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Citation

Tankou, C. M. (2013, December 12). *The interactions of human mobility and farming systems and impacts on biodiversity and soil quality in the Western Highlands of Cameroon*. Retrieved from <https://hdl.handle.net/1887/22848>

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

Issue Date: 2013-12-12

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Variation of Biodiversity in Sacred Groves and Fallows in the Western Highlands of Cameroon

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Published in the African Journal of Ecology

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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 β -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-Saharan 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; Gongga *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 $5^{\circ} 27' - 5^{\circ} 37.62' \text{ N}$ and $09^{\circ} 57.502' - 10^{\circ} 09.544' \text{ E}$ occupied by two sub-divisions in the Menoua Division (Fongo-Tongo and Nkong-ni) found in the WHC (Figure 4.1).

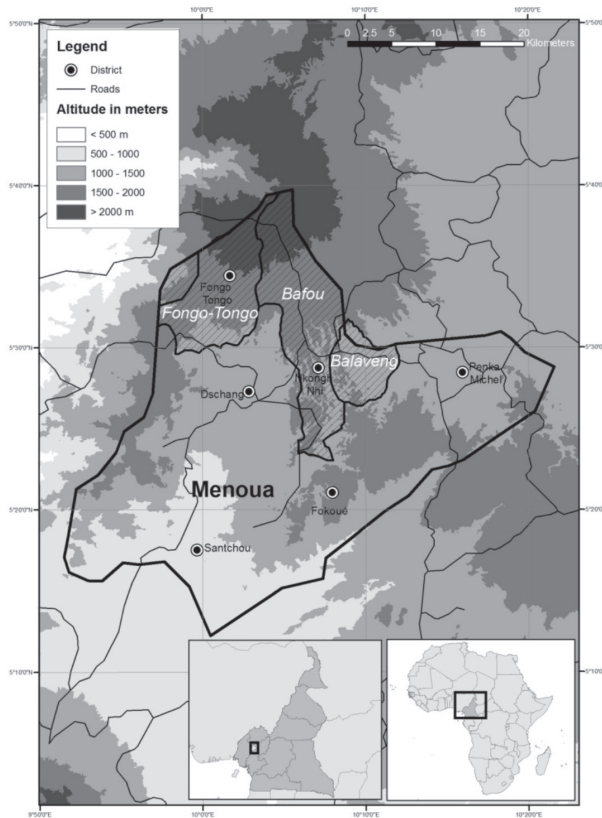


Figure 4.1
Geographical location of research site.

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)	5° 36' N / 10° 2' E	2355
Bafou (Femok)	5° 37' N/10° 2' E	2430
Bafou (Femok)	5° 37.62' N/10° 1.88' E	2310
Bafou (Femok)	5° 33' N/10° 4' E	1959
Bafou (Loung)	5° 33' N/10° 4' E	1810
Bafou (Loung)	5° 33' N/10° 5' E	1777
Baleveng	5° 30' N/10° 8' E	1523
Bafou (Nstingbeu)	5° 27' N/10° 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 wild-flower, 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 = $100 \times (\text{number of sample units containing a species} / \text{sample units for species of the sample})$

Relative density = $100 \times (\text{number of individual of a species} / \text{number of individuals of a sample})$

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:

$H = - \sum (p_i * \ln p_i)$, 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: $J = H / \ln(S)$ β -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,

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

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

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

Clearly, β -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 β -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 $CF_c \leq 1$. A maximum value of $CF_c = 1$ was obtained when both sites had the

same species richness, and thus 100% of C_j was given by the number of shared species. CF_c was lower as the differences between a and b were higher, so that the proportion of C_j given by the number of shared species was lower and that given by changes in species richness was higher.

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

$\beta_w = \gamma/(\alpha-1)$, 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 *Phyllanthus 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
<i>Aspilia Africana</i>	5.01	0.52	13.04	8.70	Asteraceae
<i>Chromolaena odora</i>	0.03	0.52	2.18	8.70	Asteraceae
<i>Commelina benghalensis</i>	4.02	3.12	21.74	17.39	Commelinaceae
<i>Desmodium hirtum</i>	1.35	0.52	13.04	8.70	Fabaceae
<i>Pteridium aquilinum</i>	1.23	1.04	17.39	8.70	Hypolepidaceae
<i>Sanicula elata</i>	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
<i>Albizia adianthifolia</i> (Schum.) W.F. Smith	3.93 / 35.75	3.54 / 36.36	Fabaceae	Erosion control and carving
<i>Allophylus africanus</i>	0.51 / 5.11	0.88 / 9.09	Sapindaceae	Toothache and diarrhoea
<i>Allophylus bullatus</i>	1.69 / 15.32	1.77 / 18.18	Sapindaceae	–
<i>Bersama engleriana</i>	1.12 / 10.21	1.77 / 18.18	Melianthaceae	Diabetes
<i>Bridelia micrantha</i> (Hochst.) Baill	5.06 / 45.97	5.31 / 54.55	Phyllanthaceae	Cough

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<i>Caloncoba glauca</i> (P. Beauv.) Gilg.	1.12 / 10.21	0.88 / 9.09	Flacourtiaceae	Inflamation and skin diseases
<i>Canthium manni</i>	1.69 / 15.32	1.77 / 18.18	Rubiaceae	Worms
<i>Carapa grandiflora</i> Sprague	1.12 / 10.21	1.77 / 18.18	Meliaceae	–
<i>Cassipourea sp.</i>	1.12 / 10.21	0.88 / 9.09	Rhizophoraceae	Timber
<i>Cola acuminata</i>	2.25 / 20.43	0.88 / 9.09	Sterculiaceae	Fatigue, Libido
<i>Crassocephalum manni</i>	1.69 / 15.32	0.88 / 9.09	Asteraceae	Malaria
<i>Croton oligandrum</i> Pierre. Mss.	1.69 / 15.32	0.88 / 9.09	Euphorbiaceae	–
<i>Cyathea manniana</i> HK.	1.12 / 10.21	0.88 / 9.09	Cyatheaceae	–
<i>Dracaena arborea</i>	0.56 / 5.11	0.88 / 9.09	Asparagaceae	–
<i>Ficus natalensis</i>	1.12 / 10.21	0.88 / 9.09	Moraceae	Stomach disorder
<i>Flacourtia flavescens</i> Wild	1.68 / 15.32	1.77 / 18.18	Flacourtiaceae	Syphilis
<i>Gambeya albida</i> Aubrev et Pellegr.	0.56 / 5.11	0.88 / 9.09	Sapotaceae	–
<i>Macaranga occidentalis</i>	2.25 / 20.43	0.88 / 9.09	Euphorbiaceae	–
<i>Maesa lanceolata</i> Forsk	2.81 / 25.54	1.77 / 18.18	Myrsinaceae	Tape worm
<i>Nuxia congesta</i> R. Br. Ex Presen.	2.25 / 20.43	2.65 / 27.27	Stilbaceae	–
<i>Olea capensis</i> Linn	0.51 / 5.11	0.88 / 9.09	Oleaceae	–
<i>Persea americana</i> Mill	2.81 / 25.54	0.88 / 9.09	Lauraceae	Hypertension and diabetes
<i>Polyscias fulva</i>	2.81 / 25.54	1.77 / 18.18	Araliaceae	Headache
<i>Protea argyrophaea</i> Hutch	2.25 / 20.43	3.54 / 36.36	Proteaceae	–
<i>Pseudospondias microcarpa</i> (A. Rich.) Engl.	2.25 / 20.43	2.65 / 27.27	Anacardiaceae	Syphilis
<i>Psoralea kunthiana</i>	0.56 / 5.11	0.88 / 9.09	Clusiaceae	–
<i>Psychotria peduncularis</i>	1.12 / 10.21	4.42 / 45.45	Rubiaceae	–
<i>Rauwolfia vomitoria</i>	2.25 / 20.43	2.65 / 27.27	Apocynaceae	Hypertension
<i>Salacia mayumbensis</i> N. Hallis	1.12 / 10.21	1.77 / 18.18	Celastraceae	–
<i>Trema guineensis</i> (Schum & Thonn.) Fialho	1.69 / 15.32	1.77 / 18.18	Cannabaceae	Hypertension and diabetes
<i>Tricalysia biagrana</i> Heirn	2.25 / 20.43	5.31 / 54.54	Rubiaceae	–
<i>Vitex doniana</i>	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
<i>Adenia cissampeloides</i>	Passifloraceae	1.56	8.70
<i>Aframomum aulacocarpus</i>	Zingiberaceae	0.51	8.70
<i>Aframomum danielli</i> (Hook. f.) K. Schum.	Zingiberaceae	2.34	21.74
<i>Arthropteris palisoti</i>	Oleandraceae	1.82	21.74
<i>Astystasia</i> sp.	Acanthaceae	2.08	8.70
<i>Asystasia gangetica</i>	Acanthaceae	17.14	17.39
<i>Begonia adpressia</i>	Begoniaceae	7.79	4.35
<i>Brillantaisia nitens</i> Lindau	Acanthaceae	0.52	8.70
<i>Clerodendron</i> sp.	Lamiaceae	0.52	8.70
<i>Crassocephalum biafrae</i>	Asteraceae	0.26	4.35
<i>Craterosiphon scandens</i>	Thymelaeaceae	0.52	8.70
<i>Cyathea manniana</i> HK.	Cyatheaceae	0.52	8.70
<i>Desmodium velutinum</i>	Fabaceae	0.52	8.70
<i>Dioda scandens</i> SW	Rubiaceae	2.86	8.70
<i>Eremomastax speciosa</i> (Hochst.) Cufod	Acanthaceae	1.56	8.70
<i>Gouania longipetala</i> Hemsl	Rhamnaceae	1.04	13.04
<i>Justicia depauperata</i>	Acanthaceae	2.86	26.09
<i>Laggera pterodonta</i> (D.C) Sch.	Asteraceae	0.26	4.35
<i>Laportea ovalifolia</i>	Urticaceae	3.38	13.04
<i>Melinis minutiflora</i>	Poaceae	5.19	8.70
<i>Microglossa angolensis</i> Oliv.	Asteraceae	0.52	8.70
<i>Momordica foetida</i> Schumach.	Curcubitaceae	1.04	13.04
<i>Oplismenus hirtellus</i>	Graminae	19.74	52.17
<i>Palisota barteri</i>	Commelinaceae	0.78	4.35
<i>Paullinia pinnata</i>	Sapindaceae	0.78	13.04

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

Table 4.8

Fallow species not found in the sacred groves.

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

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

4 Variation of Biodiversity in Sacred Groves and Fallows

<i>Sida sp.</i>	Malvaceae	0.06	2.17
<i>Siegesbeckia sp.</i>	Asteraceae	1.26	0.04
<i>Solanum scabrum</i>	Solanaceae	1.26	4.35
<i>Splilanthes filicaulis</i>	Asteraceae	1.23	6.52
<i>Sporobolus sp.</i>	Poaceae	15.07	39.13
<i>Stellaria sp.</i>	Caryophyllaceae	2.82	8.70
<i>Tithonia diversifolia</i>	Asteraceae	0.09	2.17
<i>Tradescantia sp.</i>	Commelinaceae	0.87	4.35
<i>Triplasis sp.</i>	Poaceae	0.03	2.17
<i>Urena lobata</i>	Malvaceae	0.75	8.70
<i>Vernonia amygdalina</i>	Asteraceae	0.15	6.52
<i>Vernonia calvoana</i>	Asteraceae	1.32	13.04
<i>Waltheria indica</i>	Malvaceae	0.15	2.17
<i>Xanthosoma sagitifolium</i>	Araceae	0.45	2.17
<i>Xanthosoma sp.</i>	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
<i>Acalypha manniana</i>	Euphorbiaceae	0.88	9.09	Skin diseases
<i>Acioa johurtonei</i> Hoyle	Chrysobalanaceae	0.88	9.09	–
<i>Albizia sp.</i>	Fabaceae	0.88	9.09	–
<i>Alchornea laxiflora</i>	Euphorbiaceae	0.88	9.09	–
<i>Antidesma sp.</i>	Phyllanthaceae	1.77	18.18	–
<i>Brucea antidysenterica</i>	Simarounbaceae	1.77	18.18	Dysentery
<i>Cassine aethiopica</i>	Celastraceae	0.88	9.09	
<i>Chrysobalanus icaco</i>	Chrysobalanaceae	0.88	9.09	–
<i>Clausena anisata</i>	Rutaceae	0.88	9.09	Cough, cold

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

Table 4.10
Tree species not found as shrubs in scared groves

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

<i>Mangifera indica</i>	Anacardaceae	0.56	5.11	High blood pressure
<i>Markhamia tomentosa</i>	Bignoniaceae	1.12	10.21	Oedema
<i>Octolepis casearia</i>	Thymeleaceae	0.56	5.11	–
<i>Olea hochstetteri</i>	Oleaceae	0.56	5.11	Diabetes
<i>Phoenix reclinata</i> Jacq	Arecaceae	1.69	15.32	–
<i>Pittosporum mannii</i> Hook. f.	Pittosporaceae	2.25	20.43	Intestinal diseases
<i>Prunus Africana</i>	Rosaceae	0.56	5.11	Fungal and bacterial infections, madness
<i>Psidium guajava</i>	Myrtaceae	0.56	5.11	Diarrhea
<i>Rothmannia urcelliformis</i>	Rubiaceae	1.23	10.21	–
<i>Salacia staudtiana</i>	Celastraceae	0.56	5.11	–
<i>Sapium ellipticum</i> (Hochst.) Pax	Euphorbiaceae	2.25	20.43	Purgative and eczema
<i>Schefflera barteri</i> (Seem.) Harms	Araliaceae	0.56	5.11	–
<i>Syzygium aromaticum</i>	Myrtaceae	0.56	5.11	Mouth and teeth pain
<i>Tricalysia atherura</i>	Rubiaceae	0.56	5.11	Jaundice
<i>Trichilia sp.</i>	Meliaceae	1.69	15.32	–
<i>Turraea vogelii</i>	Meliaceae	0.56	5.11	Cough
<i>Vepris louisii</i>	Rutaceae	0.56	5.11	Malaria
<i>Vernonia sp.</i>	Asteraceae	0.56	5.11	–
<i>Zanha golungensis</i>	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	15.28	10.15**	0.53*
	pH	-2.82		
	Total P	-1.90		
Species richness of herbs in sacred grove	Constant	-3.64	14.55**	0.62*
	CEC	0.21		
	Slope	0.06		
Species richness of shrubs in sacred grove	Constant	129.77	13.24**	0.87*
	Total P	-3.26		
	pH	-23.35		
	Total K	938.14		

** 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, β -diversity was examined for the trees in the sacred grove. Average βC_j and β_w were 0.94 and 2.02 respectively. βC_j and β_w showed similar patterns and were correlated ($r = 0.94$, $p < 0.001$). Generally the largest β -diversity values (βC_j and β_w) indicated comparisons between the poorest sacred grove and the richest one which were related to lowest values of CFC_j . 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 ($\beta C_j = 0.97$, $\beta_w = 0.69$ and $CFC_j = 2.06$). Generally from the table it was observed that the values of β -diversity increased gradually with increasing altitude (Table 4.15).

Table 4.15

β -diversity measures among all pairs of 0.0625-ha quadrats of trees in the sacred groves using Jaccard similarity index (β_{Cj} , in bold), Jaccard's correction factor (CFCj) (separated by /) and Whittaker's β -diversity index (β_w , 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 C₄ 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 β -diversity analyses. Givnish (1999) observed that describing and exploring the determinants of β -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 factors 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.

Acknowledgements

This research was made possible by funding from Volkswagen foundation. The authors wish to thank Maarten van't Zelfde of the Institute for Environmental Sciences (CML) Leiden, for producing the map of the research site and Tacham Walter of the University of Bamenda Cameroon, for help with the field work.

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