Patterns of land-use change and current vegetation status in peri-urban forest reserves: the case of the Barombi Mbo Forest Reserve, Cameroon

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ABSTRACT
Creation of protected areas is a cornerstone of nature conservation. However, with increasing population, the pressure on land for agriculture increases, especially in peri-urban areas. We investigated land-use changes in a peri-urban forest reserve subject to anthropogenic influence and assessed the extent plant community structure through various indices. The results show that there is active forest conversion into farmland, and this conversion affects surrounding waterbodies as well. A new guild of species dominates under anthropogenic activity and comprises cocoa farms and mosaic forest. Cocoa Farms were more diverse (H = 3.08) than Dense Forest (H = 2.75) yet both were strikingly dissimilar with high carbon stocks in Cocoa Farm (128 Mg/ha) compared to Dense Forest (51.6 Mg/ha) indicating that the forest is highly degraded. Land cover change predictions indicate further increase in forest conversion to farmland and accommodation. Our results show that legislating protected areas needs to be accompanied by consistent monitoring, and poverty alleviation alternatives that relieve pressure from forests, if conservation is to be successful.

1. Introduction
Prior to creation of nation states, most of Africa south of the Sahara consisted of myriads of small communities practicing subsistent agriculture, and tropical zones were typically covered with pristine rainforest vegetation. The Green Revolution and active state intervention in agriculture resulted in changes to development patterns, and in consequence increased urbanization and smallholder plantation schemes. The result was inevitably, changes in the land-use patterns. Lambin et al. (2001) have shown that most land-use change is a direct result of people’s responses to economic opportunities as mediated by institutional factors. Land-use changes include changes from forest to farmland which is typically accompanied by deforestation (Carlson et al., 2012; Wickramagamage, 1998). Deforestation leads to loss of biodiversity (Brook, Sohdi, & Nq, 2003; Panditt et al., 2007), and forest specialists typically experience much higher extinction rates especially butterflies, fish, birds and mammals, vascular plants, phasmids, decapods, amphibians and reptiles (Brook et al., 2003). The response of policy makers to this species extinction has typically been the creation of protected areas such as forest reserves and national parks around biodiversity hotspots. It is estimated that 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth (Myers et al., 2000). Classically, such biodiversity hotspots are preserved within protected areas such as forest reserves, national parks and wildlife sanctuaries, and in these areas the biota is expected to experience the least human interference. Protected areas are governed by national and international legislation which is accompanied by punitive measures meant to dissuade encroachments (For example Republic of Cameroon Law No 94/01 of January 1994 and Decree No 95/55 of August 1995). For such conservation to work therefore, the rules need to be implemented and respected, but this is difficult in situations of rapid urbanization, population growth and food insecurity which characterize most peri-urban areas. The Lake Barombi Mbo Forest Reserve was declared a protected area in 1940 by order No. 17 of 1940, and subsequently declared a Ramsar Site in 2006. In spite of this, agricultural activities lingered within buffer zones around the reserve, and over time, the population of the neighbouring metropolis has increased to about half a million people, with accompanying pressure on available food sources. The problem therefore is twofold. On the one hand, conservation authorities are confident of the protected status of the forest reserve so there is little follow up; it is assumed that the mere fact that the area is “protected” is sufficient to keep it...
pristine. On the other hand the rapid urbanization in the Kumba metropolis and surrounding communities has increased pressure on the forest reserve for agricultural land as well as for settlement. While it is obvious that these pressures have resulted in changing land-use patterns, the direction of the change is not known. It is essential to assess land-use and vegetation dynamics in view of determining efficiency of conservation efforts. This can be done using satellite imagery and remote sensing techniques. The main objective of this research therefore was to assess the land-use dynamics within the Lake Barombi Mbo forest reserve between 1986 and 2014, in view of elucidating such patterns in peri-urban areas worldwide. Second, we aimed to study the community structure of the extant vegetation in view of assessing the status of conservation of this forest reserve. The results show that the Lake Barombi Mbo Forest Reserve is in an advanced state of degradation through anthropogenic land-use change, and are essential in understanding changes in land uses in protected areas in peri-urban areas across the world subject to high anthropogenic pressures.

2. Materials and methods

2.1 Description of study area

Lake Barombi Mbo is located at latitude 4°39’45.75” N, and longitude 9°23’51.63” E, in Kumba, South West Region of Cameroon (Lebamba, Vincens, & Maley, 2012) at an elevation of 301 m asl and is about 60 km NNE of the 4100 m high active Mt. Cameroon strato volcano (Fonge, 2004). It is located in the Cameroon volcanic chain and is the largest volcanic lake in this region. It is one of the oldest radiocarbon-dated lakes in Africa at about 1 million years old (Balgah and Kimengsi, 2011; Giresse, Maley, & Brenac, 1994). On old colonial maps the area was known as Elefanten Sea (Elephant Lake), but the elephants living in the area were exterminated due to the trade in ivory. The climate is typically equatorial with short dry season from December to February, a rainy season from March to November and average annual rainfall of 3,000–4,000 mm. The relative humidity is between 70 and 84% with a mean temperature range of 24–35°C. The Natural vegetation was evergreen forest characterized by an abundance of leguminous trees, and a patch of semi-deciduous forest within the evergreen forest (Giresse et al., 1994). One of the objectives of this study was to assess how this forest has changed over time. The soils are mostly thick fersialitic and hydromorphic. The lake has an approximate diameter of 2.5 km, and a maximum depth of 110 m with mean depth of 89 m and a surface area of 5 km². It is drained by a steep-sided outlet stream situated to the southeast (Cornen, Bandet, Giresse, & Maley, 1992). It has been designated as Cameroon’s second Ramsar site (Duker & Borre, 2001). As reported by Balgah and Kimengsi (2011), Lake Barombi Mbo is found within the Barombi Mbo Forest Reserve North West of Kumba (Figure 1). This forest reserve was created in 1940 (Order No.17 of 16/02/1940) in accordance with the forestry Ordinance of 1938 and more recently has assumed the status of a Forest Reserve (Law No 94/01 of January 1994 and Decree No 95/55 of August 1995).

2.2 Reconnaissance survey

This research was conducted from February to October 2014. A reconnaissance survey was carried out in both the aquatic and terrestrial ecosystems to identify the different land uses within the project area.

2.3 Land-use and land cover survey

The land-use and land cover survey were carried out to study the different land-use and land cover changes using ground truthing reference data and Geographical Information System. Geographical Positioning System (GPS) coordinates of the different land uses were recorded using a hand-held GPS (Garmin eTrex Venture). These coordinates were compared with those of land uses of the classified maps from remote sensing for verification (Lunetta et al., 1991). Land cover was studied using the Braun Blanquet method and remote sensing. In the GIS approach, land uses were categorized as forest, agricultural farm lands, water, settlements, and urban area (Anisara & Rajendra, 2008). A GIS mapping approach was used to assess the land-use changes with time. Remotely sensed Images TM, ETM of the years 1986, and 2014 were downloaded from the Global Land Cover Facility (GLCF) at 30-m resolution (Figure 2). The images were georeferenced and geocoded. These were then classified using Supervised Maximum Likelihood Parametric Classifier in ArcGIS Image Analysis Software Version 9.3. Following mapping, the Kappa Index was determined, and rates of change in the different land uses calculated mathematically.

2.4 Status of the forest reserve at present

2.4.1 Site selection for tree survey in the different land uses identified

Four transects were chosen in the terrestrial habitat around the lake. They included; Transect 1 which was an open forest characterized by slash and burn agriculture for cocoyam, plantains and banana (OF), Transect 2 which is an open forest but is characterized by huge cocoa and oil palm farms (CF). Transect 3 is
characterized by a dense forest with a notably close canopy cover and little farming was done here (DF). Transect 4 was characteristic of mosaic land, highly degraded, mostly by tree cutting, since it is very accessible comparatively (MF). The GPS coordinates (UTM coordinates) of all the plots were recorded using the eTrex Garmin GPS (Table 1).

Table 1. Coordinates (UTM) describing mid-points of all transects in the Barombi Mbo forest reserve.

| Description | Latitude | Longitude | Elevation |
|-------------|----------|-----------|-----------|
| Transect 1 (OF) | 544,975 | 516,329 | 407 |
| Transect 2 (CF) | 543,559 | 515,932 | 318 |
| Transect 3 (DF) | 543,412 | 514,665 | 348 |
| Transect 4 (MF) | 545,538 | 514,417 | 317 |

OF = Open Forest, CF = Cocoa Farms, DF = Dense Forest, MF = Forest Mosaics
2.4.2 Assessment of tree diversity and standing biomass

Four transects namely Transect 1 to Transect 4 as described above, each measuring 100 by 500 m were laid around the lake. Within each transect, four quadrats of 50 by 100 m were established 100 m apart. In each quadrat, the species were identified live by a certified Botanist and counted. Species that could not be identified in situ were taken to the Limbe Botanic Garden herbarium for proper identification and a checklist of tree species produced. Ecological indices were calculated as outlined below.

\[
Shannon \text{ diversity index } (H') = \sum_{i=1}^{n} \frac{pi \ln pi}{i},
\]

where: \(H'\) = Index of species diversity, \(pi\) = Proportion of total sample belonging to \(i^{th}\) species; \(i\) = Number of species.

\[
\text{Evenness} = H/H_{\text{max}},
\]

where \(H = \) Shannon index, \(H_{\text{max}} = \ln \text{(number of species)}\)

\[
\text{Sorensen index: } Cn = 2C/(A + B),
\]

where: \(Cn\) = Sorensen’s similarity coefficient, \(A\) and \(B\) are the number of individuals per site, \(C\) = number of species common to both sites.

Species richness \((S)\) = the number of species encountered

\[
\text{Simpson Index of dominance(D)} = \frac{(n/N)^2}{as \text{ per Simpson (1949),}}
\]

where, \(S = \) total number of species, \(N = \) total number of individuals of all the species in a given area, \(n_i = \) number of individuals of the \(i^{th}\) species of the area.

The diameter at breast height (dbh ≥ 10 cm) of the trees was measured with a diameter tape, for use in calculating volume and carbon stocks. Tree volume was determined according to Eba A’tyi (2000):

\[
\text{Volume } V = 8.872 \times (\text{DBH})^{2.278},
\]

where \(V = \) Volume and 2.278 is a constant.

Biomass and carbon stocks for the tree species were calculated using the following Allometric equations derived by Segura and Kanninen (2005):

\[
\text{Biomass: } \ln B_{\text{tot}} = c + \text{DBH}
\]

\[
\text{Carbonstock } = \text{Biomass } \times 0.5,
\]

where \(c\) = estimated coefficient = 0.76 ± 0.16 and \(a\) (estimated coefficient) = 0.00015 ± 0.000023.

2.5 Collection and handling of soil samples

Two sets of top soil were collected in triplicate within the first 5 cm from each Transect. These samples were bulked to give a sample for each plot. These samples were placed in labelled polythene bags, air dried to constant weight, and sieved to pass through a 2 mm sieve for laboratory analysis. These soil samples were analysed at the Plant and Soil Laboratory of the University of Dschang for texture, \(pH(H_2O)\) and \(pH(KCl)\), organic matter, cation-exchange capacity (CEC), macro-nutrients such as total nitrogen (N), available phosphorus (P), organic carbon, sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and heavy metals such as lead (Pb), chromium (Cr), cadmium (Cd), zinc (Zn), manganese (Mn), copper (Cu), and nickel (Ni). These analyses were done using standard methods as outlined in Murphy and Riley (1962), Cottenie, Nerloo, Velghe, and Kiekens (1982), APHA (1998), Fonge (2004).

2.6 Data analysis

Bands 7–4–2 were used to display images in standard colour composites for land-use and vegetation mapping. The maps were compared on pixel by pixel basis. Change detection of the various land cover categories was done by comparing land cover statistics. Annual rates of change of land cover types were determined by dividing the total change in cover type (in ha) within each period by the number of years between the periods. The accuracy of the classifications was assessed by comparing the classifications with reference data that is believed to accurately reflect the true land cover. The comparison may have more than a binary outcome. The Kappa Coefficient was used to summarize the results of an accuracy assessment used to evaluate land-use or land cover classifications obtained by remote sensing.

Further statistical analyses related to the ecological indicators were done at \(a = 0.05\) using Minitab version 16 statistical package. The Physicochemical data for soils, and macrophytes were tested for normality using Kolmogorov–Smirnov test, then subjected to Rank transformed ANOVA to test for variations at \(a = 0.05\) following negative tests for normality and homogeneity of variance. Ordination through Simple Correspondence Analysis was done to assess species association with the different sites, and the spatial association of the different land uses with pant ecological descriptors. Spearman Rank Correlation was done to assess relationships between the different variables. Simple correspondence analysis was used to display the spatial association of the soils and tree species.

3. Results

3.1 Land uses in the Lake Barombi Mbo forest reserve

The following land uses were identified: Mosaic forest, open forest, dense forest, urban areas, and water.
Table 2 presents the Braun-Blanquet scaling of the different land uses. The Mosaic forest was highly degraded with very little canopy cover. This zone was characterized by run-off tracks and bare ground hence we classified the forest cover as class 2 using the Braun-Blanquet method. The open forest was mostly characterized by cocoyams, plantain and cocoa farms, within which some forest trees were interspersed. Using the Braun-Blanquet method we classified it in class 4. The dense forest consisted of patches in which very little or no farming was done here and we classified it in class 2. The lake water was pale yellow-to-reddish little odour and classified as class 2. The urban settlements were very few around the Station area and Barombi Mbo village of about 40 small buildings. This category was classified in class 1 using Braun-Blanquet scaling method (Table 2).

3.2 Trends of vegetation cover change

Classified maps of 1986 and 2014 produced from extracted landsat images are shown in Figure 3. Estimates of land cover and land cover changes are presented in Table 3. Over the last 28 years, the lake surface reduced at the rate of 3.4% (0.12% per year), decreasing annually by 0.51 Ha/yr. The surface area of the lake water has reduced from 426 Ha to 411.7 ha, a total change of 14.3 Ha. The area lost is typically converted into forest mozaics. The dense forest has dropped by 2007.1 Ha in the last 28 years, reducing yearly by 71.68 Ha at the rate of 90.4% (3.23% yearly. Loss of dense forest is typically a result of conversion into open forest and forest mosaics (Figure 3). Thus the Open forest increased at the rate of 366.3% (13.08% per year) with an annual increase of 31.48 Ha/yr. The Mosaic land

Table 2. The Braun-Blanquet scaling of land uses in the Lake Barombi Mbo forest reserve.

| Percentage range of Land cover | Class | Land cover category |
|--------------------------------|-------|---------------------|
| <1–5%                          | 1     | Urban               |
| 6–25%                          | 2     | Dense Forest        |
| 6–25%                          | 2     | Mosaic forest       |
| 6–25%                          | 2     | Water               |
| 51–75%                         | 4     | Open forest         |

Figure 3. Classified maps of Lake Barombi Mbo forest reserve in 1986 (top) and 2014 (bottom) showing land-use changes.
increased from 72 to 349.4 Ha at the rate of 385.3% (13.76% per year) experiencing an annual increase of 9.9 Ha/ yr. Settlements (Urban) are gradually increasing at the rate of 770% experiencing a total increase of 77 Ha from 1986 to 2014 with an annual increase of 2.75 Ha/ yr (Table 3). For the 1986 accuracy classifications, the producer accuracy for Water and Open forest was 100% and settlement had the smallest accuracy (15%), while the User accuracy was highest in settlements and lowest in the Mosaic land. In the 2014 classification matrix, the producer accuracy was 100% in the Water, Dense forest, Mosaic land and was lowest in the settlement (93%) while the User Accuracy was highest (100%) in Mosaic, settlement and lowest in the Dense forest (Table 4).

### 3.3 Soil characteristics

Results on soil characteristics are presented in Table 5. The soils are sandy loam soils, and organic carbon was highest in Cocoa farms (5.98%) and dense forest. Total nitrogen concentration was highest in Dense forest (0.23%) and lowest at cocoa farms (0.04%) while phosphorus was highest in Cocoa farms (60.78 mg/kg). Cation-exchange capacity was similar across sites. Cocoa farms had the highest carbon to nitrogen ratio (149.5) and this was lowest in the dense forest (24.61) (Table 5). Concentrations of Na, Mg and K varied significantly across sites. Sodium concentrations range from 0.04 to 0.24 mg/kg, while Potassium concentrations ranged from 0.4 to 2.4 mg/kg. Magnesium concentrations ranged from 0.01 mg/kg (cocoa farms) to 0.42 mg/kg (Mosaic forest). Concentrations of cadmium (19.4), Manganese (0.07), Nickel (3.48), and Lead (4.24) were significantly higher in the cocoa farms compared to the other land uses.

### 3.4 Community structure of extant vegetation in the different land uses

From the forest survey, 277 trees of 42 species were identified in 21 families, with Moraceae, Fabaceae and Euphorbiaceae being the most species-rich (five, four, and four species respectively). The Moraceae, Apocynaceae, Meliaceae and Anacardiaceae had the highest abundance (37, 34, 29, and 29 individuals, respectively) and the families with the least abundance were Rubiaceae, Lauraceae, and Simaroubaceae (2, 2, 1, and 1 trees, respectively). Of the 42 species, Pseudospondia microcarpa is the most abundant species (9.39%), followed by Musanga cecropioides (8.3%), while the least abundant species include Camarium schweinfurthii, and Distemonanthus binthamianus with relative abundances of 0.36% each.

### 3.5 Diversity indices across the study sites

The Dense Forest had the highest abundance while Cocoa Farms were the most species rich and most diverse. The Mozaic Forest had the lowest number of species and was also the least diverse (Table 6). Sorensen similarity index showed that the plots were very dissimilar with highest similarity (0.57) occurring between Open Forests and Cocoa farms.

### 3.6 Wood volume, biomass and carbon stock in tree species of the different land uses

Across the study site, the standing volume of wood was 3400.6 m$^3$/Ha with an average total biomass of 159.17 Mg/ha and corresponding carbon stocks of 79.6 Mg/ha. The highest wood volume (1162.81 m$^3$/Ha) was in the Open Forest, followed by Cocoa Farms which was most species rich. Cocoa farms had the highest biomass and carbon stocks. Mozaic forest had the lowest total biomass and carbon stock per hectare (Table 7).

### 3.7 Correlation and ordination results

From the four transects, 22 species were cosmopolitan across sites, and of these, five species were cosmopolitan among all the plots, while eight species occurred in three plots. Twenty species were Site specific. Figure 4 shows the associations between edaphic, anthropogenic and plant community parameters. Correlation analyses did not show any relationship between the edaphic and plant community parameters. Simple Correspondence Analysis displays...
Table 5. Soil characteristics in the land uses of the Lake Barombi Mbo forest reserve in 2014.

| Site  | Soil Type | OC (mg/kg) | OM (mg/kg) | CEC (Cmol/kg) | P (mg/kg) | pH (H2O) | CN  |
|-------|-----------|------------|------------|----------------|-----------|----------|-----|
| CF    | SL        | 5.98a      | 1.26c      | 0.04d          | 20.00ab   | 60.78a   | 6.40c| 149.50 |
| MF    | SL        | 3.45bc     | 6.03b      | 0.06bc         | 22.14a    | 23.95b   | 6.20c| 75.10  |
| OF    | SL        | 3.56b      | 6.12b      | 0.088          | 20.49ab   | 12.05c   | 6.20c| 44.50  |
| DF    | SL        | 5.66a      | 10.71a     | 0.23a          | 20.49ab   | 20.20b   | 6.30c| 24.61  |

Table 6. Diversity indices with respect to the different land uses at the Lake Barombi Mbo forest reserve.

| Transect | S  | N  | D  | H  | E  | S/N |
|----------|----|----|----|----|----|-----|
| 1 (OF)   | 26.00 | 74.00 | 8.69 | 2.72 | 0.84 | 2.85 |
| 2 (CF)   | 27.00 | 61.00 | 17.15 | 3.08 | 0.93 | 2.26 |
| 3 (DF)   | 19.00 | 81.00 | 13.53 | 2.75 | 0.94 | 4.26 |
| 4 (MF)   | 10.00 | 61.00 | 8.29 | 2.19 | 0.95 | 6.1  |

Table 7. Wood volume, total biomass and total carbon stock of the trees in the different land uses of the Lake Barombi Mbo forest reserve.

| Transect | Total volume for transect (m³/ha) | Volume (m³/ha) | Total Biomass (Mg/ha) | Total Carbon Stock (Mg/ha) |
|----------|----------------------------------|----------------|-----------------------|---------------------------|
| 1 (OF)   | 2325.62                          | 1162.81        | 186.01                | 93                        |
| 2 (CF)   | 2036.90                          | 1018.45        | 256.93                | 128                       |
| 3 (DF)   | 1042.77                          | 521.39         | 103.23                | 51.6                      |
| 4 (MF)   | 1395.90                          | 697.95         | 90.50                 | 45.3                      |
| Total    | 6801.19                          | 3400.6         | 636.67                | 317.9                     |
| Mean     | 1700.30                          | 850.15         | 159.17                | 79.5                      |

4. Discussion

Identified land uses include mosaic forest (MF), open forest (OF), dense forest (DF), urban areas, and water. Degraded zones like MF and OF are characterized by high anthropogenic activity including cocoa, plantain and cocoyam farms. This is characteristic of most rural and peri-urban areas in developing countries where forest conversion is typically for agricultural production (Akoto, Asare, & Gyabaa, 2015; Fonge, Bechem, & Juru, 2015; Houghton, 2012). The forests around the lake have been converted over time to smallholder cocoa and palm plantations as well as patches of subsistence crop farms. Trends of vegetation change and land-use changes showed a loss of Lake Surface to forest mosaics, and dense forest has been converted to open forest and forest mosaics. These mosaics are characterized by cocoa, plantain and cocoyam farms, which have intensified in spite of the fact that the site is a protected forest reserve. This is consistent with trends reported by Fonge et al. (2015) in the neighbouring Mt Cameroon Region, which also harbours a National Park and is a biodiversity hotspot. Indeed, these trends of conflicts between food production and conservation objectives have been predicted to increase (Laurance, Sayer, & Cassman, 2014). This increase in anthropogenic encroachment into protected reserves is driven by factors such as increased populations and corresponding demand for food, transportation networks and technology that change the pattern of farming from the initial subsistent basis. With the changes in land uses from initially pristine dense tropical rainforest, soil characteristics of the different land uses have equally changed to reflect the use pattern. High soil carbon, phosphorus, and heavy metal concentrations are expected in cocoa farms which have a high turnover of slow decomposing litter (Beer, 1988; Dawoe, Isaac, & Quashie-Sam, 2010) and make use of large quantities of agricultural inputs rich in phosphates and heavy metals (Wimalawansa & Wimalawansa, 2014) in cocoa farms while higher total nitrogen is expected in dense forest.

the spatial patterns of species association with edaphic parameters at the different sites. From the correspondence analysis, the first component contributes 98.62% of the observed spatial patterns. Most community parameters like abundance, richness, biomass, carbon stocks, and diversity indices have high loadings at the Open Forest with which they are most associated, while the Dense forest, Cocoa farms, and Mosaics are characterized by cocoa, plantain and cocoyam farms. This is characteristic of most rural and peri-urban areas in developing countries where forest conversion is typically for agricultural production (Akoto, Asare, & Gyabaa, 2015; Fonge, Bechem, & Juru, 2015; Houghton, 2012). The forests around the lake have been converted over time to smallholder cocoa and palm plantations as well as patches of subsistence food crop farms. Trends of vegetation change and land-use changes showed a loss of Lake Surface to forest mosaics, and dense forest has been converted to open forest and forest mosaics. These mosaics are characterized by cocoa, plantain and cocoyam farms, which have intensified in spite of the fact that the site is a protected forest reserve. This is consistent with trends reported by Fonge et al. (2015) in the neighbouring Mt Cameroon Region, which also harbours a National Park and is a biodiversity hotspot. Indeed, these trends of conflicts between food production and conservation objectives have been predicted to increase (Laurance, Sayer, & Cassman, 2014). This increase in anthropogenic encroachment into protected reserves is driven by factors such as increased populations and corresponding demand for food, transportation networks and technology that change the pattern of farming from the initial subsistent basis. With the changes in land uses from initially pristine dense tropical rainforest, soil characteristics of the different land uses have equally changed to reflect the use pattern. High soil carbon, phosphorus, and heavy metal concentrations are expected in cocoa farms which have a high turnover of slow decomposing litter (Beer, 1988; Dawoe, Isaac, & Quashie-Sam, 2010) and make use of large quantities of agricultural inputs rich in phosphates and heavy metals (Wimalawansa & Wimalawansa, 2014) in cocoa farms while higher total nitrogen is expected in dense forest.
With respect to the extant vegetation in the different land uses, the families Moraceae, Fabaceae and Euphorbiaceae are most species-rich families and Moraceae had highest abundance, and this trend is characteristic of tropical rainforests. In terms of species, *Pseudospondia microcarpa* and *Musanga cecropioides* are most abundant; these species are indicators of disturbed forests (Gourlet-Fleury et al., 2013; Mc key, 1988) and have been found in monoculture plantations established after forest clearance (Akoto et al., 2015). They are indicative of high levels of anthropogenic activities in the forest that is expected to be pristine.

In terms of abundance of species, Dense Forest had the highest abundance but conversely Cocoa Farm was richer in species. Probably, disturbances in the process of creating cocoa farms result in conditions suitable for a new guild of species to emerge. Bobo et al. (2006) have shown that new guilds of species develop across a gradient of forest conversion to farmland in South Western Cameroon. Where understorey species dominate in cocoa farms, species richness could indeed be higher than in climax forest stands, but the structure would be different, dominated by understorey species as opposed to the original climax forest species. This was evident in the high dissimilarity between transects that reflected different land uses; such dissimilarity as shown by the Sorensen Indices, can only be explained by differences in species composition. Therefore changes in land uses are accompanied by changes in species composition. Incidentally, Dense Forest had the lowest wood volume and carbon stock per hectare compared to Open Forests and Cocoa Farms. This is possibly a result of pre-eminence of high-DBH species like *Musanga cecropioides*, *Ceiba pentandra* and *Ricinodendron heudelotii* in the disturbed/modified land uses compared to Dense Forest (Gourlet-Fleury et al., 2013). Equations for biomass by Segura and Kanninen (2005) are based on DBH, and might overestimate carbon stocks since wood densities of the component species are not considered. When plant community parameters were correlated with edaphic factors, no relationships were established, and while ordination showed that Open Forest is associated with most community parameters, none of the sites is associated with high loadings of edaphic factors. Thus the observed vegetation patterns in the different land uses as at present cannot be linked to any edaphic factors suggesting that anthropogenic activities are most responsible for these changes. Such anthropogenic activities are unexpected in protected areas; hence the protective measures are ineffective. The Lake Barombi Mbo Forest Reserve is however a microcosm of other reserves in peri-urban areas worldwide, where population growth, food insecurity and rapid urbanization are defeating conservation efforts. Cernia and Schmidth-Soltau (2006) have proposed a pro-poor conservation strategy that pursues “double sustainability,” by promoting biodiversity conservation and livelihoods of the local population, as a means of reducing anthropogenic encroachment into protected areas.

5. Conclusion

The aims of this study were (1) to assess the land-use dynamics within the Lake Barombi Mbo forest reserve between 1986 and 2014, and (2) to study the community structure of the extant vegetation in view of assessing the status of conservation of this forest reserve. We found that over time, the predominant dense forest vegetation expected of a forest reserve has been converted to new
Acknowledgements

We thank the Cameroon government for research support through the Research Modernisation Allowance, and the field guides who assisted in data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was partly funded by the Cameroon Government through the Ministry of Higher Education’s Research Modernisation Allowance Scheme. Cameroon Ministry of Higher Education Research Modernisation Allowance.

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