

IMPACTS OF LAND USE CHANGES ON BIODIVERSITY IN THE MOUNT CAMEROON REGION

ABSTRACT

Introduction: Land use changes due to agricultural intensification driven by demographic growth and unemployment has increased pressure on the Mount Cameroon Forest.

Aim: To evaluate the impact of land use changes on the biodiversity of the Mount Cameroon Region.

Place and duration of study: In the mount Cameroon region from July 2009- November 2010.

Materials and Methods: Semi-structured questionnaires, interviews, focused group discussions field surveys and remote sensing technique were used in the evaluation process. Ten 50×50 m plots (0.25 ha) were established in newly opened farms in the study sites. All trees damaged by fire during farming were sampled and the diameter at breast height ($\text{dbh} \geq 10\text{cm}$) recorded.

A ground truthing survey was done to obtain ground reference data during the study period. During this survey, 49 geographical positioning system (GPS) points were recorded from different land uses observed (farmlands, forests, bare ground, plantations and settlement areas) using a hand held Garmin e Trex Venture HC GPS.

Landsat Thematic (TM) and Enhanced Thematic (ETM+) images were extracted from landsat scenes of the MCR for the periods; 1986, 2000 and 2008.

Results: The results showed that the number of farms cultivated per household correlated positively with the family sizes of the respondents ($r= 0.98$). A total of 460 trees belonging to 98 species and 33 families were damaged in the survey sites. The total basal area of the trees was 614.69 m^2 . The Malvaceae had the highest damaged individuals (44). *Terminalia superba*, *Xylopia africana* and *Entandrophragma cylindricum* were the most important species damaged. Deforestation rate from 1986-2000 was 21.19 ha per yr. (1.09%) while in 2001-2008 it was 9.75

27 ha per yr. (0.58%) from remote sensed data. During the 1986-2000 period agricultural fields
 28 increased by 12 ha per year, while there was a decrease by 33.5 ha per year from 2001-2008.
 29 **Conclusion:** Land use changes due to agricultural expansions, illegal logging and fuel wood
 30 collection have caused massive tree destruction in the Mount Cameroon Region, which is a
 31 threat to the biodiversity of the area.

32 **Key-Words:** Mount Cameroon Region, land use changes, agricultural intensifications,
 33 biodiversity

34

35 1. INTRODUCTION

36 Land use changes are one of the most crucial human impacts on natural ecosystems, causing
 37 changes in the services obtained from the ecosystems (1, 2). Increased population pressure
 38 coupled with the need for expansion in agricultural production has continued to serve as one of
 39 the driving force for conversion of tropical forests to agricultural fields (3). The Mount
 40 Cameroon Region (MCR) has rich and fertile volcanic soils is close to the coast, and has
 41 agro-industrial ventures such as the Cameroon Development Corporation (CDC), Cameroon Tea
 42 Estate, (CTE) and small scheme holders. The CDC cultivates palm, rubber, and banana on
 43 43,000 hectares of land (5). Peasant agriculture takes place in small farms of less than one
 44 hectare with mixed cropping of cocoyams, maize, plantains, yams, cassava, and vegetables.

45 According to, a change in the use of land was one of the three well established global changes
 46 that caused forest degradation worldwide. reported that land use changes leading to the
 47 expansion of agricultural lands at the expense of natural forests was the main driving force of
 48 tropical deforestation. Bird species were affected by agricultural intensifications (8) due to
 49 decline in invertebrates and seed food (9). Forest degradation affects biodiversity through
 50 habitat destruction. Several communities depend on this forest for their livelihood and obtain
 51 services which are not usually given market financial values. Such services such as nutrient
 52 cycling, soil formation, water availability, pollination, climate regulation as well as pest and
 53 pollution control are linked to biodiversity (10_b).

Loss of biodiversity affects ecosystem functioning and stability, productivity at different trophic levels, nutrient cycling and erosion control (11). (), reported that anthropogenic impacts caused by human population density accounted for 87.9% of the variation in numbers of threatened species across the tropical forest. During the last few decades, deforestation of tropical forest areas has accelerated at an alarming rate as extensive areas of forest are being cleared every year for different land use purposes (13). Man affects the forest ecosystem with activities such as the establishment of plantations for agro-industries, shifting agriculture, hunting etc. There has been an overwhelming concern about the loss of tropical diversity and an emphasis on the identification of biodiversity hot spots in an attempt to optimize conservation strategies (14). According to () land use changes from forests to farmlands and selective tree harvest caused loss of biodiversity and habitat fragmentation, which exposed forest edges. Such land use changes decrease core habitat areas, and since smaller habitat areas support fewer species, species requiring undisturbed core habitats can suffer from local and general extinction. Rimm and Raven (2000) () reported that habitat destruction was the most important cause of species extinction worldwide. Habitat destruction increases the vulnerability of forests to natural disasters such as floods, drought, crop failure, spread of diseases, and water contamination, together with alterations in the nitrogen, phosphorus, sulphur, and carbon cycles (17a). () reported that soil fertility differ with land use in different agro-ecological zones, which has an effect on vegetation cover. They also added that available soil carbon though adequate in forests decreases with the clearing of forests for crop cultivation, pasture fields and fallow land. Habitat fragmentation and degradation may lead to loss in biodiversity and influence the life cycle of tropical tree species by reducing pollination, limiting seed dispersal and increasing seed predation (19), which may affect species population sizes and their distribution. A decline in any single species is very relevant to biodiversity conservation and resource management (20). Therefore this study tries to evaluate the following research questions; (i) what are the different land use practices in the MCR? (ii) What are the effects of these land use practices on biodiversity? In order to answer these questions the research seeks to evaluate the impact of land use changes on biodiversity in the Mount Cameroon region using ground truthing, remote sensing data and field surveys.

2. MATERIALS AND METHODS

2.1 Study Site: The MCR is found in the South West Region of Cameroon and covers a surface area of 5695.5 km² (21), stretching from latitude 3°57' to 4°28' N and longitude 8°58' to 9°24' E (22). The region stretches just about 20 m from the sea to a height of 4100 m, called Mount Cameroon, situated at 4°13' N, and 9°10' E. This is the highest point in West and Central Africa. The climate is humid with annual rainfall ranging from 2085 mm to 10,000 mm. The mean temperature is 25°C and this decreases by 0.6°C per 100 m ascent (23). According to the Institute of National Statistics Cameroon (2010), the population of the South West Region is 1,384,300 people with about 400,000 people around the Mount Cameroon National Park area (24), with an average of 7.9 people per house (25). 

The landscape comprises tropical beaches, swamps, tropical and montane forests, together with agricultural lands. (26), described this region as one of the most biologically diverse sites in Africa, with about 2500 indigenous and naturalized plant species, with 42 of them endemic to this region.

According to , the vegetation of the region is characterised into zones, determined by the altitude. The vegetation changes from high evergreen lowland forests through submontane cloud forests (about 800-1700 m) to montane forests (between about 1600-1800 m). Natural openings are usually dominated by *Hypselodelphys scandens* and *Aframomum spp* (28). The canopy is discontinuous and the under storey is usually dominated by the Acanthaceae and Labiatae (29). There are patches of shrubs separated by grassland above 1800 m (28).

The present study was carried out in five sites; Bokwango, Bova, Bonakanda, Bimbila (Bonangombe and Bonabile), and Idenau (Sanje village, Scipio and Rechts Fluss CDC camp). These areas were selected to cover the leeward and wind ward sides of the mountain, and to cut across montane and coastal settlements in the Mount Cameroon Region (Figure 1).

2.2 Land use and Agricultural Systems

Semi-structured and open ended questionnaires were designed and used to study land use and agricultural systems practiced in the region. A total of 150 questionnaires were administered, 30 of them in each of the five study villages. The questionnaires were used to obtain information on

land use and agricultural systems. Information on land use history was gotten from interviews of quarter heads of villages, the elderly and focused group discussions using the method of (30).

2.3 Remote Sensing

A ground truthing survey was done to obtain ground reference data during the study period. During this survey, 49 geographical positioning system (GPS) points were recorded from different land uses observed (farmlands, forests, bare ground, plantations and settlement areas) using a hand held Garmin eTrex Venture HC GPS. These points were compared with the land uses of the classified maps gotten from remote sensing for verification (31).

Land cover changes (Forest, agricultural fields and settlement areas) were evaluated using remote sensing (32). Landsat Thematic (TM) and Enhanced Thematic (ETM+) images were extracted from landsat scenes of the MCR for the periods; 1986, 2000 and 2008. These images were acquired from the Global Land Cover Facility (GLCF) at 30 m resolution (Plate 1). The classification for land use / land cover mapping was level 1, showing general land cover, and land use systems. The categories were: (I) Urban, (II) forest, (III) agricultural land and (IV) water, described by (33, 34 and (35).

2.4 Farm Surveys

Farm surveys were carried out in 40 randomly selected farms inside the forest and the forest edges in the study villages to assess trees damaged when farms are newly opened. Twenty of these farms were in the mountain forest between Bonakanda, Bova and Bokwango, 8 in Bimbila, and 12 in Sanje and Scipio (Idenau). Out of these 40 farms, 12 of them were newly opened forests where the first planting had not yet been done, or had just been done. The trees found in these farms were under the process of destruction (lower portion of the stem debarked and burnt).

Ten plots of 50 × 50 m (0.25 ha) were established within these newly opened farms and sampled. Five of these farms were in the mountain forest area and 5 in the coastal forest. In each sampling plot, all tree species present were counted and identified using structural and morphological

characteristics. Voucher specimens of unidentified samples were taken to the Limbe Botanic Garden for identification and confirmation. The dbh for each individual tree was measured at 1.3 m from ground level. Stumps left from timber logging were counted and noted. The dbh of the trees were used to compute the basal area (BA) and relative basal area (RBA). The relative density (RD) of each tree species was calculated and the total density of all tree species encountered recorded. The frequency (F) of each species was calculated in the different plots studied. This was used to compute the relative frequency (RF)

2.4 Data Analysis

The data collected from the field on land use were analysed using descriptive statistics. Cross tabulations and frequency tables were generated on the respondent's view on land use, major occupations and agricultural systems. The Statistical Package for the Social Sciences (SPSS) version 13.0 was used.

The Importance Value Index (IVI) of each species destroyed was gotten using the formula of, (36) (Appendix A). The cover value index (CVI) was calculated for each plot using the methods of (37) and (38) (Appendix A1 to A7).

The ground reference points were geo-coded into the classified maps including the accuracy of fit noted. Classified Landsat images were analysed using the Environment for Visualizing Images (ENVI) version 4.4 software. Colour composites (combination of red, blue and green) of bands 742 were used to display images in standard colour composites for land use and vegetation mapping (39). Relevant imagery was collected for each specified period and classified using ENVI remote Sensing software and ArcGIS version 9.3 software (21). Resultant maps were compared on pixel by pixel basis. The maximum likelihood parametric classifier, using nearest neighbour algorithm was used to categorise all pixels in the test site image to land cover classes. Change detection of the various land cover categories was done by comparing land cover statistics (40) in the ENVI software. Colour composites and their band combinations were used, where colour was attributed to samples (Table 1).

Annual rates of change of land cover types were gotten by dividing the total change in cover type (in hectares) within each period by the number of years between the periods.

The Microsoft excel 2010 package was exploited to do computations on the basal area, relative frequencies and densities, cover value and importance value indices. Data on number of trees damaged and basal area were subjected to a one way ANOVA and mean number of trees, dbh class and basal area loss compared between the montane and coastal forests at the 95% confidence level.

3. RESULTS

Demographic survey

Out of the 150 questionnaires administered, 113 of them were completely filled (75.3%), with 63 respondents being males (55.75%) and 50 females (44.25%). The ages of the respondents varied from 16 to 75 years. Out of the 113 respondents, 36 (31.86%) were ≤ 30 years old, 35 of them (30.97%) were between 31 to 45 years, 27 (23.89%) were between 46 to 60 years old and 15 (13.28%) were of ages greater than 61 years. The educational level of the respondents varied from no formal education to university degrees, with 21.23% of them being holders of the General Certificate of Education (GCE) ordinary level certificate and 7.08% of them were apprentices (Table 2).

The majority of the respondents (49.56%) were farmers while 2.65% of them were herbalists. The farmers were equally involved in hunting, tapping, trading and gathering of Non timber forest product NTFPs.

A majority of the respondents (49%) had family sizes of 6 to 10 persons, while 21% of them had 1 to 5 persons in their households (Figure 2 

Land use and Agricultural systems

Land is used in the MCR for farming, house construction, plantations, fallow plots, tourists' site and forest reserves. The most common land use identified by most respondents (35.39%) was farm lands (Table 3). Results from focused group discussion and interview of the elderly showed that fallow periods dropped from five to seven years down to zero to two years, and that larger farms were now opened up and cultivated within the forest, with very little respect for local restrictions on farm sizes and entry into or collection of resources from the forests.

Subsistence farming was the most common agricultural system practiced by 84% of the respondents while 16% of them practiced plantation agriculture, while some of the farmers were also involved in bee farming, snail farming, animal rearing (fowls, pigs and goats) and mushroom growing. These activities varied with the villages. Ten percent (10%) of the respondents in Bonakanda and 3.3% of those in Bova were involved in organized bee farming while 3.3% of those in Bimbria carried out traditional bee harvesting. Mushroom growing and snail farming was carried out in Bokwango only, by 6.6% of the respondents.

From the results, 59 (52.21%) of the respondents owned 5-8 different farm lands while 8 of them (7.09%) had 13-16 farms. Twenty three (20.35%) of them owned 1-4 and 9-12 farm lands respectively. Fifty four respondents (46.02%) had farms of average size 0.27 hectare, while 2 of them (1.77%) had farms which were bigger than a hectare. A cross tabulation between farm sizes and number of farms showed that 41(69.49%) of the 59 respondents who owned 5-8 farms had these farms of average size 0.27 hectares (Table 4).

It was observed that households with few individuals had less number of farms, with a strong positive correlation between the number of farms and family sizes ($r= 0.98$) (Table 5).

3.3 Remote Sensing

The results from ground truth data showed that out of 49 GPS points collected, 38 (77.5%) fitted exactly with the land use of the classified satellite image of 2008. From land cover statistics; dense forest cover was 1993 hectares in 1986. This dropped to 1610 hectares in 2008 with a forest cover loss of 385 hectares. There was a dense forest cover loss of 305 hectares from 1986 to 2000 and 78 hectares from 2000 to 2008 (Plate 2). Agricultural fields increased by 168 hectares from 1986 to 2000, and decreased by 14.3 hectares from 2000 to 2008. Settlement areas increased by 47 hectares from 1986 to 2000 and further increased by 58 hectares from 2000 to 2008. This increasing trend continued from 2000 to 2008 at a rate of 7.25 hectares per yr. (7.9 %). Agricultural fields had an increase rate of 12 hectares per year from 1986 to 2000 (1.02%). From year 2000 to 2008, agricultural fields had a decrease of 33.5hectares per year (2.5%). From 1986 to 2008, agricultural fields decreased at a rate of 4.55 hectares per year (0.39%). (Table 6)

229

230 **3.4 Farm Survey**

231 Results from farm surveys showed that there was massive tree destruction during the
232 establishment of new farms. During this process, the under storey was removed (Plate 3a)
233 followed by pruning (3b) and debarking of the bottom 1 m of all trees found in the farm area.
234 Fire was set under the debarked portions of trees (3c), and they were finally cut and carried away
235 as fuel wood when dried (Plate 3).

236

237 A total of 2.5 hectares newly opened farm lands were surveyed. A total of 460 trees of dbh $\geq$ 10
238 cm belonging to 98 species and 33 different families were damage. The family with the highest
239 number of individuals damaged were the Malvaceae (44 individuals). In the 2.5 hectares
240 farmland surveyed a total basal area of trees under damage was 422.09 m². The most important
241 species in terms of IVI values were; *Terminalia superba* (15.78), *Xylopia africana* (13.11),
242 *Entandrophragma cylindricum* (12.13), *Hymenostegia afzelii* (11.42) and *Ceiba pentandra*
243 (10.44) (Appendix B)

244 The altitudes of the farms where the plots were established ranged from 87 m above sea level in
245 Bimbina to 1062 m above sea level in Bokwango. The highest numbers of tree destruction per
246 0.25 ha plot was recorded in Bonakanda (61 trees). Highest basal area loss of 97.41 m² per plot
247 was recorded in a plot in Bimbina. Mean tree destruction of 46 ± 2.6 trees per 0.25 hectares plots,
248 and mean basal area of 58.5 ± 8.0 m² were recorded in the study area (Table 7).

249 Basal area loss of 266.89 m² per ha were recorded in the coastal forest and 225.85 m² per hectare
250 in the montane forest. Mean tree destroyed per hectare was 188.8 trees in the coastal forests and
251 146 trees per hectare in the montane forest. There were no significant differences in the
252 cumulative basal area loss from both sites at 95% probability level (Figure 3)

253 Out of the individual trees destroyed, 207 trees (45%) belonged to the dbh class 10-30 cm, 115
254 of them (55.6%) were from the coastal forest and 92 from the montane forest. In the 31-60 cm
255 dbh class, 131 trees (28.5%) were destroyed with 77 from the montane forest and 54 from the
256 coastal forest. Diameter classes between 120 to 150 cm, had a total of 12 trees destroyed (2.6%)
257 with 7 tree species found in the montane forest and 5 in the coastal forest (Figure 4)

4. DISCUSSIONS

4.1 Demographic survey and land use practices

Out of 113 questionnaires answered, 55.75% of the respondents were males and 44.25% females. This near equality was attributed to the fact that both the males and females were actively involved in the various livelihood activities in the region. These results were similar to the findings of (25) who reported 50.8% and 49.2% gender distribution of females and males in the active working population of the people in the Mount Cameroon Region.

A high proportion of the respondents had 6 to 10 persons in their households (48.67%) and 30.09% of them had more than 10 persons in their households. This household size is in line with findings reported at the participatory land use plan (41) committee of 8 to 13 people per household in the South West Region of Cameroon. These findings contradict those of (42) where there were 5 to 6 people per household in the region with seasonal fluctuations when children and young adults returned from school. Such changes were no more evident as there are several educational facilities; health centres and social amenities within the study villages. The increase in the number of people per household is likely due to general increase in the population of the region. This population increase is most likely attributed to high influx of immigrants from all the regions of the country and neighbouring countries, attracted by employment opportunities, and trade along the coastal beaches. This puts great pressure on the forest which is surrounded by settlements and good road network. The forest is no more continuous at low and high altitudes, but broken by 'new lay outs' and towns, contradicting the view of (29) who reported that this forest was the only unbroken vegetation at 200 to 4000m above sea level in West and Central Africa.

Farm lands were the major land use (39.39%). This was also reflected in the occupation of the respondents where 49.55% of them were farmers. The high level of farming may be attributed to the presence of fertile volcanic soils. The use of land for tourism (8.85%) and for forest reserve (5.33%) was low and most likely due to the increase in farm lands and settlement areas, and degradation of the natural forest.

The uses of land keeps changing as indigenes sell farmlands that were left to fallow and the new owners construct houses there. Households with high education levels still depended on the forest and farms for their livelihood. This was most probably caused by poverty, unemployment and under employment. This finding is contrary to those of (43) who reported that African households with higher education levels have more reliable sources of income and do not depend on the forest.

Fallow periods were short (1 to 3 years) and there were no long term fallow rotation periods. This drop in fallow period is most likely attributed to land scarcity and increased population. This finding is not in conformity to those of (44) who reported fallow periods of 10 to 16 years in the MCR. Most newly opened farms as a result of shifting cultivation were inside the forests and forest edges, attributed to high organic matter content in forest soils, due to litter accumulation, thus increasing the number of farmlands in the forests and forest edges in the studied areas.

4.2 Remote sensing

There was a 77.5% fit of ground truth points on the classified maps. This was probably caused by cloud cover, or may be due to the fact that small subsistence farms were located deep in the forests and could not be represented on the satellite images. From the images of 1986 and 2000, 305 hectares of forests were lost (21.79 hectares per year). Deforestation in the MCR within the 1980s and 1990s could be attributed to increase in agricultural fields (7); (45), expansion of plantations, lava flow (21) and urban development (46). These results were in consonance to the findings of (21) who reported deforestation rates of 19.25 km² per yr. from 1987 and 2002 landsat images.

From the 2000 and 2008 images, annual deforestation was 9.75 hectares per year at an annual rate of 0.58%. This decrease trend of deforestation between the two periods may be due to conservation efforts by the Mount Cameroon Project (MCP), several Non-Governmental Organizations (NGOs), German Technical Cooperation Agency (GTZ), and the creation of community forest reserves like Bimbila Bonadikombo Community Forest Reserve (BBCFR), Woteva community forest, Bakingili/Etinde community forest and Scipio council forest reserves.

This annual deforestation percentage is similar to that of Central Africa (0.5%) reported by (47) and that of Cameroon for the 1990s (0.6%), reported by (6). This continual loss of forest may probably have a serious concern in the carbon balance and climate change mitigation.

Settlement areas increased at an annual rate of 7.46% per year from 1986 to 2000 and also at an annual rate of 7.9% per year from 2000 to 2008. The increase in settlements from 1986 to 2008 may be due to increase in population. According to reports by (25 and 24) the population increase was about 4375 persons per year from 1987-2000 and about 10000 persons per year from 2000 to 2010. This has led to the construction of more houses and creation of more new-lay-outs for settlement within the region. The decrease in agricultural fields from the year 2000-2008 is most likely due to the surrender of some plantations by the CDC for urban development and sale of some small scheme plantations and farms to new owners who changed the use of the land from agriculture fields to house constructions.

4.3 Farm Survey

The first stage of farm preparation when new farms were opened was the removal of the under storey and killing of trees. This was most likely to increase the space to plant crops and to minimise shade effects. This same trend was identified by (48) who reported that few dominant trees were felled, during the preparation of small scale subsistence farms (0.5 to 2 ha) in the forests of the MCR, which contributed to deforestation and loss of biodiversity.

The under storey was completely removed, which may be detrimental to shade plants, trees recruitment from seedlings and the habitat of several small animals. (49), reported that the under storey was home to juveniles for canopy trees and life stages of small trees, shrubs and herbs. The removal of this vegetation cover therefore affected the ecosystem balance and altered habitats. According to (19) such habitat alterations caused biodiversity loss, lowered pollination, limited dispersal and increased seed predation in humid tropical forests. (50), reported that the complete removal of vegetation cover may result to an increase in soil erosion and depletion in soil nutrients which will turn to increase biodiversity loss. (51) also reported that tree species richness decreased significantly with increased levels of habitat modifications in South Western Cameroon forests. According to (52) such modifications of habitats reduced species richness of

birds, butterflies, beetles, ants, termites and nematodes in tropical forests, which were agents of pollination, and thus a threat to biodiversity

There was tree destruction of 188.8 trees per hectare (dbh >10cm) with basal area loss of 266.89 m² per hectare in the coastal forest, and 146.4 trees per hectare, with basal area loss of 224.85 m² per hectare in the montane forests. This large number of trees destroyed may be attributed to high tree population density, accessibility and high demand for wood, for domestic and industrial uses. This finding is in consonance to those of (51 and 53) who reported significant tree basal area losses when forests were converted to farmlands in South Western Cameroon. Loss of tree standing biomass has concerns on the CO₂ balance and climate change mitigation.

From our results, there were higher losses of number of trees and basal areas in the coastal forests compared to the montane forests. This was most probably due to higher tree densities in the coastal forests at low altitudes, likely attributed to high soil moisture content, higher rates of litter decomposition, change in altitude and climatic factors. This trend of higher tree numbers in coastal forests compared to montane forests is similar to findings of (54) who studied stand biomass of trees in the coastal and montane forests of the MCR and recorded 99 trees per hectare (dbh ≥ 50 cm) in the coastal forests and 92 trees per hectare in the montane forests of the region in 1989. According to (55) basal areas and tree densities decreased when moving from forests at low altitudes to those at higher altitudes, though (54) saw little evidence of altitude effects on species turn over and growth rate from low to high altitudes.

From our results, the dbh class 10 – 30 cm contained the majority (45%) of trees destroyed. This massive loss of number of trees of small dbh class is a threat to trees recruitment from seeds and the biodiversity of the MCR, harbouring several endemic tree species, especially as the forest is a secondary forest recovering from disturbances ranging from man-made to natural disasters during eruptions of mount Cameroon.

Plants of the Malvaceae had the highest destruction (44 members). This was probably because they are among the dominant species in the forests of the MCR. This is in consonance with findings by (56 and 57) who reported that the Malvaceae were amongst the dominant tree species in the forests of the MCR, in areas where gaps existed created by past lava flow.

Terminalia superba (White afara), *Xylopia africana*, *Entandrophragma cylindricum* (Sapelle), *Hymenostegia afzelii* and *Ceiba pentandra* (Boma) were the most important species destroyed in terms of the IVI values. This was most likely attributed to their large sizes and extensive uses as furniture wood, construction materials, fuel wood and medicine. According to (42 and 54), *Hymenostegia spp* were one of the dominant species in the montane forests of the MCR, while *Entandrophragma spp* and *Ceiba pentandra* were culturally important and highly used species in the region.

5. Conclusions



The steady increase in the population of the MCR triggered land use changes, the most important being agricultural intensification and encroachment into natural forests. There was high dependence on natural fertile soils that favoured shifting cultivation and forest clearance, leading to loss of biodiversity, with concerns on water catchments, carbon storage potential and other ecosystem services provided by the Mount Cameroon forest.

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LIST OF TABLES

Table 1. Colour bands attributed to the different land use classes on the classified maps of the Mount Cameroon Region

Deep green	Light green	Light yellow	White	Blue	Red	Thistle
Dense forest	Plantation	Savannah	Cloud cover	Water	Settlement	Farmland

Table 2. Educational levels of respondents in the studied villages of the MCR and their corresponding age groups

Educational Levels	Age Groups (years)				Totals	%
	Less than 30	31-45	46-60	Above 60		
No formal education	0	2	4	5	11	9.4
FSLC	6	7	4	2	19	17.0
O / Level Certificate	8	4	9	3	24	21.2
A / Level Certificate	9	6	3	1	19	17.0
University Degree	6	7	3	2	18	15.9
Other training	5	3	4	2	14	12.4
Apprentice	2	6	0	0	8	7.10
Totals	36	35	27	12	113	100
%	31.86	30.97	23.89	13.28	100	

Table 3. Respondents view on the main land uses in the study villages of the MCR.

Land use	Frequency	Percentage
Farm lands	40	35.39
Plantations	19	16.81
House construction	21	18.58

Fallow plots	17	15.04
Tourist site	10	8.85
Forest reserve	06	5.33

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Years and cover

Changes in surface cover, annual changes and % change

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571 **Table 4.**Relationship between the number of farms owned and the sizes of the farms

572 (in hectares) by respondents in the studied villages of the MCR

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Farm size (ha)	Number of farms owned				Total
	1-4	5-8	9-12	13-16	
0.045	9	0	0	3	12
0.09	11	17	0	0	28
0.27	0	41	10	1	52
0.54	0	0	13	4	17
0.81	2	0	0	0	2
≥1	1	1	0	0	2
Total	23	59	23	8	113

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578 **Table 5.**Relationship between the size of the family (individuals per household) and the number
579 farms cultivated by respondents in the study villages of the MCR.

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Family size	Number of farms owned				Total
	1-4	5-8	9-12	13-16	
1-5 persons	21	3	0	0	24
6-10 persons	1	54	0	0	55
Above 10 Persons	1	2	23	8	34
Total	23	59	23	8	113

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588 **Table 6.** Surface cover areas of different land uses of the MCR for the year 1986, 2000 and
589 2008, with cover changes and percentage change from 1986-2000 (14 yrs.), 2000-2008
590 (8 yrs.) and 1986-2008 (22 yrs.)

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												592
	1986	2000	2008	1986 to 2008	Annual Change (Ha/yr)	%	2000 to 2008	Annual Change (Ha/yr)	%	1986 to 2008	Annual Change (Ha/yr)	593 %
												594
												595
Dense forest	1993	1688	1610	-305	-21.79	-1.09	-78	-9.75	-0.6	383	-17.41	-0.87
												596
Agricultural fields	1174	1342	1074	+168	+12	+1.0	-268	-33.5	-2.5	-100	+4.55	+0.3
												598
Settlement / Bare ground	45	92	150	+47	+3.36	+7.4	+58	+7.25	+7.9	+105	+4.77	+10.6
												600

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614 **Table 7.** Tree destruction and basal area loss in ten 0.25 hectares plots in the study villages of the
615 MCR

Locations of	Altitudes	No of trees	Mean no of	Basal area	Mean basal
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farms (sites)	(metres above sea level)	damaged (0.24 ha)	trees damaged (± 2.6)	loss (m^2)	area loss ($\pm 8m^2$)
Bokwango	1062	43		43.23	
	1001	30	36.5	21.12	32.18
Bova	1108	49		67.24	
	986	40	49.0	60.86	
Bonakanda	959	61	50.5	88.62	38.57
Bimbia	87	43		75.75	
	95	55	49.0	97.41	74.74
Idenau	102	49		78.55	
	115	45		40.90	
	104	44	46.0	41.01	86.58
Total		460	46.0	614.39	58.50

LIST OF FIGURES AND PLATES

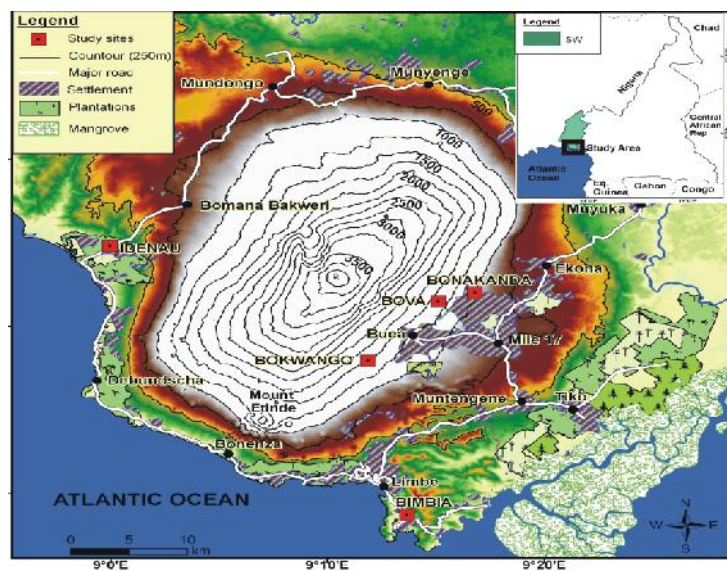


Figure 1. Map of the Mount Cameroon Region showing the study Villages

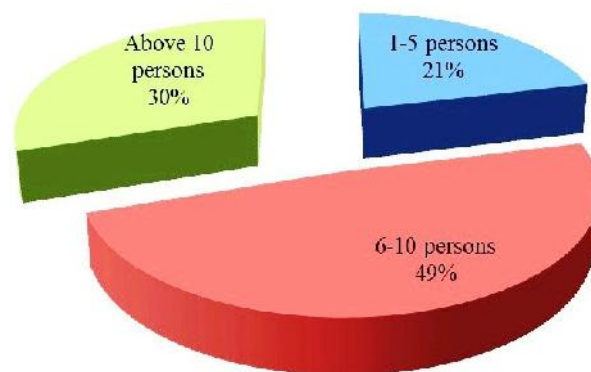


Figure 2. Number of persons per household of the respondents in the studied village

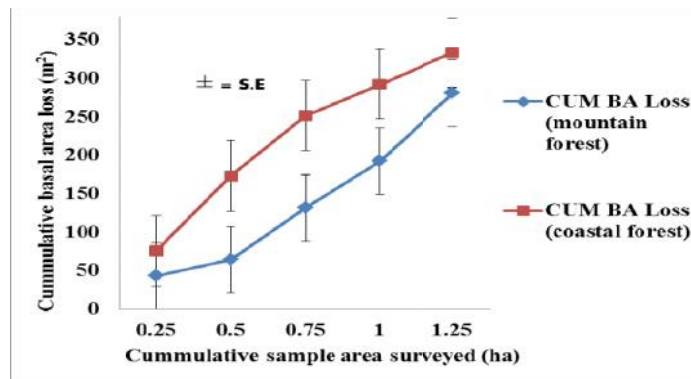


Figure 3: Cumulative basal area loss in the coastal forest, compared with that of the montane forest in the study sites

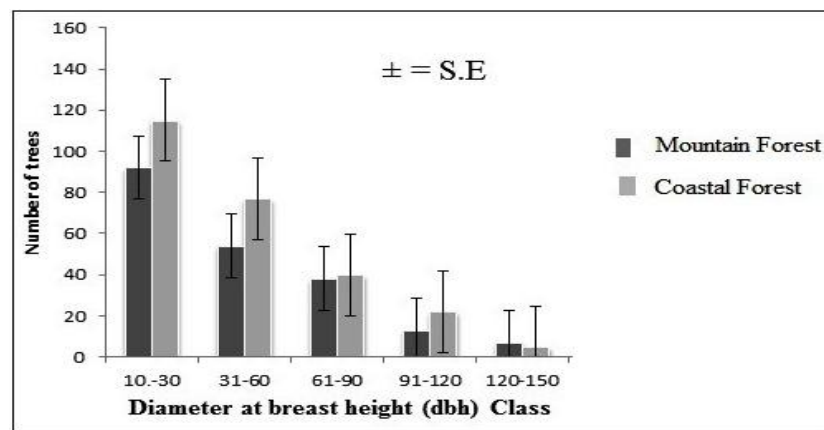
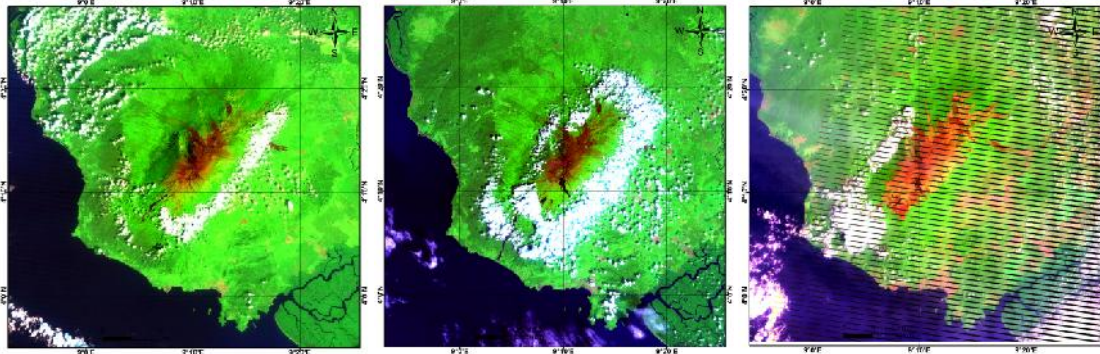


Figure 4. Diameter classes of trees destroyed between the two ecotype forests survey in the Mount Cameroon region.

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1(a) 1986

1(b) 2000

1(c) 2008

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Plate 1. Extracted optical images of land sat scenes of the Mount Cameroon Region of
(a)1986, (b) 2000 and (c) 2008

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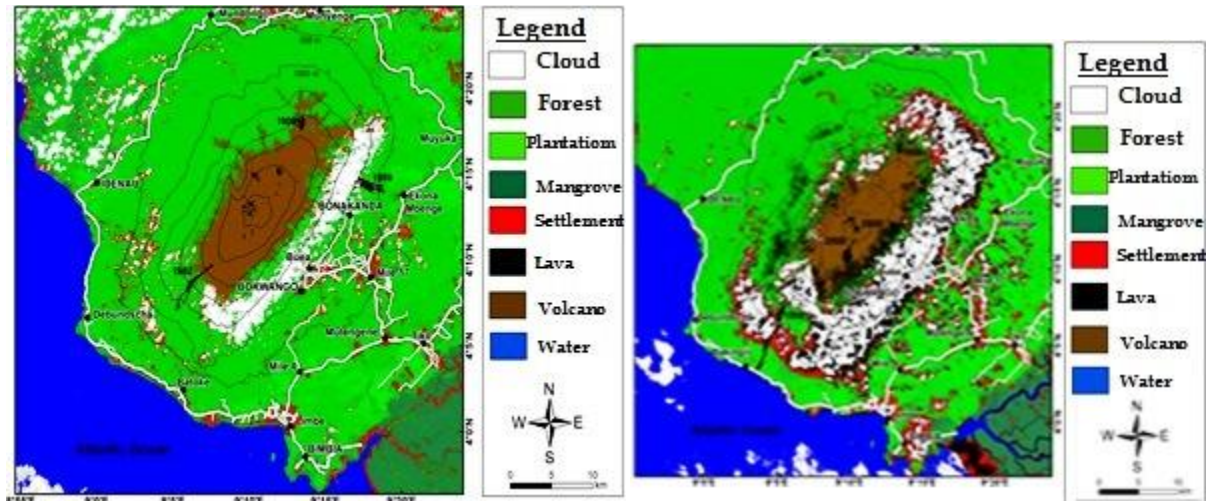


Plate 2a: 1986 classified map

Plate 2b: 2000 classified map

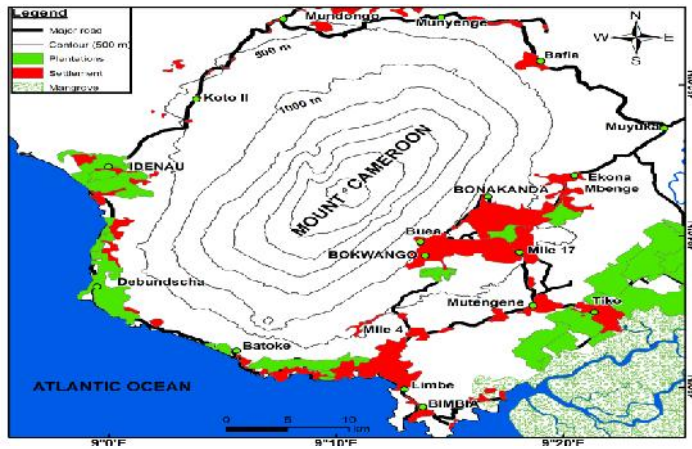


Plate 2c: 2008 settlement map
Plate 2: Classified maps of land cover of the MCR for (a) 1986, (b) 2000 and (c) 2008 settlement extract



(a) Removal of the under storey

(b) Pruning, tilling and first planting



(c) Bottom 1m tree debarked and burnt

(d) Tree species, cut for timber



(e) Abandoned wood that attracts the villages as they search for fuel wood

(f) Established cocoyam farm, all trees cut and carried away

Plate 3: Stages of farm preparation showing tree destruction, involving under storey removal (a), pruning and tilling (b), killing of pruned trees (c), logged trees for timber within the farms (d), abandoned wood in farmlands (e) and an established farm where all dried up destroyed trees had been cut down and used for fuel wood (f) in the mountain forest of the MCR.

745 APPENDIX A

746 **A1:** $IVI = RD + RBA + RF$

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749 **A2:** $RD = \frac{\text{Density of species}}{\text{Total Density}} \times 100$
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751 **A3:** $BA = \pi \left(\frac{1}{2} DBH\right)^2$

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753 **A4:** $RBA = \frac{\text{Basal area of species}}{\text{Total basal area}} \times 100$

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755 **A5:** $F = \frac{\text{N}^{\circ} \text{ of plots in which species is}}{\text{Total N}^{\circ} \text{ of plots}} \times 100$
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759 **A6:** $RF = \frac{\text{Frequency of species}}{\text{Total frequency}} \times 100$

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762 **A7:** $CVI = RD + RB$

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777 APPENDIX B

778
779 Different tree species destroyed in ten plots of 0.25 ha. each from newly opened farms, their
780 frequency (F), relative frequency (RF), density (D), relative density (RD), diameter at breast
781 height (DBH), basal area (BA), relative basal area (RBA) and importance value index (IVI) in
782 the study sites

	SPECIES	FAMILIES	F	RF	D	RD	DBH (M ²)	BA	RBA	IVI
1	<i>Aidia geniculata</i>	Icacinaceae	0.1	0.45	1	0.22	0.26	0.053	0.01	0.68
2	<i>Allophylus africanus</i>	Sapindaceae	0.2	0.91	2	0.44	0.36	0.10	0.02	1.36
3	<i>Alsodeiopsisweisse nborniana</i>	Icacinaceae	0.3	1.36	6	1.31	0.91	0.65	0.11	2.77
4	<i>Annickia chlorantha</i>	Annonaceae	0.2	0.91	4	0.87	0.88	0.61	0.01	1.87
5	<i>Anthocleistavogeli i</i>	Loganiaceae	0.2	0.91	2	0.44	0.31	0.08	0.01	1.35
6	<i>Antidesmavogenali um</i>	Phyllanthaceae	0.1	0.46	3	0.66	0.98	0.76	0.12	1.23
7	<i>Araliopsis soyauxii</i>	Rutaceae	0.1	0.46	1	0.22	0.45	0.16	0.03	0.70
8	<i>Aulacocalyxcaudat a</i>	Rutaceae	0.1	0.46	1	0.22	0.43	0.15	0.02	0.69
9	<i>Aulacocalyxtalboti i</i>	Fabaceae	0.1	0.45	1	0.22	0.37	0.11	0.02	0.69
10	<i>Baphia sp</i>	Fabaceae	0.1	0.46	1	0.22	0.32	0.08	0.01	0.68
11	<i>Bridelia micrantha</i>	Phyllanthaceae	0.5	2.26	8	1.74	1.09	0.93	0.15	4.15
12	<i>Calycosiphoniaspa thicalyx</i>	Rubiaceae	0.2	0.91	2	0.44	0.87	0.59	0.10	1.44
13	<i>Carapa parviflora</i>	Meliaceae	0.2	0.91	2	0.44	0.73	0.42	0.07	1.41
14	<i>Cecropia sp</i>	Moraceae	0.1	0.46	3	0.66	0.97	0.74	0.12	1.23
15	<i>Ceiba pentandra</i>	Malvaceae	0.2	0.91	14	3.04	7.13	39.91	6.49	10.44
16	<i>Chytranthus sp</i>	Sapindaceae	0.4	1.81	10	2.17	1.09	0.93	0.15	4.12
17	<i>Cleistopholis patens</i>	Annonaceae	0.2	0.91	5	1.09	1.86	2.72	0.44	2.44
18	<i>Coelocaryon preussii</i>	Myristicaceae	0.1	0.46	8	1.74	1.12	0.99	0.16	2.35
19	<i>Coffea sp</i>	Rubiaceae	0.1	0.46	2	0.44	0.42	0.14	0.02	0.91
20	<i>Cola</i>	Malvaceae	0.3	1.36	10	2.17	1.44	1.63	0.27	3.80

	<i>chlamydanth</i>									
21	<i>Cola flavo-volonina</i>	Malvaceae	0.2	0.91	7	1.52	0.88	0.61	0.10	2.53
22	<i>Cola laterita</i>	Malvaceae	0.2	0.91	5	1.09	0.63	0.31	0.05	2.04
23	<i>Cola marsupium</i>	Malvaceae	0.2	0.91	6	1.31	0.71	0.40	0.06	2.27
24	<i>Cola praeacuta</i>	Malvaceae	0.4	1.81	11	2.39	1.53	1.84	0.30	4.50
25	<i>Cola sp</i>	Malvaceae	0.3	1.36	5	1.09	0.66	0.35	0.06	2.50
26	<i>Crotonogynetalbotii</i>	Euphorbiaceae	0.2	0.91	2	0.44	0.41	0.13	0.02	1.36
27	<i>Dacryodes edulis</i>	Burseraceae	0.2	0.91	3	0.66	0.92	0.66	0.11	1.67
28	<i>Dacryodes klaineana</i>	Burseraceae	0.1	0.46	2	0.44	0.47	0.17	0.03	0.92
29	<i>Dead trees</i>		0.2	0.91	5	1.09	0.78	0.48	0.08	2.07
30	<i>Deinbolliapychnophyla</i>	Sapindaceae	0.2	0.91	2	0.44	0.61	0.29	0.05	1.39
31	<i>Dichostemma glaucescens</i>	Euphorbiaceae	0.3	1.36	4	0.87	0.89	0.62	0.10	2.33
32	<i>Didymosalpinx sp</i>	Rubiaceae	0.1	0.46	1	0.22	0.2	0.03	0.01	0.68
33	<i>Diogoazenkeri</i>	Olacaceae	0.2	0.91	3	0.66	1.76	2.43	0.40	1.95
34	<i>Diospyros zenkeri</i>	Ebenaceae	0.1	0.46	2	0.44	0.87	0.59	0.10	0.98
35	<i>Diospyros gabonensis</i>	Ebenaceae	0.2	0.91	2	0.44	0.76	0.45	0.08	1.41
36	<i>Diospyros turturiansis</i>	Ebenaceae	0.1	0.46	1	0.22	0.53	0.22	0.04	0.71
37	<i>Diospyros kamerunensis</i>	Ebenaceae	0.2	0.91	3	0.66	0.76	0.45	0.074	1.63
38	<i>Diospyros korupensis</i>	Ebenaceae	0.2	0.91	3	0.67	0.78	0.48	0.08	1.64
39	<i>Diospyros preussii</i>	Ebenaceae	0.2	0.91	3	0.67	0.68	0.36	0.06	1.62
40	<i>Diospyros zenkeri</i>	Ebenaceae	0.1	0.46	2	0.44	0.43	0.15	0.02	0.91
41	<i>Discoglyxanlon hexandrium</i>	Euphorbiaceae	0.4	1.81	5	1.09	1.31	1.35	0.22	3.12
42	<i>Drypetes sp</i>	Putrangivaceae	0.2	0.91	4	0.87	1.31	1.35	0.22	1.99
43	<i>Dysplasia sp</i>	Moraceae	0.6	2.7	10	2.17	1.98	3.08	0.50	5.39
44	<i>Entandrophragma cylindricum</i>	Meliaceae	0.5	2.26	12	2.61	7.54	44.63	7.26	12.13
45	<i>Ficus sp</i>	Moraceae	0.2	0.91	4	0.87	1.43	1.61	0.26	2.04
46	<i>Garcinia sp</i>	Clusiaceae	0.1	0.46	1	0.22	0.24	0.05	0.01	0.68
47	<i>Harunganamadagascariensis</i>	Clusiaceae	0.3	1.36	6	1.31	1.56	1.91	0.31	2.97
48	<i>Homalium letestui</i>	Salicaceae	0.3	1.36	4	0.87	0.87	0.59	0.097	2.32

49	<i>Hymenostegia afzelia</i>	Fabaceae	0.3	1.36	8	1.74	8.07	51.12	8.32	11.42
50	<i>Jollydoraduparquitiana</i>	Connaraceae	0.3	1.36	7	1.52	0.87	0.59	0.10	2.98
51	<i>Kigelia africana</i>	Bignoniaceae	0.4	1.81	7	1.52	2.75	5.94	0.97	4.30
52	<i>Klainedoxa gabonensis</i>	Irvingiaceae	0.1	0.46	1	0.22	0.65	0.33	0.06	0.72
53	<i>Lasianthera africana</i>	Icacinaceae	0.2	0.91	6	1.31	0.82	0.53	0.09	2.30
54	<i>Leptaulusdephnoides</i>	Icacinaceae	0.4	1.81	13	2.83	2.09	3.43	0.56	5.19
55	<i>Macaranga monandra</i>	Euphorbiaceae	0.3	1.36	5	1.09	0.98	0.75	0.12	2.57
56	<i>Macaranga sp</i>	Euphorbiaceae	0.2	0.91	3	0.66	0.97	0.74	0.12	1.68
57	<i>Massularia acuminate</i>	Rubiaceae	0.1	0.46	4	0.87	0.84	0.56	0.09	1.41
58	<i>Memecylon sp</i>	Memecylaceae	0.2	0.91	3	0.66	0.75	0.44	0.07	1.63
59	<i>Microdesmispuberula</i>	Pandaceae	0.1	0.46	1	0.22	0.26	0.05	0.01	0.68
60	<i>Microdesmis sp</i>	Pandaceae	0.2	0.91	3	0.66	0.75	0.44	0.07	1.63
61	<i>Musangacecropioides</i>	Moraceae	0.4	1.81	8	1.74	1.93	2.92	0.48	4.03
62	<i>Napoleonoea sp</i>	Lecythidaceae	0.2	0.91	3	0.66	0.68	0.36	0.06	1.62
63	<i>Oncobaglauca</i>	Salicaceae	0.1	0.46	2	0.44	0.44	0.15	0.03	0.91
64	<i>Picnanthus angulensis</i>	Myristicaceae	0.2	0.91	5	1.09	5.08	20.26	3.30	5.29
65	<i>Pleiocarpabicarpe llata</i>	Apocynaceae	0.1	0.46	1	0.22	0.18	0.03	0.01	0.67
66	<i>Polyceratocarpusp arvilflarus</i>	Annonaceae	0.2	0.91	3	0.65	2.51	4.95	0.81	2.36
67	<i>Polysia fulva</i>	Araliaceae	0.4	1.81	9	1.96	3.87	11.76	1.91	5.68
68	<i>Rauvolfiavomitorea</i>	Apocynaceae	0.6	2.72	10	2.17	2.18	3.73	0.61	5.50
69	<i>Rhabdophyllum sp</i>	Moraceae	0.2	0.91	2	0.44	0.87	0.59	0.10	1.44
70	<i>Rinoreadentata</i>	Violaceae	0.1	0.46	2	0.44	0.44	0.15	0.03	0.91
71	<i>Rinoreaoblongifolia</i>	Violaceae	0.2	0.91	2	0.44	1.56	1.91	0.31	1.65
72	<i>Rothmannia hispida</i>	Rubiaceae	0.2	0.91	2	0.44	0.69	0.37	0.06	1.40
73	<i>Santirabasalfera</i>	Burseraceae	0.1	0.46	2	0.44	0.87	0.59	0.10	0.98
74	<i>Solanum sp</i>	Solanaceae	0.3	1.36	4	0.87	0.79	0.49	0.08	2.31
75	<i>Spathodiacompan</i>	Bignonaceae	0.1	0.46	2	0.44	0.65	0.33	0.05	0.94

	<i>ulata</i>									
76	<i>Staudtiakamerunensis</i>	Myristaceae	0.1	0.46	3	0.66	0.68	0.36	0.059	1.16
77	<i>Strombosiascheffleri</i>	Olacaceae	0.1	0.46	2	0.44	0.71	0.40	0.064	0.95
78	<i>Strombosia sp</i>	Olacaceae	0.4	1.81	6	1.31	3.87	11.76	1.91	5.03
79	<i>Strombosia spl</i>	Olacaceae	0.2	0.91	2	0.46	1.06	0.88	0.14	1.48
80	<i>Strombosia sp2</i>	Olacaceae	0.1	0.46	1	0.22	0.36	0.10	0.02	0.69
81	<i>Strombosiosistetranda</i>	Olacaceae	0.1	0.46	2	0.44	1.99	3.11	0.51	1.39
82	<i>Tabenomontanabrachyantha</i>	Apocynaceae	0.2	0.91	2	0.44	0.52	0.21	0.035	1.37
83	<i>Tabenomontana sp</i>	Apocynaceae	0.1	0.46	5	1.09	2.51	4.95	0.81	2.34
84	<i>Terminalia superba</i>	Combretaceae	0.1	0.46	3	0.66	10.72	90.21	14.68	15.78
85	<i>Tremaorientalis</i>	Ulmaceae	0.3	1.36	4	0.87	0.87	0.59	0.10	2.32
86	<i>Tricalysia sp</i>	Rubiaceae	0.1	0.46	4	0.87	0.76	0.45	0.07	1.40
87	<i>Trichilia sp</i>	Sapindaceae	0.1	0.46	1	0.22	0.30	0.07	0.01	0.68
88	<i>Trichoscyphaklain ei</i>	Anacardiaceae	0.2	0.91	3	0.65	1.09	0.93	0.15	1.71
89	<i>Turreanthus africanus</i>	Meliaceae	0.4	1.81	6	1.30	1.83	2.63	0.43	3.54
90	<i>Uapaca sp</i>	Euphorbiaceae	0.1	0.46	2	0.44	4.76	17.79	2.89	3.78
91	<i>Unidentified stump (logged)</i>	-	1	4.56	49	10.66	15.67	192.8	31.37	46.54
92	<i>Uvariadendron sp</i>	Annonaceae	0.2	0.91	5	1.09	1.46	1.67	0.27	2.26
93	<i>Vernonia conferta</i>	Asteraceae	0.4	1.81	8	1.74	0.98	0.75	0.12	3.67
94	<i>Vitex sp</i>	Verbanaceae	0.2	0.91	3	0.66	0.55	0.24	0.04	1.60
95	<i>Voacanga psilocalyx</i>	Apocinaceae	0.2	0.91	4	0.87	0.65	0.33	0.05	1.83
96	<i>Warneckea jasminoides</i>	Melastomataceae	0.2	0.91	5	1.09	1.98	3.08	0.50	2.49
97	<i>Xylopia africana</i>	Annonaceae	0.5	2.26	14	3.04	7.82	48.01	7.81	13.12
98	<i>Zanthoxylon SP</i>	Rutaceae	0.3	1.36	4	0.87	1.75	2.40	0.39	2.62
TOTALS			22.1	100	460	100		614.5	100	300