useful forage species have been introduced in the area. Habitat changes in the sacred groves may be driven by biophysical while a combination of human and biophysical factors could be considered in the case of rotational fallow vegetation.

Key words

Biodiversity, Western Highlands of Cameroon, sacred groves, rotational fallows, abiotic factors.

4.1 Introduction

Loss of biodiversity in the tropics is principally due to the destruction of habitat by anthropogenic activities (Wilson, 2000) especially the clearing of natural vegetation and conversion into agricultural cropland, harvesting non-timber forest products, selective extraction of plants and animals, biological invasion, and monoculture (Swamy *et al.*, 2000; Mishra *et al.* 2004; Sundarapandian *et al.*, 2005). Biodiversity strongly influences the provision of ecosystem services and therefore human wellbeing (Ma, 2005). Cameroon has a complex mosaic of diverse habitats, with moist, tropical forest dominating in the south and covering 54% of the country (UNEP-WCMC, 2003), montane forest and alpine savannah in the highlands, and sub-Sahelian savannah in the far north (Letouzey, 1968, 1985; White, 1983). These diverse habitats harbour more than 9,000 species of plants, 160 of which are endemic (UNEP-WCMC, 2003). In the Western Highlands of Cameroon (WHC) there is however a preponderance of patches of land still preserved as sacred groves because of strong religious beliefs held by the indigenous people. These sacred groves, rich in medicinal, rare, and endemic plants, are refugia for the relic flora of the region

(Whittaker, 1975; Jeeva *et al.*, 2007). The WHC is considered one of the major agricultural zones of Cameroon. Intensive land-use due to demographic pressure has led to major changes in the agro-ecosystem in the WHC including the reduction in biodiversity. Most of the research on biodiversity has been concentrated in the humid rainforest agro-ecological zone of Cameroon (Comiskey *et al.*, 2003) and virtually little or no attention paid to the species richness and diversity in the WHC. This paper aims at highlighting the biodiversity situation of this hitherto neglected zone with emphasis on the potential of the sacred groves and their differences with fallowed lands.

The primary determinants of change in species composition and community structure in undisturbed ecosystems are abiotic factors that vary with altitude (Whittaker, 1975). The establishment and management of a modified and simplified plant community, influences the composition and activities of the associated herbivore, predator, symbiont and decomposer sub-communities (Swift & Anderson, 1993). Timber exploitation and shifting cultivation have accounted for the destruction of biodiversity in the humid south of Cameroon (Zapfack *et al.*, 2002), while demographic pressure and human mobility have provoked fragmentation of large natural areas into small pockets in the WHC. This has resulted in increased intensity of land use over time and space and the permanent destruction of natural habitats that have greatly influenced plant species richness and diversity in the area. Fallow vegetation dominated by herbs and grasses that succeed several years of intensive food and cash crop production dominates most of the fragmented land cover in this zone which was previously occupied by a significant population of trees and shrubs (FAO-UNDP, 1979).

Species richness which represents the number of species in a given area (Reitalu *et al.*, 2009) is considered to be a prominent factor of productivity and stability (Cristofoli *et al.*, 2010; Gonga *et al.*, 2008). Species richness is predominantly controlled by local factors, and only secondarily by factors operating at the landscape level (Marini *et al.*, 2007). Quantifying the species richness for a site, landscape, or region is a practical way of describing plant community diversity and is a useful and most widely used measure for making comparisons among sites (Gotelli & Colwell, 2001). Species richness determines resource availability, growth conditions or the degree of impact from disturbance and resilience (Peet *et al.*, 1998; Fridley *et al.*, 2005). Many studies have observed that abiotic environmental factors, such as topographic (altitude, slope angle and aspect) and soil parameters can be important determinants of plant diversity (Bennie *et al.*, 2006; Marini *et al.*, 2007; Cristofoli *et al.*, 2010; Marini *et al.*, 2007). To understand the dynamics of population extinction and (re)colonization in fragmented landscapes, it is necessary to consider the cumulative effects of abiotic and biotic factors on the performance of adult plant species (Soomers, 2012).

Two types of agricultural biodiversity are identified by the Convention on Biological Diversity, a managed portion that is manipulated by people for their own needs and an unmanaged portion such as soil microbes, natural enemies, pollinators and their food plants that support production (Biodiversity International, 2007). Conventional practices have tended to promote a small number of species, and scientific research has typically been focused on these species (FAO, 2002), resulting in a decline in genetic diversity for agricultural crops. Many villages in the WHC have sacred groves which have great traditional values and contain contrasting biodiversity compared to the intensively used fragmented agricultural lands (Pélissier, 1980).The groves are repositories of biodiversity and harbour many threatened floral and faunal species and are the places where the village deity resides.Their ecological significance includes: conservation of biodiversity, recharge of aquifers, and soil conservation. Rotational fallows are the predominant land cover in the WHC especially during the dry season when the soil moisture content does not favour the cultivation of the common annual crops of the area. The ecosystems considered in this study are thus the sacred groves and the rotational fallows.

Theoretical explorations of the relationship between biotic and abiotic diversity are abundant (Huston, 1994; Rosenzweig, 1995). To gain an insight into the processes that may affect species distribution and diversity in the WHC, we analyzed the species diversity components with respect to abiotic environmental factors (altitude, slope angle, slope aspect, soil physical and chemical properties) and the basic ecosystems of the area. The main objective of the present study was to investigate the extent of tree, shrub and herbaceous plant species richness in the sacred groves, as dictated by topographical features and abiotic factors and quantify the impact of human disturbance through the evaluation of the herbaceous species in the fallowed lands with a view to generating baseline data of use to conservation. One of our hypotheses is that variation in altitude and abiotic factors contribute significantly to the explanation of species distribution. Another hypothesis is that the intensive land-use for agricultural purposes has had a significant effect on species composition of the different ecosystems.

The aims of this study were thus to:

- Identify and analyse botanical species composition and richness in the sacred groves
- Identify and analyse botanical species composition and richness in fallowed land
- Quantify the influence of abiotic factors and altitude on species diversity indices.

4.2 Materials and Methods

4.2.1 Study Area

The research was conducted in an area situated between the geographical coordinates 5º 27’ - 5º 37.62’ N and 09º 57.502’ - 10º 09.544’ E occupied by two sub-divisions in the Menoua Division (Fongo-Tongo and Nkong-ni) found in the WHC (Figure 4.1).

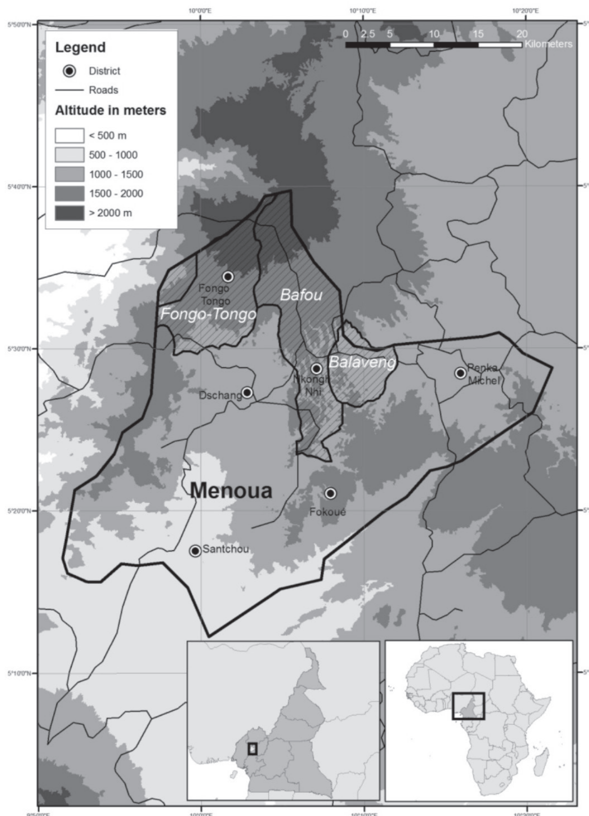

Figure 4.1
Geographical location of research site.

The characteristics of these two sub-divisions reflect the main features found in the WHC. The altitudinal range of the research sites are between 1400 m and 2500 m above sea level. The site has a tropical climate with a unimodal rainfall distribution. The growing season is between mid March and mid November and the dry season is between mid November and mid March. The annual rainfall is estimated to be between 1000 and 2000 mm (Kay *et* *al*., 1985), with a mean annual temperature estimated at 20°C and the average annual sunshine estimated at 2000 hours. The soil is characterized by granite and gneisses in the southern lower altitudes and basaltic plateau at northern higher altitudes (Fotsing, 1992). The natural vegetation is dominated by grass withshrubs and trees. Many households have planted Eucalyptus trees (most often for border demarcation) which are commonly used as timber and wood for fuel. Remnants of what used to exist in this area can be found in the traditional sacred groves which are strictly out of bounds, especially to foreigners. These groves are believed to be the home of the ancestors. It is thanks to the fact that these groves are sacred and thus revered, that the miscellany of the original plant species of the area has been preserved.

Cool season vegetable crop production is dominant at higher altitudes and agricultural activities are also very common in inland valley swamps and on steep slopes due to land scarcity. Cropping systems vary according to altitude, with intercropping predominant at lower altitudes while at higher altitudes, sole cropping is more practiced and the crops (predominantly cool season vegetables) grown are more for the market. Fallowing is less common in the highly populated Bafou village while it lasts for between 2 and 5 years in some parts of Fongo-Tongo and Baleveng villages. Fallows are generally dominated by bush vegetation which is often exploited by cattle herders.

4.2.2 Data Collection

Data were collected at different altitudinal levels across the undisturbed (sacred groves) and disturbed vegetation (fallows) of the study area (Tables 4.1 and 4.2).

Table 4.1
Location of fallowed land used for biodiversity data collection.

Location	Geographic coordinates	Elevation (m)
Bafou (Femok)	5º 36´ N / 10º 2´ E	2355
Bafou (Femok)	5º 37´N/10º 2´ E	2430
Bafou (Femok)	5º 37.62´N/10º 1.88´E	2310
Bafou (Femok)	5º 33´N/10º 4´ E	1959
Bafou (Loung)	5º 33´N/10º 4´ E	1810
Bafou (Loung)	5º 33´N/10º 5´ E	1777
Baleveng	5º 30´ N/10º 8´ E	1523
Bafou (Nstingbeu)	5º 27´N/10º 7´ E	1516

Table 4.2
Location of sacred groves used for biodiversity data collection

Location	Geographic coordinates	Elevation (m)	Terrain slope (%) aspect
Baleveng (Fohnon)	5° 30.348´ N 10° 09.544´ E	1450	16.21 N
Bafou (Batsingla)	5° 27.332´ N 10° 06.6178´ E	1516	25.78 NW
Fongo-tongo (Mamiwatta)	5° 32.594´ N 09° 59.678´ E	1543	49.17 SE
Fongo-tongo (Apouh)	5° 27.332´ N 10° 06.617´ E	1597	33.70 NW
Fongo-tongo (Ndento)	5° 30.225´ N 09° 57.502´ E	1664	60.77 N
Fongo-tongo (Mepong)	5° 34.852´ N 10° 00.167´ E	1699	76.80 N
Fongo-tongo	5° 34.003´ N 09° 59.986´ E	1804	44.11 NE
Fongo-tongo	5° 34.185´ N 10° 00.281´ E	1809	43.37 N
Fongo-tongo (Apouh)	5° 34.133´ N 10° 00.166´ E	1812	47.51 NE
Fongo-tongo	5° 34.091´ N 10° 00.099´ E	1827	70.72 N
Fongo-tongo (Femok)	5° 35.153´ N 10° 00.957´ E	1981	42.91 N

At each level, we randomly sampled all major vegetation communities on fallows, using 1 m × 1 m quadrat. Trees and shrubs were not sampled in the fallows because they were virtually absent. In the sacred groves, data was collected randomly from 11 locations, each of which comprised a 0.0625 ha (25 m × 25 m quadrat) for trees with a diameter at breast height (DBH) greater than 10 cm, 0.01 ha (10 m × 10 m quadrat for shrubs or regenerated plants with DBH less than 10 cm and with a height of less than 3m. and 0.001ha (1 m × 1 m quadrat) for under storey herbaceous plants or ground-layer species. The research site was divided into two major groups with respect to altitude. Low altitude comprised all sites below 1800 m above sea level, while high altitude comprised all the sites above 1800 m above sea level. A total of six and five sacred groves were analysed for wild trees and shrubs in the low and high altitudes respectively while there were 12 and 11 samples collected in the low and high altitudes respectively for understorey herbaceous plants in the sacred groves. There were 18 and 28 samples collected in the fallow vegetation in the low and high altitudes respectively. Within and between altitudes, replications were thus carried out for the 1 m × 1 m data collection in the different systems, while within altitudes replications were used for the trees and shrubs data collection in the sacred groves.

Biological and morphological types were identified in the field using wildflower, grass, and tree/shrub guides. Specimens of unidentified species were collected dried, and mounted in accordance with conventional herbarium practice for identification at the National Herbarium in Yaounde.

The altitude, percent slope and slope aspect of the plot were determined in the field.

Three replicate soil samples were taken per site at a depth of 0-30 cm in each of the sacred groves studied. The samples were homogenized by hand mixing and large live plant material (roots and shoots) and pebbles in each sample were separated by hand and discarded. The soil samples were air-dried and sieved for determination of soil factors through routine analyses in the Soil and Environmental laboratory in the University of Dschang, using methods described by Anderson and Ingram (1993).

The North-West and West Regions (Table 4.3) that make up this agro-ecological zone are the densest in the country as shown by the 2005 census results (Libite, 2010).

Table 4.3
Population data in 2005 and land area distribution in Cameroon.

Region	Population	Area (km^2)	Number of Divisions	Population density (inhabitants/km^2)
Adamawa	884289	63701	5	13.9
Centre	3098044	68953	10	44.9
East	771755	109002	4	7.1
Far North	3111793	34263	6	90.8
Littoral	2510363	20248	4	124
North	1687959	66090	4	25.5
North-West	1728953	17300	7	99.9
West	1720047	13892	8	123.8
South	634655	47191	4	13.4
South-West	1316079	25410	6	51.8

4.2.3 Analytical methods

Relative density and relative frequency were calculated according to Mori *et al.* (1983).

Relative frequency = 100 × (number of sample units containing a species/sample units for species of the sample)

Relative density = 100 × (number of individual of a species/number of individuals of a sample)

Species richness (S) was determined by the total number of species present in a sample. In order to evaluate the species diversity we used the Shannon-Weaver index, which represents α biodiversity showing local richness (Shannon & Weaver, 1949; Magurran, 1988; Frontier & Pichot-Viale, 1998; Vanpeene-Bruhier, 1998; Faurie, 2003; Gosselin & Laroussinie, 2004). The Shannon-Weiner index is:

$H = - \Sigma (p_i * \ln p_i)$, where p_i, is the proportion of species *i* in the sample and ln the natural log function. The Shannon evenness index (J) was used to measure the equality of the abundance of each species. It was calculated as: $J = H / \ln(S)$ ß-diversity used to assess the environmental variability of trees in the sacred groves was measured as described by Balvanera *et al.* (2002) on the basis of the Jaccard similarity index,

$$Cj = j/(a+ b- j)$$

with j = number of species shared by two sites, a = number of species in site 1, and b = number of species in site 2. ß -diversity was defined here as:

$ß\ C_j = 1- C_j = (a+ b-2 j)/(a+ b- j)$ = Number of species exclusive to *a and b*/ Total number of species in both sites.

Clearly, ß-diversity is highest when the similarity is lowest. A correction factor was used to assess the role played by changes in species richness relative to changes in the amount of shared species in Jaccard's ß-diversity values:

$$CF_c = C_{j[a = b]} / C_{j[a \neq b]} = (a+ b- j)/(2a-j)$$

$C_{j[a = b]}$ or the Jaccard index when both sites had the same richness, and $C_{j[a \neq b]}$ or the Jaccard index when both sites had a different richness. In the calculations, *a* was used for the richness of the site with the largest number of species so that $CFc \leq 1$. A maximum value of $CFc = 1$ was obtained when both sites had the same species richness, and thus 100% of *Cj* was given by the number of shared species. *CFc*was lower as the differences between *a* and *b* were higher, so that the proportion of *Cj* given by the number of shared species was lower and that given by changes in species richness was higher.

ß -diversity was also measured using Whittaker's index,

$ß_w = \gamma/(\alpha\text{-}1)$, where $\gamma = a + b - j$, for pair-wise comparisons only, and γ = overall richness, for multiple site comparisons. Also, $\alpha = (a + b)/2$ for pair-wise comparisons, and α= average richness of all sites, for multiple site comparisons.

Stepwise regression analysis was used to understand the effects of independent variables on dependent variables and the t-test was used to separate means between treatments.

4.3 Results

The total number of species, genera and families in the research area is summarized in Table 4.4.

Table 4.4
Species, genera and families recorded in the research area.

Treatment	Number of species	Number of families	Number of genera
Fallow herbs	76	24	56
Sacred grove herbs	42	26	38
Sacred grove shrubs	65	39	58
Sacred grove trees	82	38	63

The highest number of species and genera were found in the tree vegetation of the sacred grove and the highest number of families found in the shrub vegetation of the sacred grove. The fallow herbaceous species had the highest species/family and genera/family ratios of 3.17 and 2.33 respectively while the least with 1.62 and 1.46 respectively was found in the sacred grove herbaceous species. The species with the highest relative density (15.07) in the fallow ecosystem was *Sporobolus sp* and the species with the highest relative frequency (39.13) were *Ageratum conyzoides* and *Sporobolus sp*. The herbaceous species with the highest relative density (19.74) in the sacred grove was *Oplismenus hirtellus* and the one with the highest frequency (86.96) was *Phyllantus amarus*. The shrub species with the highest relative density (5.31) and relative frequency (54.55) in the sacred grove were *Dracaena diesteliana*, and *Bridelia* *micrantha*. The tree species with the highest relative density (5.06) and frequency (45.97) was *Bridelia micrantha*.

4.3.1 Shared Species

There were six herbaceous species common in the fallow ecosystem and the sacred groves (Table 4.5) belonging to five families.

Table 4.5
Species of herbs in both fallows and sacred grove.

Species	Relative density in fallows	Relative density in sacred grove	Relative frequency in fallows	Relative frequency in sacred grove	Family
Aspilia Africana	5.01	0.52	13.04	8.70	Asteraceae
Chromolaena odora	0.03	0.52	2.18	8.70	Asteraceae
Commelina benghalensis	4.02	3.12	21.74	17.39	Commelinaceae
Desmodium hirtum	1.35	0.52	13.04	8.70	Fabaceae
Pteridium aquilinum	1.23	1.04	17.39	8.70	Hypolepidaceae
Sanicula elata	0.66	2.08	6.57	8.70	Apiaceae

There were 32 common species present both as shrubs and trees in the sacred grove belonging to 26 families (Table 4.6).

Table 4.6
Common species of trees and shrubs in the sacred groves.

Species	Relative density / frequency of trees	Relative density / frequency of shrubs	Family	Uses
Albizia adianthifolia (Schum.) W.F. Smith	3.93 / 35.75	3.54 / 36.36	Fabaceae	Erosion control and carving
Allophylus africanus	0.51 / 5.11	0.88 / 9.09	Sapindaceae	Toothache and diarrhoea
Allophylus bullatus	1.69 / 15.32	1.77 / 18.18	Sapindaceae	–
Bersama engleriana	1.12 / 10.21	1.77 / 18.18	Melianthaceae	Diabetes
Bridelia micrantha (Hochst.) Baill	5.06 / 45.97	5.31 / 54.55	Phyllanthaceae	Cough

Caloncoba glauca (P. Beauv.) Gilg.	1.12 / 10.21	0.88 / 9.09	Flacourtiaceae	Inflamation andskin diseases
Canthium mannii	1.69 / 15.32	1.77 / 18.18	Rubiaceae	Worms
Carapa grandiflora Sprague	1.12 / 10.21	1.77 / 18.18	Meliaceae	–
Cassipourea sp.	1.12 / 10.21	0.88 / 9.09	Rhizophoraceae	Timber
Cola acuminate	2.25 / 20.43	0.88 / 9.09	Sterculiaceae	Fatigue, Libido
Crassocephalum mannii	1.69 / 15.32	0.88 / 9.09	Asteraceae	Malaria
Croton oligandrum Pierre. Mss.	1.69 / 15.32	0.88 / 9.09	Euphorbiaceae	–
Cyathea manniana HK.	1.12 / 10.21	0.88 / 9.09	Cyatheaceae	–
Dracaena arborea	0.56 / 5.11	0.88 / 9.09	Asparagaceae	–
Ficus natalensis	1.12 / 10.21	0.88 / 9.09	Moraceae	Stomach disorder
Flacourtia flavescens Wild	1.68 / 15.32	1.77 / 18.18	Flacourtiaceae	Syphilis
Gambeya albida Aubrev et Pellegr.	0.56 / 5.11	0.88 / 9.09	Sapotaceae	–
Macaranga occidentalis	2.25 / 20.43	0.88 / 9.09	Euphorbiaceae	–
Maesa lanceolata Forsk	2.81 / 25.54	1.77 / 18.18	Myrsinaceae	Tape worm
Nuxia congesta R. Br. Ex Presen.	2.25 / 20.43	2.65 / 27.27	Stilbaceae	–
Olea capensis Linn	0.51 / 5.11	0.88 / 9.09	Oleaceae	–
Persea americana Mill	2.81 / 25.54	0.88 / 9.09	Lauraceae	Hypertension and diabetes
Polyscias fulva	2.81 / 25.54	1.77 / 18.18	Araliaceae	Headache
Protea argyrophaea Hutch	2.25 / 20.43	3.54 / 36.36	Proteaeceae	–
Pseudospondias microcarpa (A. Rich.) Engl.	2.25 / 20.43	2.65 / 27.27	Anacardiaceae	Syphilis
Psorospemum kunthianum	0.56 / 5.11	0.88 / 9.09	Clusiaceae	–
Psychotria peduncularis	1.12 / 10.21	4.42 / 45.45	Rubiaceae	–
Rauwolfia vomitoria	2.25 / 20.43	2.65 / 27.27	Apocynaceae	Hypertension
Salacia mayumbensis N. Hallis	1.12 / 10.21	1.77 / 18.18	Celastraceae	–
Trema guineensis (Schum & Thonn.) Ficalho	1.69 / 15.32	1.77 / 18.18	Cannabaceae	Hypertension and diabetes
Tricalysia biagrana Heirn	2.25 / 20.43	5.31 / 54.54	Rubiaceae	–
Vitex doniana	0.56 / 5.11	0.88/ 9.09	Verbenaceae	Epilepsy

4.3.2 Unique Species

There were 35 herbaceous species belonging to 23 families found in the sacred groves and absent in the fallow vegetation (Table 4.7) while 70 herbaceous species belonging to 23 families found in the fallow vegetation were absent in the ground layer of the sacred groves (Table 4.8).

Table 4.7
Species of herbs in the ground-level sacred grove absent in the fallow vegetation.

Species	Family	Relative density	Relative frequency
Adenia cissampeloides	Passifloraceae	1.56	8.70
Aframomum aulacocarpus	Zingeberaceae	0.51	8.70
Aframomum danielli (Hook. f.) K. Schum.	Zingeberaceae	2.34	21.74
Arthropteris palisoti	Oleandraceae	1.82	21.74
Astystasia sp.	Acanthaceae	2.08	8.70
Asystasia gangetica	Acanthaceae	17.14	17.39
Begonia adpressia	Begoniaceae	7.79	4.35
Brillantaisia nitens Lindau	Acanthaceae	0.52	8.70
Clerodendron sp.	Lamiaceae	0.52	8.70
Crassocephalum biafrae	Asteraceae	0.26	4.35
Craterosiphon scandens	Thymelaeaceae	0.52	8.70
Cyathea manniana HK.	Cyatheaceae	0.52	8.70
Desmodium velutinum	Fabaceae	0.52	8.70
Dioda scandens SW	Rubiaceae	2.86	8.70
Eremomastax speciosa (Hochst.) cufod	Acanthaceae	1.56	8.70
Gouania longipetala Hemsl	Rhamnaceae	1.04	13.04
Justicia depauperata	Acanthaceae	2.86	26.09
Laggera pterodonta (D.C) Sch.	Asteraceae	0.26	4.35
Laportea ovalifolia	Urticaceae	3.38	13.04
Melinus minutiflora	Poaceae	5.19	8.70
Microglossa angolensis Oliv.	Asteraceae	0.52	8.70
Momordica foetida Schumach.	Curcubitaceae	1.04	13.04
Oplismenus hirtellus	Graminae	19.74	52.17
Palisota barteri	Commelinaceae	0.78	4.35
Paullinia pinnata	Sapindaceae	0.78	13.04

Phyllantus amarus	Euphorbiaceae	0.52	86.96
Piper capensis	Piperaceae	3.38	13.04
Rubus idaeus	Rosaceae	0.52	8.70
Setaria faberi Herrm	Poaceae	0.26	4.35
Smilax kraussiana	Smilacaceae	0.52	8.70
Spermacoce princeae k. Schum	Rubiaceae	7.79	8.70
Spermacoce saticola k. Schum.	Rubiaceae	0.26	4.35
Tectaria angelicifolia	Tectariaceae	0.52	8.70
Tragia benthami Bak	Euphorbiaceae	0.26	4.34
Urera gabonensis Pierre ms	Urticaceae	0.26	4.34

Table 4.8
Fallow species not found in the sacred groves.

Species	Family	Relative density	Relative frequency
Acanthus montanus	Acanthaceae	0.24	4.34
Acanthus sp.	Acanthaceae	0.06	2.17
Achyranthes aspera	Amaranthaceae	0.18	4.35
Achyranthes sp.	Amaranthaceae	0.45	2.18
Ageratum conyzoides	Asteraceae	8.58	39.13
Ageratum houtonium	Asteraceae	0.63	4.35
Ageratum sp.	Asteraceae	0.42	4.35
Amaranthus spinosus	Amaranthaceae	0.12	6.52
Aneilema commelina	Commelinaceae	0.51	4.31
Aneilema sp.	Commelinaceae	0.42	4.34
Bidens pilosa	Asteraceae	4.29	30.43
Bidens spinosa	Asteraceae	0.48	6.52
Caucalis platycarpos	Apiaceae	0.06	4.34
Colocassia esculenta	Araceae	1.17	2.17
Comelina sp.	Commelinaceae	0.12	2.17
Crepis sp.	Asteraceaae	0.21	6.52
Crotalaria irsuta	Fabaceae	0.09	2.17
Crotalaria sp.	Fabaceae	4.23	8.7
Cynodon dactylon	Poaceae	5.37	21.74
Cyperus distans	Cyperaceae	0.06	2.17
Cyperus sp.	Cyperaceae	1.38	10.87

Desmodium trifolia	Fabaceae	0.09	2.17
Dichrocephala integrifolia	Asteraceae	0.45	2.17
Diodia sanders	Rubiaceae	0.54	2.17
Dioscorea sp.	Dioscoreaceae	0.03	2.17
Echinops giganteus	Asteraceae	0.06	4.35
Emilia coccinea	Asteraceae	0.12	2.17
Erigeron floribundus	Asteraceae	3.09	26.09
Erigeron sp.	Asteraceae	0.54	6.52
Eriosema linifolium	Fabaceae	0.06	2.17
Euphorbia sp.	Euphorbiaceae	0.15	2.17
Galinsoga sp.	Asteraceae	0.06	2.17
Helichrysum rutidolepis	Asteraceae	3.00	13.04
Helichrysum cymosun	Asteraceae	0.27	6.52
Hydrocotyle manii	Araliaceae	0.06	2.17
Hypericum lanceolatum	Hypericaceae	0.30	6.52
Imperata cylindrical	Poaceae	3.48	13.04
Imperata sp.	Poaceae	0.81	6.52
Kosteletzkya sp.	Malvaceae	0.12	2.17
Ludwigia sp.	Onagraceae	1.11	4.35
Mariscus alternifolius Vahl.	Cyperaceae	0.03	2.17
Mimosa sp.	Fabaceae	0.69	4.35
Mitracorpus villosus	Rubiaceae	0.15	2.17
Musa sp. (AB)	Musaceae	0.03	2.17
Musa sp. (AA)	Musaceae	0.18	4.35
Oxalis corniculata	Oxalidaceae	2.91	4.35
Oxalis sp.	Oxalidaceae	3.45	26.09
Paspalum sp.	Poaceae	0.03	2.17
Pennisetum clandestinum	Poaceae	6.78	28.26
Pennisetum purpureum	Poaceae	1.68	15.22
Persea Americana	Lauraceae	0.12	6.52
Polystichum sp.	Dryopteridacea	1.32	10.87
Satureja robusta	Labiatae	0.06	4.35
Sida acuta	Malvaceae	1.80	17.39
Sida rhombifolia	Malvaceae	0.69	4.35

Sida sp.	Malvaceae	0.06	2.17
Siegesbeckia sp.	Asteraceae	1.26	0.04
Solanum scabrum	Solanaceae	1.26	4.35
Splilanthes filicaulis	Asteraceae	1.23	6.52
Sporobolus sp.	Poaceae	15.07	39.13
Stellaria sp.	Caryophyllaceae	2.82	8.70
Tithonia diversifolia	Asteraceae	0.09	2.17
Tradescantia sp.	Commelinaceae	0.87	4.35
Triplasis sp.	Poaceae	0.03	2.17
Urena lobata	Malvaceae	0.75	8.70
Vernonia amygdalina	Asteraceae	0.15	6.52
Vernonia calvoana	Asteraceae	1.32	13.04
Waltheria indica	Malvaceae	0.15	2.17
Xanthosoma sagitifolium	Araceae	0.45	2.17
Xanthosoma sp.	Araceae	0.03	2.17

In addition, there were 32 unique shrub species belonging to 19 families (Table 4.9) and 49 unique tree species belonging to 28 families in the sacred groves (Table 4.10). The species found in the sacred groves possessed varied potentials including land conservation, timber and especially medicinal properties (Tables 4.6, 4.9 and 4.10).

Table 4.9
Shrub species not found as trees in scared groves

Species	Family	Relative density	Relative frequency	Uses
Acalypha manniana	Euphorbiaceae	0.88	9.09	Skin diseases
Acioa johurtonei Hoyle	Chrysobalanaceae	0.88	9.09	–
Albizia sp.	Fabaceae	0.88	9.09	–
Alchornea laxiflora	Euphorbiaceae	0.88	9.09	–
Antidesma sp.	Phyllanthaceae	1.77	18.18	–
Brucea antidysenterica	Simaraounbaceae	1.77	18.18	Dysentery
Cassine aethiopica	Celastraceae	0.88	9.09	
Chrysobalanus icaco	Chrysobalanaceae	0.88	9.09	–
Clausena anisata	Rutaceae	0.88	9.09	Cough, cold

Clutia kamerunica	Euphorbiaceae	0.88	9.09	–
Dalbergia oligophylla Hutch & Dalziel	Fabaceae	1.77	18.18	–
Diphasia angolensis	Rutaceae	0.88	9.09	–
Dracaena diesteliana	Agavaceae	5.31	54.55	–
Elaeis sp.	Arecaceae	0.88	9.09	–
Ficus mucoso	Moraceae	0.88	9.09	Insomnia
Gnidia glauca	Thymelaeaceae	0.88	9.09	–
Leea guineensis	Leeaceae	1.77	18.18	Toothache
Neoboutonia glabrescens	Euphorbiaceae	0.88	9.09	Worms
Peddiea fischeri	Thymelaeaceae	0.88	9.09	–
Piper capensis	Piperaceae	1.77	18.18	
Pittosporum mannii Hook. f.	Pittosporaceae	1.77	18.18	Intestinal diseases
Psorospermum cf. aurantiacum Engl.	Clusiaceae	1.77	18.18	–
Psorospermum senegalensis Spach.	Clusiaceae	0.88	9.09	–
Psychotria camtopus	Rubiaceae	0.88	9.09	–
Psychotria cf djumaensis	Rubiaceae	0.88	9.09	–
Raphia sp.	Arecaceae	1.77	18.18	–
Stombosiopsis tetrandra	Olacaceae	0.88	9.09	–
Tarenna baconioides	Rubiaceae	0.88	9.09	–
Tephrosia vogelii Hook. f.	Fabaceae	0.88	9.09	Diarrhea
Tilia sp.	Malvaceae	0.88	9.09	–
Vernonia amygdalina	Asteraceae	0.88	9.09	Malaria
Xymalos monospora	Monimiaceae	0.88	9.09	–

Table 4.10
Tree species not found as shrubs in scared groves

Species	Family	Relative density	Relative frequency	Uses
Acioa sp.	Chrysobalanaceae	0.56	5.11	–
Agauria salicifolia	Ericaceae	0.56	5.11	–
Alangium chinense	Alangiaceae	2.81	25.54	Skin diseases
Albizia gummifera	Fabaceae	0.56	5.11	Malaria
Albizia zygia	Fabaceae	0.56	5.11	Depression
Allophylus hamatus	Sapindaceae	1.12	10.21	–
Bersama abysinica	Melianthaceae	1.12	10.21	
Bridelia sp.	Phyllanthaceae	0.56	5.11	–
Campylostemon sp.	Celastraceae	0.56	5.11	–
Canarium schweinfurthii	Sapotaceae	0.56	5.11	Gonorrhoea
Canthium subcordatum	Rubiaceae	1.69	15.32	–
Cassine sp.	Celastraceae	1.12	10.21	–
Cordia auranthiata	Boraginaceae	1.12	10.21	
Cordia platythirsa Bak.	Boraginaceae	0.56	5.11	
Croton macrostachys	Euphorbiaceae	0.56	5.11	
Cussonia sp.	Araliaceae	0.56	5.11	–
Entandrophragma angolense	Meliaceae	0.56	5.11	Malaria
Fagara tessmannii	Rutaceae	0.56	5.11	–
Fagara zanthozyloides	Rutaceae	0.56	5.11	–
Ficus exasperate	Moraceae	1.12	10.21	Scabies
Ficus mucuso	Moraceae	1.69	15.32	Insomnia
Ficus sp.	Moraceae	0.56	5.11	–
Ficus thonningii	Moraceae	0.56	5.11	Wounds
Ficus tricopoda	Moraceae	2.25	20.43	–
Flacourtia sp.	Flacourtiaceae	0.56	5.11	–
Garcinia smeathmannii	Clusiaceae	0.56	5.11	
Holarrhena floribunda	Apocynaceae	0.56	5.11	Jaundice
Kigelia Africana	Bignomiaceae	1.12	10.21	Hemorrhage
Landolphia sp.	Apocynaceae	0.56	5.11	–
Magnistipula conrauana	Chrysobalanaceae	0.56	5.11	–

Mangifera indica	Anacardaceae	0.56	5.11	High blood pressure
Markhamia tomentosa	Bignoniaceae	1.12	10.21	Oedema
Octolepis casearia	Thymeleaceae	0.56	5.11	–
Olea hochstetteri	Oleaceae	0.56	5.11	Diabetes
Phoenix reclinata Jacq	Arecaceae	1.69	15.32	–
Pittosporum mannii Hook. f.	Pittosporaceae	2.25	20.43	Intestinal diseases
Prunus Africana	Rosaceae	0.56	5.11	Fungal and bacterial infections, madness
Psidium guajava	Myrtaceae	0.56	5.11	Diarrhea
Rothmannia urcelliformis	Rubiaceae	1.23	10.21	–
Salacia staudtiana	Celastraceae	0.56	5.11	–
Sapium ellipticum (Hochst.) Pax	Euphorbiaceae	2.25	20.43	Purgative and eczema
Schefflera barteri (Seem.) Harms	Araliaceae	0.56	5.11	–
Syzygium aromaticum	Myrtaceae	0.56	5.11	Mouth and teeth pain
Tricalysia atherura	Rubiaceae	0.56	5.11	Jaundice
Trichilia sp.	Meliaceae	1.69	15.32	–
Turraea vogelii	Meliaceae	0.56	5.11	Cough
Vepris louisii	Rutaceae	0.56	5.11	Malaria
Vernonia sp.	Asteraceae	0.56	5.11	–
Zanha golungensis	Sapindaceae	0.56	5.11	Wounds

4.3.3 Species richness and diversity in different systems

The herbaceous species richness and diversity recorded in the fallow vegetation and the sacred groves were compared. A significantly ($p < 0.05$) higher value of species richness was observed in the fallow system at the low altitude while there was no significant difference in the Shannon indices. At the high altitude, no significant differences were observed for the biodiversity indicators. The Shannon evenness indices for both the low and high altitudes were not significantly different (Table 4.11).

Table 4.11
Species richness and diversity of herbs in different ecosystems.

Variable	Means in the low altitude		Df	t-value[a]
	Fallow land n = 18	Sacred grove n = 12		
Species richness	6.00	3.75	28	2.66*
Shannon index	1.26	0.99	28	1.40 ns
Shannon evenness	0.74	0.65	28	0.84 ns
	Means in the high altitude			
	N = 28	N =11		
Species richness	5.96	5.36	37	0.99 ns
Shannon index	1.32	1.17	37	1.36 ns
Shannon evenness	0.76	0.71	37	1.03 ns

[a] * indicates significant at 5% probability level, ns indicates non significant ($p > 0.05$).

4.3.4 Variation within ecosystems

The effect of altitude on the different ecosystems was noticed only with tree vegetation of the sacred groves where both species richness and Shannon index were significantly higher at the lower than at the higher altitudes while all the variables were not significantly different for the shrub and herbaceous species (Table 4.12)

Table 4.12
Species richness and diversity within systems

Variable	Means				df	t-value[a]
	Low altitude	N	High altitude	n		
Species richness of trees in sacred grove	19.67	6	12	5	9	4.44**
Shannon index of trees in sacred grove	2.61	6	1.98	5	9	2.64*
Shannon evenness of trees in sacred grove	0.88	6	0.80	5	9	1.28ns
Species richness of shrubs	11.00	6	9.40	5	9	0.71 ns
Shannon index of shrubs in sacred grove	1.64	6	1.64	5	9	0.02 ns
Species richness of herbs in sacred grove	3.75	12	5.36	11	21	1.92 ns

Shannon index of herbs in sacred grove	0.99	12	1.17	11	21	0.78 ns
Shannon evenness of herbs in sacred grove	0.65	12	0.71	11	21	0.45ns
Species richness of herbs in fallows	6.00	18	5.96	28	42	0.06 ns
Shannon index of herbs in fallows	1.26	18	1.32	28	42	0.55 ns
Shannon evenness of herbs in fallow	0.75	18	0.76	28	42	0.34ns

[a] ** and * indicates significant at 1% and 5% probability levels respectively, ns indicates non significant ($p > 0.05$).

4.3.5 Variation of soil chemical and physical properties with altitude

Significantly higher values of organic matter and CEC were recorded at the higher altitude while significantly higher values of total K were found at the lower altitude (Table 4.13).

Table 4.13
Soil chemical and physical properties

Variable	Means		Df	t-value [a]
	Lowlands (n = 12)	Highlands (n = 11)		
pH	4.72	4.61	19	1.90 ns
Organic matter (%)	11.75	14.60	19	3.54**
CEC (cmol+/kg)	24.13	30.68	19	4.28**
Total N (%)	2.57	3.20	19	1.66 ns
Total P (ppm)	4.87	5.58	19	1.37 ns
Total K (‰)	0.08	0.06	19	3.35**
Sand (%)	17.40	10.36	19	1.34 ns
Silt (%)	68.00	77.82	19	1.24 ns
Clay (%)	15.00	12.00	19	0.65 ns

[a] ** indicates significant at 1% probability levels, ns indicates non significant ($p > 0.05$).

4.3.6 Influence of environmental factors on biodiversity indices.

The combination of abiotic factors was tested for all life forms. Statistically significant models were only detected for shrubs and herbaceous sacred grove species. Decreasing soil pH and total P increased the Shannon index of herbs in the sacred groves while increasing CEC and slope increased species richness of herbs in the sacred groves and decreasing total P, decreasing pH and increasing K increased species richness of shrubs in the sacred groves (Table 4.14).

Table 4.14
Significant stepwise regression results between biodiversity indices and environmental factors

Dependent variable	Model	Coefficients	F	R square
Shannon index of herbs in sacred grove	Constant pH Total P	15.28 -2.82 -1.90	10.15**	0.53*
Species richness of herbs in sacred grove	Constant CEC Slope	-3.64 0.21 0.06	14.55**	0.62*
Species richness of shrubs in sacred grove	Constant Total P pH Total K	129.77 -3.26 -23.35 938.14	13.24**	0.87*

** and * indicates significant at 1% and 5% probability levels respectively.

The slope aspect had no significant effect ($p > 0.05$) on all the variables examined.

4.3.7 Assessment of altitudinal variability of trees

In order to gain more insight into the altitudinal variation shown in table 4.5, ß-diversity was examined for the trees in the sacred grove. Average $ßC_j$ and $ß_w$ were 0.94 and 2.02 respectively. $ßC_j$ and $ß_w$ showed similar patterns and were correlated ($r = 0.94$, $p < 0.001$). Generally the largest ß-diversity values ($ßC_j$ and $ß_w$) indicated comparisons between the poorest sacred grove and the richest one which were related to lowest values of *CFCj*. The poorest sacred grove was that found at altitude 1809 m asl with 10 species recorded while the richest was found at altitude 1664 with 25 species recorded $ßC_j = 0.97$, $ß_w = 0.69$ and *CFCj* = 2.06). Generally from the table it was observed that the values of ß-diversity increased gradually with increasing altitude (Table 4.15).

Table 4.15
ß-diversity measures among all pairs of 0.0625-ha quadrats of trees in the sacred groves using Jaccard similarity index (ßCj, in bold), Jaccard's correction factor (CFCj) (separated by /) and Whittaker's ß -diversity index (ßw, in parentheses)

Altitude (m)	1450	1516	1543	1597	1664	1699	1804	1809	1812	1827	1981
1450		**.82**/.90 (1.81)	**.88**/.97 (1.89)	**.81**/.94 (1.78)	**.74**/.83 (1.66)	**.89**/.92 (1.89)	**.89**/.82 (1.93)	**.92**/.77 (2)	**.97**/.86 (2.07)	**.83**/.75 (1.85)	**.94**/.91 (2)
1516			**.94**/.89 (2)	**.94**/.87 (2)	**.82**/.77 (1.79)	**1**/.86 (2.12)	**.96**/.9 (2.08)	**1**/.83 (2.17)	**1**/.93 (2.15)	**.91**/.82 (2)	**1**/1 (2.14)
1543				**.89**/.97 (1.89)	**.87**/.87 (1.86)	**.95**/.95 (2)	**.97**/.81 (2.07)	**1**/.76 (2.15)	**1**/.84 (2.13)	**1**/.76 (2.15)	**1**/.89 (2.13)
1597					**.90**/.89 (1.91)	**.98**/.98 (2.05)	**.97**/.79 (2.07)	**.97**/.74 (2.07)	**1**/.83 (2.13)	**1**/.75 (2.14)	**1**/.88 (2.12)
1664						**.93**/.91 (1.95)	**.91**/.72 (1.94)	**.97**/.69 (2.06)	**1**/.76 (2.11)	**.94**/.69 (2)	**.97**/.8 (2.05)
1699							**1**/.79 (2.13)	**1**/.74 (2.14)	**.97**/.8 (2.06)	**1**/.74 (2.14)	**1**/.86 (2.12)
1804								**.84**/.91 (1.9)	**.86**/.96 (1.91)	**.9**/.91 (2)	**.96**/.90 (2.08)
1809									**.85**/.87 (1.9)	**.95**/1 (2.11)	**1**/.83 (2.17)
1812										.**9**/.88 (2)	**.96**/.93 (2.08)
1827											**.96**/.83 (2.09)
No species	18	15	19	20	25	21	12	10	13	10	15

4.4 Discussion

The results of this research show that the WHC harbours significant numbers of species of different life forms. Fewer families nearly all of which were herbaceous species were found in the disturbed fallow ecosystem compared to the un-disturbed sacred grove ecosystem with trees and shrubs. The results also show that the WHC harbours a significant number of species with diverse importance in the sacred groves that include pharmaceutical substances, timber, firewood and raw materials for artistic works. This ties in with the findings that tropical vegetation are important as timber sources (Finegan, 1992), providers of environmental services such as protection from erosion and atmospheric carbon fixation, templates for forest rehabilitation (Lugo, 1992), refugia of biodiversity in fragmented landscapes (Lamb *et al*., 1997), and as local providers of medicinal and useful plants (Lamb *et al*., 1997).

4.4.1 Effect of altitude on biodiversity

At the lower altitudes, herbaceous species diversity was significantly higher in the fallow ecosystem than in the sacred grove indicating that the species pool in the sacred grove was limited by some natural factors. Differences in herbaceous species-type between the fallows and the sacred grove could be linked to the shading effect in the sacred grove which was not favourable to heliophilic species such as those of the Poaceae family. This explained the near nonexistence of C_4 herbaceous species in the sacred grove. The high altitude areas are very suitable for cool season crops which are the principal sources of revenue for rural farmers in the zone. Due to intense rural-rural mobility, the natural vegetation had, to a large extent been replaced by agriculture. The intensive land-use in the WHC has consequences for soil erosion and soil quality. In natural ecosystems, the vegetative cover of a forest or grassland has been shown to prevent soil erosion, replenish ground water and control flooding by enhancing infiltration and reducing water runoff (Perry, 1994). These processes depend upon the maintenance of biological diversity (Altieri, 1994). When the ecosystem services of biodiversity are lost due to biological degradation, the economic and environmental costs can be quite significant. Often the costs involve a reduction in the quality of life due to decreased soil, water, and food quality orchestrated by the negative effects of chemical inputs. The net result is an agro-ecosystem which is a man-made ecosystem that requires constant human intervention, whereas in natural ecosystems the internal regulation is a product of plant biodiversity through flows of energy and nutrients, and this form of control is progressively lost under agricultural intensification (Swift & Anderson, 1993). Despite the fact that intensive land-use had eroded some natural species, other important species have been introduced such as *Pennisetum clandestinum* which is an important pasture species for dairy cattle and is also widely used when laying a lawn. However it should be noted that the sacred grooves harbour a high biodiversity of trees, shrubs and herbaceous plants compared to the fallowed lands of the study area where trees and shrubs have been greatly eliminated.

Amongst all the life forms studied, significant differences in biodiversity with altitude were recorded only for tree vegetation. The trend of tree biodiversity variation was made clearer with the ß-diversity analyses. Givnish (1999) observed that describing and exploring the determinants of ß-diversity was particularly critical for tropical vegetation. The number of tree species decreased with altitude. Similar findings were shown by Ohlemüller and Wilson (2000). Variation of species richness with altitude had been greatly attributed to lower temperature at higher altitudes that were not favourable to many species. Rawat (2011) found that the number of species reduced at a rate of 3–4% per 100 m elevation in the high altitudes of Garhwal Himalaya due to increasing stress (lowering of temperature and pressure, thinning of air, etc.) amongst other factors. However, Khem & Ole (2003) stated that climate-elevational gradient of plant species richness was group-specific and varied according to life forms.

4.4.2 Variation and influence of abiotic factors

The soil organic matter content showed significant increase with altitude. The organic matter content could be linked to the varying rate of decomposition imposed by temperature where decreasing temperature with altitude decreased the decomposition rate and hence resulted in more accumulation at higher altitudes. Similar results were shown by Trumbore *et al*. (1996) who observed that light-fraction organic carbon increased exponentially with increasing temperature. CEC is the maximum quantity of total cations of any class, that a soil is capable of holding at a given pH value, for exchange with the soil solution. It was thus used as a measure of fertility. Higher altitudes were thus more fertile than the lower altitudes due to their high organic matter content. The potassium content was lower at the high altitudes than at the low altitudes. The higher the amount of exchangeable base cations, the more acidity could be neutralized. This explained why there was a decrease in soil acidity conditions at lower altitudes compared to higher altitudes. Though individual abiotic factors did not show any significant relationships with biodiversity indices measured, Hooper *et al*., 2005 revealed that ecosystem properties were apparently more influenced by abiotic conditions than by species richness. Spatial heterogeneity in the physical environment (e.g. substrate, nutrients, soil moisture and structure) has been positively and linearly correlated with diversity at a number of spatial scales (Harman, 1972; Schlosser, 1982; Tonn & Magnuson, 1982; Crozier & Boerner, 1984; Chambers & Prepas, 1990; Kaczor & Hartnett, 1990; Pringle, 1990; Scarsbrook & Townsend, 1993).

Combined abiotic factors explained the herbaceous and shrub biodiversity of the WHC. Soil pH and phosphorus decreased the Shannon index of herbaceous sacred grove species while CEC and slope increased the herbaceous species richness. Decreasing pH and phosphorus with increasing potassium increased shrub species richness. This is vital information as large-scale national biodiversity hotspots identified for plant species using abiotic methods, can become the nuclei for further detailed conservation planning (Venevsky & Venevskaia, 2005). John *et al*. (2007) analysed the variation in soil nutrients in three neo-tropical forest plots and concluded that the distribution of 40% of the species showed affinities with soil nutrients.

The sacred grove is a great treasure to the inhabitants of the WHC. They are the living granary of medicinal plants in the region. Forty-two species of medicinal plants were identified in the study area and similar results have been reported by Zapfack *et al*. (2002) in the forest zone of Cameroon.

4.5 Conclusion

The present study of plant communities with respect to ecosystems and abiotic factors at the local scale leads to valuable insights in resource partitioning and niche differentiation of the area studied. Land use is among the most important determinants of biodiversity as shown by the data collected in the WHC. Elevation influences the air temperature, its daily fluctuations, and the humidity levels, and all of these in turn influence the growth and development of plants. Altitudinal gradient influenced the partitioning of the tree species in the study area. Analysis of the abiotic factors showed that both fertility and soil pH increased with altitude and accounted for the richness of herbaceous species richness. Habitat changes in the sacred groves may be driven by biophysical factorss while in the rotational fallow vegetation it could be linked to a combination of human and biophysical factors.

Increase in human population numbers, causing loss of natural habitat and promoting the invasion of less desirable species such *Sporobolus sp* which are known to decrease pasture productivity, and decreasing the population of highly valued medicinal plants such as *Prunus africana* could be considered as the greatest single threat to species diversity in the region. Mobility within the rural communities in search of additional farming space, higher value arable land, and land for construction of houses in addition to the destruction of habitat through the creation of new roads, significantly aggravates plant diversity losses.

While intensive land use has deprived the area of much of the profit that can be derived from shrub and tree biodiversity depicted by the potential of the sacred groves, some valuable forage species have colonized most of the uncultivated portions. Given the importance of the conservation of biodiversity and the ecosystem, attempts should be made to maintain the sanctity of the sacred groves where there exist a high biodiversity of trees, shrubs and herbaceous plants that can hardly be found in the fallow vegetation and cultivated lands of the study area.

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References

Altieri, M.A. (1994) Biodiversity and Pest Management in Agro ecosystems. New York: Haworth Press, 185 p.

Anderson, J.M. & Ingram, J.S. (1993) *Tropical Soil Biology and Fertility: Handbook and Methods*, 2nd Edition. CAB International, Wallingford, UK, 221 p.

Balvanera, P., Lott, E., Segura, G., Siebe, C. & Islas, A. (2002) Betadiversity patterns and correlates in a tropical dry forest of Mexico. *J. Veg. Sci.* 13: 145-158.

Bennie, J., Hill, M., Baxter, R. & Huntley, B. (2006) Influence of slope and aspect on long-term vegetation change in British chalk grasslands. *Journal of Ecology* 94: 355-368.

Biodiversity International (2007) *Sub-Saharan Africa*. Rome: Biodiversity Int.

Chambers, P.A, & Prepas, E.E. (1990) Competition and coexistence in submerged aquatic plant communities: the effects of species interactions versus abiotic factors. *Freshwater Biology* 23: 541-550.

Comiskey, J.A., Sunderland, T.C.H. & Sunderland-Groves, J.L. (2003) *Takamanda: the Biodiversity of an African Rainforest*. SI/MAB Series #8. Washington, DC: Smithsonian Institution.

Cristofoli, S., Monty, A. & Mahy, G. (2010) Historical landscape structure affects plant species richness in wet heath lands with complex landscape dynamics. *Landscape and Urban Planning* 98: 92-98.

Crozier, C.R. & Boerner, R.E.J. (1984) Correlations of ecol 79 114 understory herb distribution patterns with microhabitats under different tree species in a mixed mesophytic forest. *Oecologia* 62: 337-343.

FAO (2002) *The state of agricultural biodiversity in the livestock sector: Threats to livestock genetic diversity*. Rome: FAO.

FAO-UNDP (1979) *Soil Science Project. Soil survey and Land Evaluation for the Selection of land for seed multiplication farm*. UCAO-World Bank Development Project. Haut plateau de L'Ouest Technical Report No 9. Soil Science Department IRA-FONAREST ELOMA (Cameroon).

Faurie, C. (2003) *Ecologie. Approche scientifique et pratique*. Paris: Tec and Doc 5th edition, 407 p.

Finegan, B. (1992) The management potential of neotropical secondary lowland rain forest. *For. Ecol. Mgmt.* 47: 295-321.

Fotsing, J.M. (1992) Stratégies paysannes de gestion de terrains et de LAE en pays Bamiléké Ouest Cameroun. *Bull. Réseau Erosion* 12: 241-254.

Fridley, J.D., Peet, R.K., Wentworth, T.R. & White, P.S. (2005) Connecting fine- and broad-scale species-area relationships of southeastern US flora. *Ecology* 86: 1172-1177.

Frontier, S. & Pichot-Viale, D. (1998) *Ecosystèmes. Structure, Fonctionnement, Evolution*. Paris: Dunod, 445 p.

Givnish, T.J. (1999) On the causes of gradients in tropical tree diversity. *Journal of Ecology* 87: 193-210.

Gonga, X.Y., Brueck, H., Giese, K.M., Zhang, L., Sattelmacher, B. & Lin, S. (2008) Slope aspect has effects on productivity and species composition of hilly grassland in the Xilin River Basin, Inner Mongolia. *China. Journal of Arid Environments* 72: 483-493.

Gosselin, M. & Laroussinie, O. (coord.) (2004) *Biodiversité et gestion forestière. Connaître pour préserver. Synthèse bibliographique*. Paris: Cemagref Éditions, ECOFOR, Études, gestion des territoires 20, 320 p.

Gotelli, N., Colwell, R.K. (2001) Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* 4: 379-391.

Harman, W.N. (1972) Benthic substrates: their effect on freshwater mollusca. *Ecology* 53: 271-277.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P. & Lawton, J.H. (2005) Effects of biodiversity on ecosystem functioning, A consensus of current knowledge. *Ecological Monographs* 75(1): 3-35.

Huston, M.A. (1994) *Biological diversity*. Cambridge, UK: Cambridge University Press.

John, R., Dalling, J.W., Harms, K.E., Yavitt, J.B., Stallard, R.F., Mirabello, M., Hubbell, S.P., Valencia, R., Navarrete, H., Vallejo, M. & Foster, R.B. (2007) Soil nutrients influence spatial distributions of tropical tree species. *Proceeding of the National Academy of Science* 104: 864-869.

Jeeva, S., Kingston, C., Kiruba, S., Kannan, D. & Jasmine, T.S. (2007) Medicinal plants in the sacred forests of Southern Western Ghats. In: *National Conference on Recent Trends on Medicinal Plants Research* (NCRTMPR – 2007). Organized by Centre for Advanced Studies in Botany, University of Madras, Guindy Campus, Chennai – 600 025.

Kaczor, S.A. & Hartnett, D.C. (1990) Gopher tortoise (Gopherus polyphemus) effects on soils and vegetation ina Florida sandhill community. *American Midland Naturalist* 123: 100-111.

Khem, R.B. & Ole, R.V. (2003) Variation in plant species richness of different life forms along a Sub-tropical elevation gradient in the Himalayas, east Nepal. *Global Ecology* & *Biogeography* 12: 327-340.

Lamb, D., Parrota, J., Keenan, R. & Tucker, N. (1997) Rejoining habitat remnants; restoring degraded Rainforest lands. In: Letouzey, R. (1968) *Étude Phytogéographique du Cameroun*. Paris: P. Le Chevalier.

Letouzey, R. (1985) *Notice de la carte phytogeographique du Cameroun*. Toulouse: Institute de la Carte Internationalede la Vegetation.

Libite, P.R. (2010) *La répartition spatiale de la population au Cameroun*. 6th ASSD-Cairo.

Lugo, A.E. (1992) Comparison of tropical tree plantations with secondary forest of similar age. *Ecol. Monographs* 62: 1-41.

Ma, M. (2005) Species richness versus evenness: independent relationship and different responses to edaphic factors. *Oikos* 111: 192-198.

Magurran, A.E. (1988) *Ecological diversity and its measurement*. Princeton, NJ: Princeton University Press.

Marini, L., Scotton, M., Klimek, S., Isselstein, J. & Pecile, A. (2007) Effects of local factors on plant species richness and composition of Alpine meadows. *Agriculture Ecosystems & Environment* 119: 281–288.

Mishra, B.P., Tripathi, O.P., Tripathi, R.S. & Pandey, H.N. (2004) Effect of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, northeast India. *Biodiver Conser* 13: 421-436.

Mori, S.A., Boom, B.M., de Carvalho, A.M. & dos Santos, T.S. (1983) Southern Bahian moist forests. *Bot. Rev.* 49(2): 155-232.

Ohlemüller, R. & Wilson, J.B. (2000) Vascular plant species richness along latitudinal and altitudinal gradients: a contribution from New Zealand temperate forest. *Ecological letters* 3: 262-266.

Pélissier, P. (1980) *L'arbre en Afrique tropicale*. La fonction et le signe Cahiers ORSTOM série Sciences Humaines XVII(3-4), 322 p.

Perry, D.A. (1994) *Forest Ecosystems*. Baltimore, MD: Johns Hopkins University Press, 649 p.

Peet, R.K., Wentworth, T.R. & White, P.S. (1998) A flexible, multipurpose method for recording vegetation composition and structure. *Castanea* 63: 262-274.

Pringle, C.M. (1990) Nutrient spatial heterogeneity: effects on community structure, physiognomy, and diversity of stream algae. *Ecology* 71: 905-920.

Reitalu, T, Sykes, M.T., Johansson, L.J., Lonn, M., Hall, K., Vandewalle, M. & Prentice, H.C. (2009) Small-scale plant species richness and evenness in semi-natural grasslands respond differently to habitat fragmentation. *Biological Conservation* 142: 899-908.

Rawat, S.D. (2011) Elevation reduction of plant species diversity in high altitudes of Garhwal, Himalaya, India. *Current science* 100(6): 833-836.

Rosenzweig, M.L. (1995) *Species diversity in space and time*. Cambridge, UK: Cambridge University Press.

Scarsbrook, M.R. & Townsend, C.R. (1993) Stream community structure in relation to spatial and temporal variation: a habitat template study of two contrasting New Zealand streams. *Freshwater Biology* 29: 395-410.

Schlosser, I.J. (1982) Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monographs* 52: 395-414.

Shannon, C.E., Weaver, W. (1949) *The mathematical theory communication*. Urbana II, University of Illinois Press.

Soomers, H., Derek K.D., Verhoeven, J.T.A., Verweij, P.A. & Wassen, M.J. (2012) The effect of habitat fragmentation and abiotic factors on fen plant occurrence. *Biodivers Conserv* 22(2): 405-424.

Sundarapandian, S.M., Chandrasekaran, S. & Swamy, P.S. (2005) Phenological behaviour of selected tree species in tropical forests at Kodayar in the Western Ghats, Tamil Nadu, India. *Cur. Sci.* 88: 805-809.

Swamy, P.S. Sundarapandian, S.M., Chandrasekar, P. & Chandrasekaran, S. (2000) Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. *Biodiversity and Conservation* 9: 1643-1669.

Tonn, W.M. & Magnuson, J.J. (1982) Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. *Ecology* 63: 1149-1166.

Swift, M.J. & Anderson, J.M. (1993) Biodiversity and ecosystem function in agro ecosystems. In: Schultze, E., Mooney, H.A. (eds) *Biodiversity and Ecosystem Function*. Spinger, NewYork, pp. 57-83.

Trumbore, S.E., Chadwick, O. & Amundson (1996) A rapid exchange between soil carbon and atmospheric carbon dioxide driven by temperature change. *Science* 272: 393-396.

UNEP-WCMC (United Nations Environment Programme – World Conservation Monitoring Centre) (2003) *WorldDatabase on Protected Areas (WDPA),* Version 6. Compiled by the World Database for protected Areas Consortium, UK. August 2003.

Wilson, E.O. (2000) On the future of conservation biology. *Conservation Biology* 14: 1-4.

Vanpeene-Bruhier, S. (1998) *Transformation des paysages et dynamiques de la biodiversité végétale. Les écotones, un concept pour l'étude des végétations post-culturales. L'exemple de la commune d'Aussois (Savoie)*, PHD. Grenoble, ENGREF, T.1, 312 p., T.2, 127 p.

Venevsky, S. & Venevskaia, I. (2005) Hierarchical systematic conservation planning at the national level: Identifying national biodiversity hotspots using abiotic factors in Russia. *Biological Conservation* 12: 235-251.

White, F. (1983) *The Vegetation of Africa*. Paris: UNESCO.

Whittaker, R.H. (1975) *Communities and ecosystems*, 2nd edn. New York: MacMillan.

Zapfack, L., Engwald, S., Sonke, B., Achoundong, G. & Mandong, B.A. (2002) The impact of land conversion on plant biodiversity in the forest zone of Cameroon. *Biodiversity and Conservation* 11: 2047-2061.