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Ecological Processes

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Floristic composition, growth temperament and conservation status of woody plant species in the Cameroonian tropical rainforests

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Abstract

Introduction: Cameroon's tropical rainforests are nowadays strewn with rural forests maintained by local populations; however, these forests are not officially recognized in the non-permanent forest domain. Rural forests are non-delimited riparian areas within the dense moist forest, reserved for rural housing, agricultural activities and agroforestry practices, freely exploited by the local communities for their livelihood without them having any rights to artisanal and commercial logging. This study aimed at contributing to the flora knowledge and the conservation state of woody plant species in rainforests. The study was carried out in two rural forests located in the Eastern and Southern agroforestry zones of Cameroon.

Methods: The method adopted for floristic inventories combined a fixed area sampling unit and a variable area sampling unit. Woody individuals with diameter at breast height (dbh) < 3.2 cm were counted and shrubs of 3.2 ≤ dbh < 10 cm were measured to analyse the understorey, while trees with dbh ≥ 10 cm were measured and identified to characterize the canopy.

Results: In the Essiengbot-Mbankoho rural forest in Eastern Cameroon, 468 species belonging to 61 families were recorded in the understory while 227 species belonging to 53 families were identified at the canopy level. A total of 40 (7.68%) threatened species, 18 (3.45%) Near Threatened species and 408 (78.31%) Least Concern species were recorded. In the Nbgwassa-Opkweng rural forest in Southern Cameroon, 534 species belonging to 64 families were identified in the understory while 225 species belonging to 43 families were recorded in the canopy. A total of 54 (9.69%) threatened species, 25 (4.49%) Near Threatened species and 421 (75.58%) Least Concern species were identified in this forest. Shannon's diversity indices were above five in the understories and canopies of both forests. Shade-bearer species were the most represented in the understories while the non-pioneer light-demanding and shade-bearer species were the most abundant in the canopies.

Conclusions: Despite the influence of slash-and-burn agriculture and subsistence farming practices, rural forests managed by local populations provide opportunities for preserving plant biodiversity. However, the presence of threatened species, pioneer species and non-pioneer light-demanding species in these forests is an indicator of moderate and man-induced disturbances that, in the absence of a forest management plan or sustainable management, may threaten this biodiversity. Legal management of rural forests could help in limiting the anthropogenic activities and pressures on community forests.

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Introduction

The Congo Basin forests are sources of livelihood, essential for the well-being of humanity (FAO 2005). Their immense biodiversity generates a variety of natural resources, which help to sustain the livelihood of local communities (Kumar et al. 2006). They produce goods and services necessary for the population's well-being by providing food, medical products, construction materials, wood energy and timber. Forests also serve as habitat for many animal and plant species (Fraticelli et al. 2013). Deforestation and forest degradation in the Congo Basin have considerably increased in recent years (Megevand 2013). The annual rate of forest degradation has been estimated to be 0.09% between 2000 and 2005 (Ernst et al. 2013), whereas the rate of deforestation increased to 0.23% per year within the period of 2000–2010 (FAO 2011). The disappearance of forests threatens the livelihoods of local populations, in particular those who obtain most of their income from forest products (Oumba 2007). According to Danquah (2016), deforestation on community land results from land insecurity and weak property rights. As a result, forest management and conservation policies have been adopted by various countries in Central Africa to protect forests and strengthen the rights of local peoples. In Cameroon, the zoning plan has become a key tool of the management model of forested areas (Karsenty 1999). Established in 1995, the zoning plan defines multi-purposed zones where population activities are allowed (Nguiffo 2001). This multi-purposed zone is an unassessed agroforestry territory that occupies most of the local land in dense forests regions. The agroforestry zones are part of the non-permanent forest estate that can be used for other purposes than forestry (Tchouto 2004). Therefore, agroforestry zone includes areas of rural forestry intended for agricultural activities for local communities, community forests and possibly private forests (Dkamela 2011). Rural forestry includes forestry, agroforestry and silvopastoral practices linked to a family or village activities in rural areas (Sonwa et al. 2001).

Rural forest is a non-delimited space located in the non-permanent forest domain without being identified as a community forest or a private forest. Still, it corresponds to forest land reserved for rural housing, agricultural activities and agroforestry practices, freely exploited by the local communities as part of their livelihoods. The main forestry activity in this rural space is subsistence agriculture, mainly for self-consumption and the village household's economy. Agricultural activities are essentially based on the association of food crops and perennial cash crops with forest trees to form forest-crop mosaics. Agroforestry practices carried out by farmers aim to harmonize the intensification of agricultural activities along with the conservation of natural species (Michon and Bompard 1987). All the local communities freely exploit the rural forest, without any industrial and commercial logging rights. Customary rights were restricted to the subsistence use of forests and trade-in forest products became no longer authorized without an individual permit from the government (Lescuyer 2013). This forest is mostly managed according to traditional local rules without an explicit development plan (Poissonnet 2005). Traditional rights are exercised freely as long as the beneficiaries maintain their geographical proximity to the forest, do not harm any protected species and only take the products necessary for their well-being (Topa et al. 2010). Rural forests constantly adapt to local needs and global conditions and evolve according to the change in requirements without necessarily or drastically changing their forest structures and functions (Michon et al. 2013).

However, in addition to the practice of slash-and-burn agriculture, local populations carry out hunting, fishing, firewood extraction, and harvesting of non-timber forest products in rural forests. Reconciling these human activities, vital for rural communities, and preserving biodiversity, is one of the main challenges for the sustainable management of tropical rainforests today. The ever-increasing needs of the populations living along the forest margin are nowadays coupled with a strong external demand for land designated for large-scale agricultural plantations (Djiofack 2018). This part of the dense forest is regularly subjected to human activities and presents secondary exploited formations with an influence on woody species. The forested area that results from rural practices is made up of secondary forests, fallows of different ages, food-producing field's plots, swampy areas, cocoa and coffee plantations, all scattered within the dense moist forest (Kengne 2019). Increases in agricultural plots coupled with repeated clearing and the reduction of fallow periods in rural forests can lead to changes in floristic composition and plant structure, influence the growth status of the woody vegetation or the growth behaviour of plants, and be a threat to the existing plant resources. In settling this rural forest, which combines the human-change effect of spaces by repeated practices (Michon 2004), it is difficult to have a clear idea of the plant species composition, the effective growth temperament of woody plants and the number of threatened plants in this environment.

Anthropogenic ecosystems can in some cases be considered analogous to natural habitats, and may present opportunities for biodiversity conservation (Lundholm and Richardson 2010). Biodiversity conservation efforts have mainly focused on "natural" protected areas (Lomolino 1994), while agricultural areas and locally exploited forest areas, such as rural forests, harbour biodiversity that needs to be preserved for subsistence and sustainable use. The biodiversity in agricultural areas is not without value, it provides, among other things, many agronomic services (Altieri 1999; Clergué 2008). Therefore, the sustainable management of rural forests represents a major concern, both for the local populations who withdraw most of the resources for their survival from these forests, and for the authorities in charge of forests whose priority is to preserve biodiversity. Research, development and teaching activities have shown that it is possible to revitalize the management of these agroforestry systems at the farm and village community level (Smektala et al. 2005). This work is a contribution to the knowledge of the rural forests' flora and the conservation state of woody plant species in rainforests to increase the sustainable management of plant biodiversity. More specifically, we: (i) determined the floristic composition of rural forests; (ii) identified the dominant plant groups according to their growth ratio with respect to light; and (iii) assessed the conservation status of woody plant species under human activities.

Materials and methods

Study area

The study was carried out in two rural forests sites located in the agroforestry zone of the Eastern and Southern Regions of Cameroon (Fig. 1). The agroforestry zone is approximately 10 km wide, with 5 km on either side of the main road (Ngoufo et al. 2012). The rural forest in the Eastern Region of Cameroon extends from the Essiengbot village to the Mbankoho village, at 28 km north of

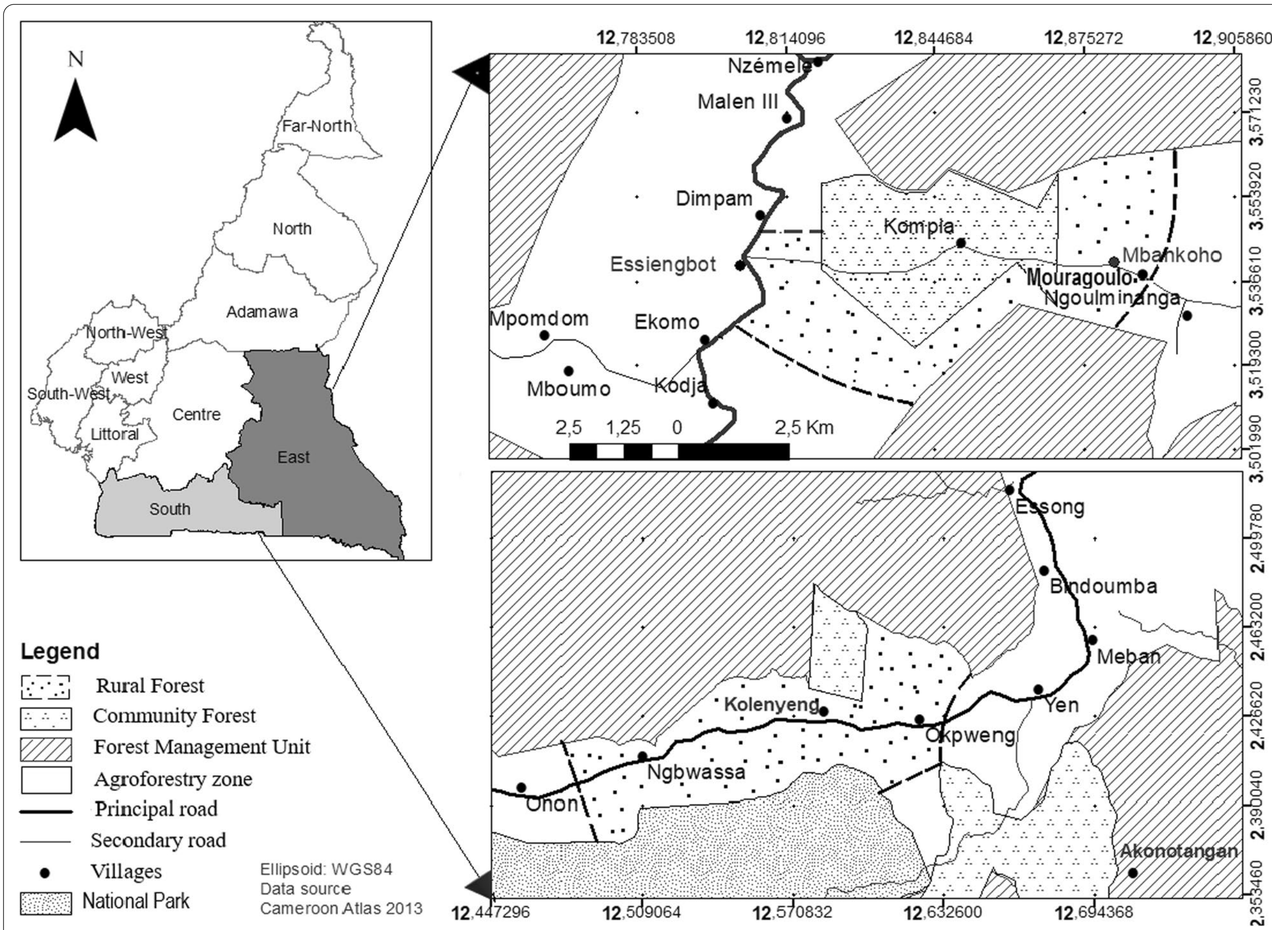

Fig. 1 Map showing the location of the study areas in Cameroon: Essiengbot-Mbankoho rural forest in the East Region, Nbgwassa-Opkweng rural forest in the South Region

the Dja Fauna Reserve (DFR). This study area is located between latitudes 3°30′–3°35′ N and longitudes 12°45′–13°22′ E. The climate on the northern periphery of the DFR is an equatorial humid type, characterized by four seasons, including two rainy seasons and two dry seasons (De Wachter 1995). The mean annual temperature is 23.5 °C, with minimum average monthly temperatures of 22.8 °C and maximum average monthly temperatures of 24.6 °C (Delving 2001) while the average annual rainfall ranges from 1500 to 1700 mm (Suchel 1987). The relief is based on the Precambrian formations of the lower Dja series, made up of shallow valleys with hills whose average altitude varies between 500 and 700 m. The soils are of red ferralitic type, strongly desaturated, with indurated and deep ferruginous concretions (Ekodeck 2002). Due to their acidity and low mineral content, these are not very fertile soils. However, the permeability of these clay-sandy soils provides the necessary fertility for food and cash crops. The Essiengbot, Kompia and Mbankoho villages from the northern periphery of the Dja Fauna Reserve fall in the transitional zone between the semi-deciduous rainforest with Sterculiaceae (now Malvaceae) and Ulmaceae (Cannabaceae), and the evergreen moist forest (Letouzey 1968). The current forest on the northern periphery of the Dja Fauna Reserve is being invaded by species found in the semi-deciduous forest. Gregarious formations of *Coula edulis* (Coulaceae) or *Gilbertiodendron dewevrei* (Fabaceae) can be observed (MINFOF 2011). The detailed vegetation typology consists of forests on rocks (5%), forests on hydromorphic soils (20%) and forests on firm land (75%) (Sonké 1998).

The second rural forest site located in the Southern Region of Cameroon stretches from the Nbgwassa village to the Opkweng village on the northern periphery of the Kom National Park-Mengamé Gorilla Sanctuary complex (Fig. 1). This study area is between latitudes 2°22′–2°28′ N and longitudes 12°30′–12°40′ E. The climate is an equatorial Guinean type, characterized by four seasons, including two dry and two rainy seasons that alternate throughout the year. The average annual temperature is 24.9 °C, with minimum average monthly temperatures of 23.6 °C and maximum average monthly temperatures of 26.5 °C (Anonymous 2004; Sock and Soua 2004). The average annual rainfall varies from 1500 to 1600 mm (Suchel 1987). The low-marked relief is presented in an indented plateau of valleys with several hills whose altitude ranges between 500 and 700 m. The ferralitic soils are highly desaturated with yellow facies, indurated depth and hydromorphic. The dominant soils of moist dense forests are acidic, poor in nutrients and have low organic matter content (Vallerie 1995). Under these conditions, shifting slash-and-burn agriculture is widely practised. The vegetation on the northern periphery of the Kom National Park-Mengamé Gorilla Sanctuary complex belongs to the mixed forest. Plant formations encountered there consist of species from the semi-deciduous and evergreen rainforests (Letouzey 1968, 1985). Logging and slash-and-burn agriculture have degraded the forest. The main consequence of anthropogenic activities in the area has been the transformation of forest landscapes into secondary plant formations. Affected environments, i.e. mosaics of crops, degraded forests, fallow lands and forest recruits allowed the settling of some species of semi-deciduous forest than those of evergreen rain forest (Letouzey 1985). The vegetation physiognomy of the Nbgwassa, Nkolenyeng and Opkweng villages showcase more of the elements of the semi-deciduous forest, even though the evergreen forest is the primary formation of the southern region.

Two main Bantu ethnic groups, who are sedentary and traditional cultivators, are found in our study area. The populations of the villages in the East Cameroon belong to the Badjoués ethnic group, while those in the South Cameroon villages belong to the Fangs ethnic group. The Baka Pygmies are also present in the different villages, but are a minority. These rural populations live mainly from shifting slash-and-burn agriculture, non-timber forest products, wild fruit gathering, hunting, traditional fishing and artisanal logging (Gockowski et al. 2004). Their agricultural activities are based on food and cash crops such as cocoa, coffee and to a lesser extent, palm oil. In general, the population density is very low, between 1.5 and 2.8 inhabitants/km^2 (De Watcher 2001).

Data collection

Sampling procedure

The method adopted for the floristic inventories combines a fixed area sampling unit and a variable area sampling unit laid out on the same 40-m-long transect. The fixed area sampling method consisted of setting up a 5 m × 40 m rectangular plot. The plot was then subdivided into ten 2.5 m × 4 m quadrats arranged in alternate rows around the 40 m central transect or baseline. Within each quadrat, the woody species found were recorded and identified. All woody individuals of diameter at breast height (dbh) < 3.2 cm and height ≥ 0.5 m were counted while shrubs of 3.2 ≤ dbh < 10 cm were measured. The variable area sampling method, developed and detailed by Sheil et al. (2003), consists of realizing a plot of 40 m in length and variable width. The plot which represents a floristic survey was subdivided into eight subplots of 10 m width each, but of variable length and orthogonal to the 40 m central transect. The length of each subplot was determined by the position of the fifth-most distant tree from the baseline. If five trees were identified within 20 m from the baseline, the subplot length was the distance to the fifth tree, whereas if less than five trees were encountered, the subplot length was taken as 20 m (Nath et al. 2009). In each subplot, trees with dbh ≥ 10 cm were measured at 1.3 m above ground.

The woody species inventory was carried out in randomly selected plots. A total of 80 plots covering 5.75 ha were sampled. The distance between two plots was more than 500 m. We considered understory species as all those individuals < 10 cm in diameter and height ≤ 15 m, completely overtopped by trees close to the canopy, while canopy species were trees of dbh ≥ 10 cm and height > 20 m, with crowns exposed to direct sunlight. Species collected during floristic inventories were identified by comparison with specimens from the National Herbarium of Cameroon. Taxonomic nomenclature adopted for the flora was based on the families classification established by the Angiosperm Phylogeny Group (APG III 2009).

Data analysis

Data processing and statistical analysis

Data were managed using Microsoft Excel and analysed using SPSS 18.0 software. The floristic composition of each studied forest was obtained by determining the total number of species, genera and families. The Shannon index and the Pielou's evenness index were computed to quantify the species diversity and assess the species distribution within the plant community. The Shannon index (H') was calculated using the formula: $H' = -\sum_{i=1}^{S} \frac{N_i}{N} \times \log_2\left(\frac{N_i}{N}\right)$, where N_i is the number of individuals of species i, and N the total number of individuals of all species. The evenness index (E) was expressed by the equation: $E = \frac{H'}{\log_2 S}$ with H' = the Shannon index; S = the total number of species in all the plots sampled. Stem density and the basal area were also calculated to compare the woody vegetation's structure. The density (D) was determined by the number of stems per hectare according to the formula: D = N/S, where N is the total number of stems counted and S is the total area of the plots in ha. The basal area (BA) expressed in m^2 ha^{-1}, was calculated according to the formula:

$BA = \frac{\sum \frac{\pi D^2}{4}}{S}$, where D is the diameter (m) of all individuals belonging to a particular species taken at 1.3 m from the ground, and S in ha is the total area of all surveyed or sampled plots.

The importance of each species within the sampled forest was determined with the Importance Value Index (IVI) of species of Curtis and McIntosh (1950). This index expressed in percentage was calculated using the following formula: IVI = Der + Dor + Fr, where Der is the relative density, Dor the relative dominance, and Fr the relative frequency of species. The importance of each family in the entire sampling unit was determined from the Family Importance Value index (FIV) of Mori et al. (1983). The family importance index expressed in percentage was calculated by the formula: FIV = Dir + Der + Dor, where Dir is the relative diversity, Der the relative density, and Dor the relative dominance of each family. The relative values of frequency, density, dominance and diversity were computed according to the formulae of Cottam and Curtis (1956) and Mori et al. (1983). The importance value indices allow us to identify dominant species and families with high ecological value within the vegetation. We considered species with IVI ≥ 10% and the families with FIV ≥ 10% as having strong ecological importance in the environment.

All recorded woody plant species were classified according to their ecological growth (with respect to light requirement) into three distinct classes: shade-bearers, non-pioneer light demanders and pioneers (Hawthorne 1993). Pioneers (P) are species requiring full light conditions throughout their life cycle; Non-pioneer light demanders (NPLD) are species able to recruit in understories, but needing light to grow up to the canopy; Shade-bearers (SB) are species able to recruit and grow in shade conditions (Gourlet-Fleury et al. 2013), they are shade-tolerant species. The different ecological growth temperaments with respect to light have been attributed to woody species based on the work of Hawthorne (1993, 1995, 1996), then completed by those of other authors such as Tchouto (2004), Beina (2011) and Kengne (2019). The numbers of pioneer, non-pioneer light-demanding and shade-bearer/tolerant species were determined in the overall species recorded and identified. The percentages of individuals of these three temperaments were calculated in relation to the total number of individuals. A descriptive statistical analysis allowed us to compare the different plant groups according to their light requirements. The Pearson's Chi-square (χ^2) test was performed to compare the percentages and to determine the significance level of potential differences in light requirements. We considered differences significant when P was less than 0.05.

The management and conservation status of plant biodiversity in rural forests was assessed using the conservation status of plant species of the International Union for Conservation of Nature (IUCN). The conservation status has been assigned to each plant species based on information from the global threat assessments provided by IUCN (2011), IUCN (2012a, 2012b). The species statuses were obtained through the online consultation of the Red List of Threatened Species published by IUCN (2021). The works on the Red Lists of the plants of Cameroon by authors such as Tchouto (2004), Onana (2011), Onana and Cheek (2011), have also allowed us to determine the conservation status of plant species and were used to calculate the percent of threatened species. The IUCN Red List categories used in this study are: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species are those listed as threatened in the IUCN Red List of Threatened Species (IUCN 2021).

Results

Floristic composition, species diversity and vegetation structure

A total of 468 species of dbh < 10 cm belonging to 226 genera and 61 families were identified in the understory of the Essiengbot-Mbankoho rural forest. The Shannon index was 6.98 with an evenness index of 0.79. The average density of woody individuals was 3452 stems ha^{-1} for an average basal area of 9.22 m^2 ha^{-1}. The Importance Value Index (IVI) of species in the understory ranged from 0.05 to 8.85%. The species with the highest Importance Value Index were *Theobroma cacao* (8.85%), *Albizia adianthifolia* (7.08%), *Coffea canephora* (6.24%), *Tabernaemontana crassa* (5.31%), *Trichilia monadelpha* (5.30%), and *Petersianthus macrocarpus* (5.01%; Table 1). The Family Importance Value (FIV) index ranged from 0.23 to 38.94%. Eight families with FIV > 10% account for 146.29% of the total family importance value indices. These were Rubiaceae (38.94%), Euphorbiaceae (19.15%), Meliaceae (18.33%), Fabaceae-Mimosoideae (17.01%), and Malvaceae (15.71%; Table 2).

In the canopy or arborescent strata of this forest, 227 species with dbh ≥ 10 cm comprising 153 genera and 53 families were recorded. The Shannon index reached a value of 6.81 for an evenness index of 0.87. The average density of trees was 477 stems ha^{-1} for an average basal area of 53.56 m^2 ha^{-1}. The Importance Value Index of species ranged from 0.22 to 15.06% in the canopy. The most important species with an IVI ≥ 10% were *Ricinodendron heudelotii* (15.06%), *Musanga cecropioides* (13.15%) and *Petersianthus macrocarpus* (12.86%; Table 1), which together accounted for 41.07% of the total importance value. The Family Importance Value index ranged from 0.51 to 25.31%. Thirteen families with FIV > 10% were the most important. These families constituted 191.47% of the total family importance value. They were the Euphorbiaceae (25.31%), Malvaceae (19.62%), Phyllanthaceae (17.66%), Meliaceae (17.12%), and Fabaceae-Mimosoideae (15.68%; Table 2).

In the Nbgwassa-Opkweng rural forest, a total of 534 species with dbh < 10 cm representing 263 genera and 64 families were identified in the understory. The Shannon index was 6.96 with an evenness index of 0.77. The average density of woody individuals was 3824 stems ha^{-1} for an average basal area of 10.21 m^2 ha^{-1}. The Importance Value Index (IVI) of species ranged from 0.03 to 22.18%. The most important species were *Theobroma cacao* (22.18%) and *Mallotus oppositifolius* (11.11%; Table 1). These two species with IVI ≥ 10% contributed 33.29% of the total of IVI. The Family Importance Value (FIV) index ranged from 0.19 to 36.31% for the families of the understory. Seven families with FIV > 10% represented 157.26% of the importance values of families. These were the Rubiaceae (36.30%), Malvaceae (34.43%), Euphorbiaceae (33.05%), Fabaceae-Papilionoideae (15.78%), and Fabaceae-Mimosoideae (12.97%; Table 2).

In the canopy of this forest, 225 species of dbh ≥ 10 cm belonging to 151 genera and 43 families were recorded. The Shannon index reached a value of 6.55 for an evenness index of 0.84. The average density of trees was 371 trees ha^{-1} and an average basal area of 41.98 m^2 ha^{-1}. The Importance Value Index of species ranged from 0.17 to 17.61%. The most important species with an IVI ≥ 10% were *Musanga cecropioides* (17.61%) and *Petersianthus macrocarpus* (10.65%; Table 1). These were the two ecologically important species in the upper strata which together contributed to 28.26% of the total importance value index. The Family Importance Value (FIV) index ranged from 0.51 to 30.01% for the families of the canopy. Fourteen families with FIV > 10% were the most important. These families constituted 211.49% of the families importance values. They were the Malvaceae (30.01%), Euphorbiaceae (23.59%), Urticaceae (19.23%), Fabaceae-Mimosoideae (18.00%), Fabaceae-Papilionoideae (14.51%; Table 2).

Ecological growth temperament of woody plant species

The analysis of the growth temperament of species with respect to light showed that out of 468 species recorded in the understory of the Essiengbot-Mbankoho rural forest, the shade-bearer species were the most represented with 244 species (52.14%). The pioneer and non-pioneer light-demanding species were lower in number with 111 species (23.72%) and 97 species (20.73%), respectively. The percentages of the species showed a highly significant difference between the growth temperaments in the understory ($\chi^2 = 65.18$; $df = 3$; $P < 0.001$). On the other hand, there was no difference between the numbers of pioneer species and non-pioneer light-demanding species ($\chi^2 = 1.06$; $df = 1$; $P = 0.373$). In terms of individuals, pioneers and shade-bearers were the most represented in the understory with 40.45% and 39.27% of the total of individuals (Table 3). The Chi-squared test showed a significant difference of the percentages of individuals between the guilds ($\chi^2 = 57.35$; $df = 3$; $P < 0.001$) but there was no

Table 1 The 15 most important species in the understory and canopy in each rural forest according to decreasing order of importance value index

Species	Understory				Species	Canopy			
	Fr (%)	Der (%)	Dor (%)	IVI (%)		Fr (%)	Der (%)	Dor (%)	IVI (%)
Essiengbot-Mbankoho rural forest									
Theobroma cacao	0.17	1.02	7.66	8.85	*Ricinodendron heudelotii*	2.16	2.46	10.44	15.06
Albizia adianthifolia	0.95	4.56	1.58	7.08	*Musanga cecropioides*	1.89	5.61	5.65	13.15
Coffea canephora	0.26	1.28	4.70	6.24	*Petersianthus macrocarpus*	2.84	4.38	5.64	12.86
Tabernaemontana crassa	1.12	2.08	2.11	5.31	*Albizia adianthifolia*	2.16	2.61	1.76	6.54
Trichilia monadelpha	0.82	1.19	3.30	5.30	*Triplochiton scleroxylon*	0.54	0.54	5.38	6.46
Petersianthus macrocarpus	1.07	1.51	2.43	5.01	*Distemonanthus benthamianus*	2.03	1.46	2.68	6.17
Myrianthus arboreus	1.03	1.22	2.45	4.71	*Theobroma cacao*	0.27	4.84	0.64	5.75
Vernonia conferta	0.39	0.89	2.94	4.21	*Uapaca guineensis*	1.62	1.46	1.96	5.04
Microdesmis puberula	0.99	2.69	0.19	3.87	*Sterculia tragacantha*	1.76	1.54	1.60	4.89
Whitfieldia elongata	0.64	3.21	0.00	3.86	*Heisteria trillesiana*	1.22	1.77	1.76	4.75
Distemonanthus benthamianus	0.99	2.82	0.00	3.80	*Pycnanthus angolensis*	2.03	1.46	1.25	4.74
Alchornea floribunda	0.82	0.54	2.22	3.57	*Alstonia boonei*	1.35	0.92	2.40	4.67
Albizia glaberrima	0.86	2.60	0.00	3.46	*Ficus mucoso*	1.08	1.23	1.98	4.29
Uapaca paludosa	0.90	1.82	0.73	3.45	*Persea americana*	1.08	2.31	0.67	4.06
Pycnanthus angolensis	0.39	0.91	1.93	3.23	*Macaranga barteri*	1.08	1.84	0.70	3.63
Remains (453)	88.61	71.66	67.75	228.02	Remains (212)	76.89	65.56	55.49	197.95
Total	100.00	100.00	100.00	300.00	Total	100.00	100.00	100.00	300.00
Nbgwassa-Opkweng rural forest									
Theobroma cacao	0.57	1.90	19.71	22.18	*Musanga cecropioides*	2.81	7.47	7.33	17.61
Mallotus oppositifolius	0.78	9.57	0.75	11.11	*Petersianthus macrocarpus*	1.98	3.71	4.97	10.65
Millettia sanagana	0.97	4.94	2.41	8.33	*Terminalia superba*	1.87	1.55	5.38	8.81
Myrianthus arboreus	1.03	1.33	5.36	7.72	*Theobroma cacao*	0.73	7.11	0.69	8.54
Desbordesia glaucescens	0.84	3.46	0.50	4.80	*Coelocaryon preussii*	2.39	3.41	1.77	7.57
Coelocaryon preussii	0.97	0.68	2.87	4.52	*Distemonanthus benthamianus*	2.29	1.85	3.30	7.44
Psychotria lastistipula	0.81	3.58	0.00	4.40	*Triplochiton scleroxylon*	0.83	0.96	5.51	7.30
Albizia adianthifolia	1.06	1.64	1.55	4.24	*Dichostemma glaucescens*	1.56	2.87	1.79	6.22
Tetrorchidium didymostemon	0.51	0.48	3.03	4.02	*Pterocarpus soyauxii*	1.14	0.96	3.97	6.07
Tabernaemontana crassa	0.97	1.76	1.28	4.01	*Myrianthus arboreus*	2.19	2.57	0.97	5.73
Microdesmis puberula	0.81	1.37	1.83	4.01	*Pseudospondias microcarpa*	2.08	1.79	1.76	5.63
Distemonanthus benthamianus	0.92	1.50	1.28	3.70	*Margaritaria discoidea*	1.87	2.03	1.54	5.44
Bridelia micrantha	0.81	0.98	1.55	3.34	*Pycnanthus angolensis*	1.56	1.32	2.52	5.40
Macaranga barteri	0.65	0.58	2.08	3.31	*Celtis tessmannii*	1.66	1.26	2.12	5.04
Vernonia conferta	1.27	2.03	0.00	3.30	*Ricinodendron heudelotii*	1.14	0.96	2.91	5.01
Remains (519)	87.01	64.18	55.80	206.99	Remains (210)	73.88	60.19	53.47	187.54
Total	100.00	100.00	100.00	300.00	Total	100.00	100.00	100.00	300.00

Fr relative frequency, *Der* relative density, *Dor* relative dominance, *IVI* importance value index

significant difference among pioneer and shade-bearer individuals ($\chi^2 = 2.35$; $df = 1$; $P = 0.226$). In the canopy, the number of non-pioneer light-demanding species was higher with 87 species (38.33%), followed by shade-bearer species (78 species; 34.36%) and pioneer species (55 species; 24.23%). The difference was highly significant between the number of species of these light requirement temperament ($\chi^2 = 39.79$; $df = 3$; $P < 0.001$). However, there was no significant difference between non-pioneer light-demanding species and shade-bearer species ($\chi^2 = 2.51$; $df = 1$; $P = 0.194$). In terms of individuals, the non-pioneer light-demanding species were the most represented with 561 individuals (43.12%) followed by the pioneer species with 460 individuals (35.36%) (Table 3). The difference between the percentages of individuals were highly significant ($\chi^2 = 55.85$; $df = 3$; $P < 0.001$).

Table 2 The 15 most important families (sub-families) in the understory and canopy in each rural forest according to decreasing order of family importance value

Family	Understory				Canopy				
	Dir (%)	Der (%)	Dor (%)	FIV (%)	Family	Dir (%)	Der (%)	Dor (%)	FIV (%)
Essiengbot-Mbankoho rural forest									
Rubiaceae	17.83	12.38	8.72	38.94	Euphorbiaceae	4.72	8.15	12.44	25.31
Euphorbiaceae	4.46	8.10	6.58	19.15	Malvaceae	3.86	7.61	8.14	19.62
Meliaceae	5.73	4.82	7.78	18.33	Phyllanthaceae	5.15	7.76	4.74	17.66
Mimosoideae	3.82	8.90	4.29	17.01	Meliaceae	7.30	6.76	3.06	17.12
Malvaceae	4.46	2.02	9.23	15.71	Mimosoideae	4.29	5.30	6.09	15.68
Apocynaceae	2.76	5.77	5.28	13.81	Moraceae	3.86	4.61	5.61	14.08
Phyllanthaceae	3.40	3.90	5.83	13.13	Caesalpinioideae	4.72	3.69	5.57	13.99
Caesalpinioideae	3.40	2.80	4.02	10.21	Urticaceae	0.86	6.53	5.83	13.22
Olacaceae	3.61	4.70	1.65	9.96	Olacaceae	3.43	4.46	4.51	12.40
Annonaceae	3.82	3.31	2.40	9.53	Apocynaceae	3.86	3.46	3.60	10.93
Papilionoideae	2.76	2.16	2.64	7.56	Annonaceae	4.29	3.84	2.45	10.58
Sapindaceae	4.25	1.53	1.53	7.30	Lecythidaceae	0.43	4.38	5.64	10.45
Myristicaceae	1.70	5.10	0.00	6.80	Rubiaceae	5.58	2.61	2.24	10.43
Acanthaceae	0.85	1.91	3.29	6.04	Cannabaceae	3.00	3.15	2.58	8.73
Urticaceae	0.64	5.35	0.00	5.99	Papilionoideae	2.58	3.69	2.35	8.61
Remains (46)	36.52	27.26	36.75	100.53	Remains (49)	42.06	23.98	25.15	91.19
Total	100.00	100.00	100.00	300.00	Total	100.00	100.00	100.00	300.00
Nbgwassa-Opkweng rural forest									
Rubiaceae	19.48	13.34	3.49	36.30	Malvaceae	9.25	12.12	8.27	29.64
Malvaceae	6.18	4.68	23.57	34.43	Euphorbiaceae	4.41	11.64	7.52	23.57
Euphorbiaceae	4.31	19.03	9.71	33.05	Urticaceae	0.88	9.93	8.12	18.93
Papilionoideae	3.56	7.68	4.54	15.78	Mimosoideae	5.29	5.85	6.75	17.89
Mimosoideae	2.81	6.48	3.69	12.97	Papilionoideae	4.85	3.13	6.70	14.68
Meliaceae	4.12	2.74	5.88	12.74	Cannabaceae	2.64	5.02	6.17	13.84
Phyllanthaceae	3.75	2.91	5.34	12.00	Meliaceae	6.61	3.84	2.29	12.74
Apocynaceae	3.18	4.14	2.04	9.36	Moraceae	3.52	4.85	3.94	12.31
Urticaceae	0.37	1.70	7.06	9.13	Phyllanthaceae	4.85	4.43	2.91	12.19
Caesalpinioideae	3.93	2.20	2.70	8.84	Myristicaceae	1.76	5.50	4.57	11.83
Moraceae	1.69	2.56	3.22	7.47	Caesalpinioideae	4.41	2.42	4.72	11.55
Annonaceae	3.56	1.52	2.30	7.38	Rubiaceae	7.93	1.77	1.47	11.18
Myristicaceae	0.75	1.84	4.47	7.06	Apocynaceae	4.41	2.96	3.58	10.94
Cannabaceae	2.25	3.87	0.07	6.19	Annonaceae	4.85	2.90	2.42	10.17
Irvingiaceae	1.31	1.98	2.74	6.03	Combretaceae	1.32	2.07	6.18	9.57
Remains (38)	38.76	23.32	19.18	81.27	Remains (28)	33.04	21.57	24.37	78.98
Total	100.00	100.00	100.00	300.00	Total	100.00	100.00	100.00	300.00

Dir relative diversity, *Der* relative density, *Dor* relative dominance, *FIV* family importance value

Out of the 534 species recorded in the understory of the Nbgwassa-Opkweng rural forest, the shade-bearer species were the most common with 284 species (53.18%). Pioneer species and non-pioneer light-demanding species were low in number with 119 and 113 species (22.29% vs. 21.16%), respectively (Table 3). The difference between these two types of growth behaviour was not significant ($\chi^2 = 1.18$; $df = 1$; $P = 0.278$). The individuals of pioneers species were the most represented (44.69%) followed by the individuals of shade-bearer species (33.63%). The differences observed between the percentages of individuals were highly significant ($\chi^2 = 58.09$; $df = 3$; $P < 0.001$). The shade-bearer species with 83 species (36.89%) and non-pioneer light-demanding species (79 species; 35.11%) were the most dominant in the canopy. According to the percentages of the species, the difference between these

Table 3 Numbers of species and individuals by growth temperament category with respect to light in the understories and canopies of the rural forests

	Essiengbot-Mbankoho rural forest		Nbgwassa-Opkweng rural forest	
	No. of species (%)	**No. of individuals (%)**	**No. of species (%)**	**No. of individuals (%)**
Understory (individuals < 10 cm dbh)				
P	111 (23.72)[a]	4368 (40.45)[a]	119 (22.29)[a]	11,171 (44.69)[a]
NPLD	97 (20.73)[a]	2151 (19.92)[b]	113 (21.16)[a]	5368 (21.47)[b]
SB	244 (52.14)[b]	4240 (39.27)[a]	284 (53.18)[b]	8408 (33.63)[c]
Unidentified	16 (3.42)[c]	39 (0.36)[c]	18 (3.37)[c]	52 (0.21)[d]
Total	468 (100.00)	10,798 (100.00)	534 (100.00)	24,999 (100.00)
Canopy (trees ≥ 10 cm dbh)				
P	55 (24.23)[a]	460 (35.36)[a]	58 (25.78)[a]	554 (32.74)[a]
NPLD	87 (38.33)[b]	561 (43.12)[b]	79 (35.11)[b]	852 (50.36)[b]
SB	78 (34.36)[b]	272 (20.91)[c]	83 (36.89)[b]	276 (16.31)[c]
Unidentified	7 (3.08)[c]	8 (0.61)[d]	5 (2.22)[c]	10 (0.59)[d]
Total	227 (100.00)	1301(100.00)	225 (100.00)	1692 (100.00)

P pioneer, *NPLD* non-pioneer light-demanding, *SB* shade-bearer. Proportion (in %) of species and individuals are noted parenthetically. Values followed by different letters (a, b, c, d) within a column indicate a significant difference between the growth temperament categories in relation to light (χ^2-test, $p < 0.05$)

two dominant guilds was not significant ($\chi^2 = 4.63$; $df = 1$; $P = 0.311$). The individuals of the non-pioneer light-demanding species were the most represented with 852 individuals (50.35%) followed by the individuals of pioneer species (554 individuals; 32.74%) (Table 3). The percentages of individuals differed very significantly between species groups ($\chi^2 = 73.30$; $df = 3$; $P < 0.001$).

Conservation status of woody plant species

A total of 521 plant species assessed in the Essiengbot-Mbankoho rural forest according to the IUCN Red List Categories allowed us to identify 3 species (0.58%) Critically Endangered (CR: *Ardisia etindensis*, *Ardisia schlechteri*, *Beilschmiedia preussi*), 5 species (0.96%) Endangered (EN: *Autranella congolensis*, *Beilschmiedia letouzeyi*, *Placodiscus angustifolius*, *Pericopsis elata* and *Tieghemella africana*) and 32 species (6.14%) Vulnerable (VU: e.g., *Allanblackia gabonensis*, *Antrocaryon micraster*, *Baillonella toxisperma*, *Boutiquea platypetala*, *Calpocalyx hertzii*, *Coffea mapiana*, *Cordia platythyrsa*, *Empogona talbotii*, *Entandrophragma cylindricum*, *Entandrophragma utile*, *Garcinia kola*, *Khaya grandifoliola*, *Leplaea cedrata*, *Macaranga paxii*, *Memecylon candidum*, *Nesogordonia papaverifera*, *Pterygota macrocarpa*, *Terminalia ivorensis*, *Turraeanthus africanus*). According to these results, 40 species (7.68%) of the flora are considered as threatened (i.e. Vulnerable, Endangered and Critically Endangered), and 18 species (3.45%) were assessed as Near Threatened. In addition, 408 species (78.31%) were categorized as Least Concern (Fig. 2a). In this case, 81.77% of plant species were considered as not threatened in this forest.

In the Nbgwassa-Opkweng rural forest, the assessment carried out on 557 plant species showed that 4 species (0.72%) were Critically Endangered (CR: *Ardisia etindensis*, *Ardisia oligantha*, *Beilschmiedia preussii*, *Plagiosiphon longitubus*), 10 species (1.80%) were Endangered (EN: *Anisotes zenkeri*, *Autranella congolensis*, *Cola attiensis*, *Millettia laurentii*, *Pericopsis elata*, *Placodiscus caudatus*, *Prioria balsamifera*, *Rhaptopetalum depressum*, *Tieghemella africana and Vitex lehmbachii*) and 40 species (7.18%) were Vulnerable. Among the species considered Vulnerable (VU), we found *Afzelia bipindensis*, *Baillonella toxisperma*, *Boutiquea platypetala*, *Calpocalyx heitzii*, *Cola mahoundensis*, *Cola nigerica*, *Cordia platythyrsa*, *Dacryodes buettneri*, *Diospyros crassiflora*, *Drypetes molunduana*, *Entandrophragma angolense*, *Entandrophragma candollei*, *Garcinia kola*, *Khaya anthotheca*, *Leplaea thompsonii*, *Neosogordonia papaverifera*, *Pterygota bequaertii*, *Sterculia oblonga*, *Tricalysia amplexicaulis*, and *Trichoscypha engong*. It was shown that 54 species (9.69%) of the flora in the forest are threatened (i.e. Vulnerable, Endangered and Critically Endangered), and 25 species (4.49%) were listed as Near Threatened. Moreover, 421 species (75.58%) were classified as of Least Concern meaning that 80.07% of plant species were considered not threatened in this rural forest (Fig. 2b).

Distribution of species growth temperaments by IUCN Red List categories

The distribution by IUCN threat category of species growth temperaments in relation to light revealed that

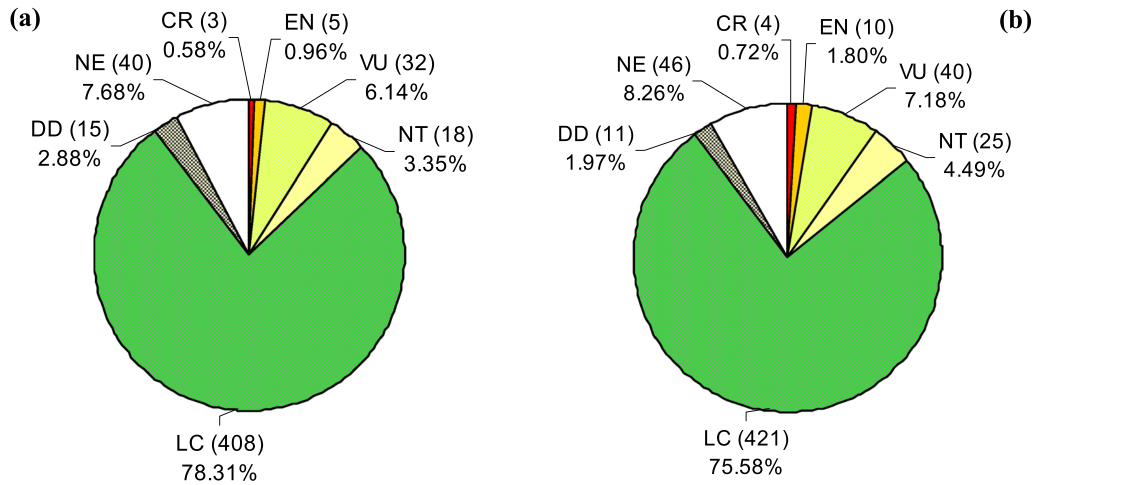

Fig. 2 Number and percentage of plant species in each IUCN Red List category of the Essiengbot-Mbankoho (**a**) and Nbgwassa-Opkweng (**b**) rural forests. The number of species is given in parentheses. IUCN Red List Categories: *CR* Critically Endangered, *EN* Endangered, *VU* Vulnerable, *NT* Near Threatened, *LC* Least Concern, *DD* Data Deficient, *NE* Not Evaluated

in the Essiengbot-Mbankoho rural forest, shade-bearer species with 199 species (49.63%) were the most represented in the Least Concern (LC) category followed by 110 pioneer species (27.43%) and 92 non-pioneer light-demanding species (22.94%) (Fig. 3a). The same trend was observed in the Nbgwassa-Opkweng rural forest where the Least Concern (LC) category was dominated by 210 shade-bearer species (49.88%), 114 pioneer species (27.08%) and 97 non-pioneer light-demanding species (23.04%) (Fig. 3b). The other threat categories, with very low numbers of shade-bearer, pioneer and non-pioneer light-demanding species were the less represented in the whole forests. In the Essiengbot-Mbankoho rural forest, the densities of shrubs of 3.2–10 cm dbh and trees ≥ 10 cm dbh showed that pioneer species and shade-bearer species were the most represented with, respectively, 1308 stems ha^{-1} (37.77% of the total density) and 1149 stems ha^{-1} (33.17%) in the Least Concern category. In the same IUCN category, non-pioneer light-demanding species had the lowest density of individuals with 717 stems ha^{-1} (20.70%) (Fig. 3c). In the Nbgwassa-Opkweng rural forest, pioneer species with 2021 stems ha^{-1} (43.47%) had the higher density in the Least Concern category followed by shade-bearer species with 1406 stems ha^{-1} (30.25%). However, non-pioneer light-demanding species with 888 stems ha^{-1} (19.10%) had the lowest density of individuals in this category (Fig. 3d).

Discussion

Floristic composition, species diversity, and vegetation structure

The results of the floristic inventories showed that the numbers of species, genera and families in both understories and canopies of rural forests were higher than many other forests. More than 400 species with dbh < 10 cm in the understory have been reported by many previous studies in tropical rainforests (Gentry 1990; Schmitt 1996; Turner et al. 1996; Losos and Leigh 2004; Tchouto et al. 2006; Berry et al. 2008; Beina 2011). The high species richness in the understories of rural forests could be due to the nature of the soil, presence of nutrients, light intensity, canopy cover, species composition of the upper strata and the types of disturbances. Wittmann and Junk (2003) in Amazonian várzea forests in Brazil and Singh et al. (2014) in a tropical dry deciduous forest in India made similar observations. According to these authors, species composition also depends on the forest structure of the overstory and the amount of radiation intake during the time of plant establishment. Sporadic disturbances, whether natural or induced by human activities, create favourable growing conditions for the regeneration and the establishment of new species in the understory. The high numbers of species in the understories would be also linked to the abundance of different pioneer species and non-pioneer light-demanding species, due to the presence of gaps in the canopy that favoured the entrance of light into the understory. In tropical rain forests, high light availability in gaps promotes seed germination and growth of seedlings of most canopy and understorey species (Balderrama and Chazdon 2005). The shade-bearer species that colonize small windthrows also increase the number of species in the understory. We can deduce from the results that the understory is the forest stratum that participates the most in the in situ conservation of species biodiversity.

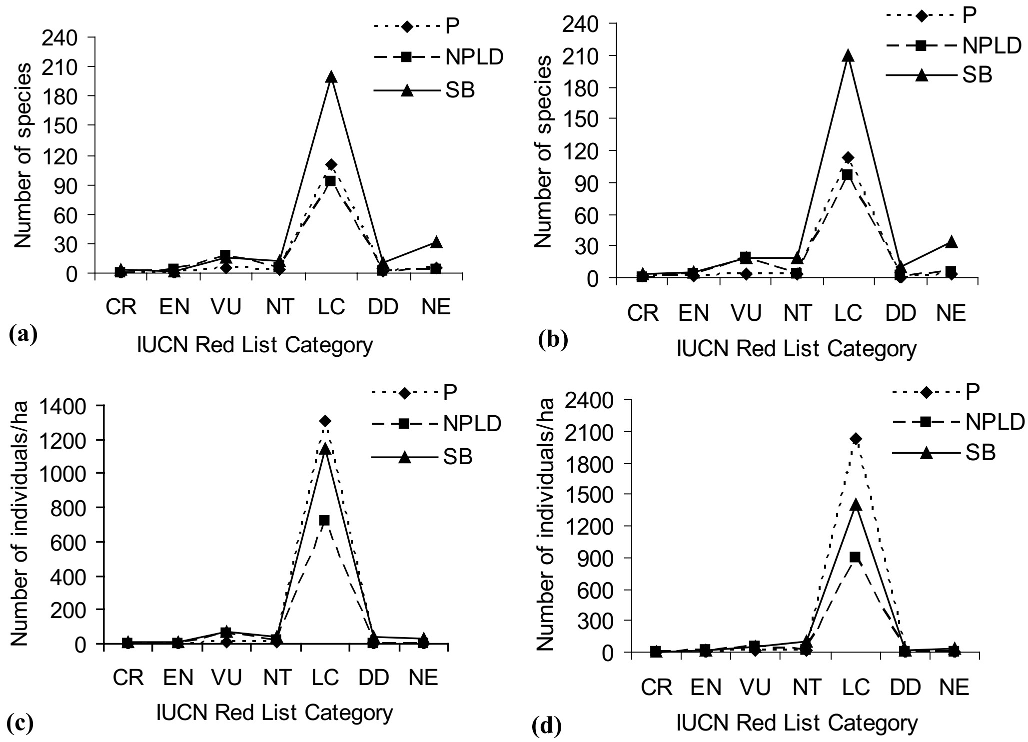

Fig. 3 Distribution of pioneer, non-pioneer light demanding, shade-bearer species and densities in different IUCN Red List categories in the rural forests of Essiengbot-Mbankoho (**a, c**) and Nbgwassa-Opkweng (**b, d**). *P* pioneer, *NPLD* non-pioneer light demanding, *SB* shade-bearer. *CR* Critically Endangered, *EN* Endangered, *VU* Vulnerable, *NT* Near Threatened, *LC* Least Concern, *DD* Data Deficient, *NE* Not Evaluated

In the canopies of rural forests, the number of species was slightly more than 200 species. This species richness in the upper strata is similar to that of other studies made in tropical moist forests (van Germeden et al. 2003; Natta 2003; Barbar et al. 2011; Beina 2011; Fongnzossie et al. 2011; Lisingo 2015; Memiaghe et al. 2016; Sainge 2017). The Shannon indices (H') of the understories and the canopies were very high in the two rural forests (6.55–6.98). These diversity values were close to those between 4.39 and 7.04 reported in Cameroon by other researchers (Zapfack et al. 2002; Sonké 2004; Fongnzossie et al. 2011; Noiha et al. 2015; Kengne et al. 2018). In addition, many other works in Africa and Asia reported Shannon indices ranging from 5.51 to 7.89 (Babar et al. 2011; Beina 2011; Kimpouni et al. 2013; Sajib et al. 2016). According to Kent and Coker (1992), the Shannon diversity index (H') can reach a value $\geq$ 4.5 for the most diverse communities in tropical forests. Our results showed that the diversity index H' can reach a value $\geq$ 6.0 for highly diverse and less disturbed plant stands of dense tropical rainforests. This very high value indicates the great floristic diversity of the forest milieu. The high diversity observed in rural forests could be explained by the lack of dominant species and the equitable distribution of woody plant individuals within species at different levels of the forest. This allows to say that the high diversity is due to the greater evenness. According to Ramade (2009), greater diversity increases the stability of the system through the interactions between the populations constituting the vegetation. In the face of anthropogenic activities, rural forests are subjected to fragmentation that generates a mosaic of land-use types with a very heterogeneous flora (primary forests relics, secondary forests, swamps, fallows, fields, cocoa and coffee plantations). The different activities carried out by local populations in rural forests would not have a negative effect on the floristic diversity due to their periodicity and low intensity (Kengne 2019). Dahan et al. (2018) estimated that the cropping system based on fallow-crop rotation and the practice of agroforestry would favour species maintenance at the agricultural areas level.

The understories are characterized by high numbers of species and individuals belonging to the Rubiaceae family. The same observation was made by Lü and Tang (2010) and Lü et al. (2011) in the understories of tropical seasonal rainforests in China. However, the presence of Euphorbiaceae, Phyllanthaceae, Urticaceae and even Fabaceae-Mimosoideae both in the understory and in the canopy illustrates the secondary and non-climax character of these forest areas with farmers' exploitation. The ecological importance of these families is reflected by the presence of colonizing species that participate in the reconstitution of degraded areas (Kengne et al. 2018).

The average densities of individuals obtained in the understories of the two rural forests were quite similar to the mean values of 3914, 3068 and 3600 stems ha^{-1} found in other understories of tropical rainforests, respectively, by Tchouto et al. (2006), Lü et al. (2011) and Sainge (2017). However, the values recorded in rural forests were higher than those obtained in other tropical forests (Wittmann and Junk 2003; Rasingam and Parthasarathy 2009; Lü and Tang 2010; Tiokeng et al. 2015). This high density could be explained by the dynamics of forest regeneration and resilience after disturbance, which would favour the development of young individuals of different plant species in the understories. The high densities of small-diameter individuals (3–10 cm) prove that the renewal of seed-bearing trees and the replacement of cut down, felled or dead trees will be ensured in forest areas with farming activities. According to Memiaghe et al. (2016), the diversity and abundance of the small-diameter trees suggest that the forest could have the ability to respond to disturbances in general.

The average tree densities obtained in the canopies of the two rural forests were lower than the densities of more than 500 trees ha^{-1} found in tropical rainforests by other authors (Tchouto et al. 2006; van Germeden et al. 2003; Sonké 2004; Sainge 2017; Tiokeng et al. 2015; Natta 2003; Beina 2011). The illegal exploitation of timber by logging companies in previous years and the expansion of slash-and-burn agriculture in the forest zone of eastern and southern Cameroon have led to a significant reduction in tree density. The low densities observed in the canopies would also be the result of the large spacing between individuals followed by the random dispersal of large-diameter trees in forest areas. During the establishment of agricultural plots, some trees that can be harmful to crops are cut down, which causes a considerable decrease in the density of the wooded cover. Indeed, Gartlan (1989) reported that the felling of an individual tree of a species increases the distance between breeding individuals.

The mean basal areas of woody species obtained in the understories of the two rural forests were higher than those recorded in the lower strata of other tropical rainforests (Wittmann and Junk 2003; Enninful 2013; Memiaghe et al. 2016; Sainge 2017). The higher values of basal areas in the understories of these forests would be related to the abundance of species with great capacities to grow faster in diameter than in height. The large basal areas were largely due to the abundance of shrubs and small trees with diameters between 5 and 10 cm in the understories of secondary forests, fallow land and cash crop plantations of the rural forests.

The mean values of tree basal areas in canopies were higher compared to those reported in tropical forests by previous studies (Zapfack et al. 2002; van Gemerden et al. 2003; Sonké 2004; Pappoe et al. 2010; Enninful 2013; Lisingo 2015; Sainge 2017). The large basal areas in the upper strata of rural forests would be explained by the conservation of very large-diameter trees because of the ban of artisanal and commercial logging activities.

Ecological growth temperament of woody plant species

The analysis of growth temperament of woody plants with respect to light revealed that the understories of the two rural forests were richer in shade-bearer species (52.14–53.18%) than in pioneer species (22.29–23.72%) and non-pioneer light-demanding species (20.73–21.16%). However, there was no significant difference between the number of pioneer species and the number of non-pioneer light-demanding species. Enninful (2013) in Ghana reported similar results where indeed, shade-bearer species constituted the highest proportion of the understory layer (42.48%), followed by non-pioneer light-demanding species (28.32%) and pioneer species (19.47%). The great richness of shade-bearer species could be explained by their facility to settle and develop in the absence of light. According to Dreyer et al. (2005), shade-bearer plants can survive at low light levels for long periods and quickly resume active growth after re-exposure to light. Saplings are able to survive understory light conditions owing to low respiration rates and low light requirements at saturation, but they are dependent on some canopy opening for substantive growth and reproduction (Denslow 1987; McCarthy 2001). Gravel et al. (2010) pointed out that shade-bearer species would colonize small-sized windthrows, same as Delcamp (2007) who found that environments with smaller openings favour the regeneration of a greater diversity of shade-bearer species. When pioneer and non-pioneer light-demanding species settle in the understory, light conditions must be sufficient to ensure their growth and survival.

On the other hand, pioneer species were the most represented in individuals (40.45–44.69%) in the understory, followed by shade-bearer species (33.63–39.27%). For species needing light to germinate and not being able to grow under low light intensities, the effect of light spots can lead to the massive survival of individuals (Traissac 2003). Our results showed that pioneer species poorly represented in the understory produce very large numbers of individuals to colonize open surfaces and degraded environments. This suggests that the number of individuals produced by pioneer species depends on the level of disturbance and the size of the windthrow to be reconstituted. This finding corroborates with Thorsten (2011) observations for whom the abundance of pioneers increased with ascending gap size and was even significantly higher in medium and large size logging gaps compared to undisturbed forest sites. Alexandre (1986) estimated that the gaps are colonized by pioneer shrubs that constitute a less diversified dense vegetation after a disturbance phase. Several factors such as forest shade, soil fertility, small gaps in the closed canopy, low level of light, fast regeneration and gregarious distribution of stems could explain the abundance of shade-bearing individuals in the understory. The abundance of shade-bearers species can be explained by the capability of those species to accumulate under shaded conditions in the forest understory (Mwavu and Witkowski 2009; Thorsten 2011). Vieilledent (2009) noted that under the canopy, shade-bearer species more adapted to poor light conditions in young stages have a significantly higher probability of regeneration than non-pioneer light-demanding species.

Analysis of the growth temperament with respect to light of species with dhp $\geq$ 10 cm revealed that the numbers of non-pioneer light-demanding species (35.11–38.33%) and shade-bearer species (34.36–36.89%) were the most dominant in the canopies of the two rural forests. Our results are close to those of Lisingo (2015) who found in the DRC, 49.90% and 40.49% of shade-bearer species, 36.40% and 49.15% of non-pioneer light-demanding species, 10.90% and 5.80% of pioneer species in the tree stand of mixed forests and in the stand of monodominant forests, respectively. The number of long-lived pioneer species generally important in the canopies of intensely degraded or highly disturbed forests is low in the upper strata of our study forests. This could be explained by the fact that after canopy openings by slash-and-burn agriculture and tree fall, the long-lived pioneer species that first participate in the reconstitution of the formed gaps, arrive very quickly in the canopy during forest succession, but will later be replaced by non-pioneer light-demanding species and shade-bearer taller trees of superior longevity, which will dominate in the canopy affected by the past disturbances. Beina (2011) argued that when disturbances are infrequent, the vegetation is dominated by the most competitive, long-lived shade-bearer species, with few pioneer species in the canopy. In general, shade-bearer species or late-successional species grew better in small or older gaps (Obiri and Lawes 2004; Muscolo et al. 2014). Gillet (2013) estimated that the plant formations with open canopies and/or dominated by large non-pioneer light-demanding trees would reflect past human disturbances. Non-pioneer light-demanding tree species and shade-bearing tree species would play a major role in the stability of the forest, as they participate in the canopy closure, set up the upper strata of the forest, maintain the height of the canopy, allow the reconstruction of the crown architecture and restructuring the forest cover after any natural or anthropogenic disturbance. Cirimwami et al. (2017) noted that when the forest tends to be stable it becomes more dominated by non-pioneer light-demanding and shade-bearer species. These species have developed specific strategies with respect to light, to grow as fast as possible. Their ability to quickly cover the canopy would be bound to their temperament (Oldeman 1974; Palla et al. 2011).

Nevertheless, individuals of non-pioneer light-demanding species were the most represented in the canopies (43.12–50.36%), followed by individuals of pioneer species (32.76–35.36%). A similar result was obtained in the Kahuzi-Biega National Park in the DRC by Cirimwami et al. (2017) where non-pioneer light-demanding individuals were most represented in the canopy layers (64.0%) followed by shade-bearer individuals (21.8%) and pioneer individuals (13.3%). The abundance of non-pioneer light-demanding trees and the presence of many long-lived pioneer individuals in the arborescent strata would be linked to the canopy reconstitution process due to the past degradation of the upper strata of rural forests by former logging companies, illegal selective logging and slash-and-burn agriculture. Doucet (2003) also found that only a regular burning of the forest in particular for agricultural purposes, could have modelled forest composition by increasing the amount of light-demanding species. The openings closure created in the canopy would be done by the tree stands mainly constituted by individuals of non-pioneer light-demanding species. Tree species that have a high demand for light are at larger proportion of the flora in such forests (Whitmore 1985; Denslow 1987).

Conservation status of woody plant species

The assessment of the threat level of woody plant species according to the IUCN Red List showed that the vascular flora of the two rural forests had high percentages (75.58% and 78.31%) of plant species of Least Concern (LC), but low percentages (7.68% and 9.69%) of threatened species (CR, EN, VU). Our results are similar to those reported for vascular flora in the regions of France. Noble et al. (2015) found for the vascular flora of Provence-Alpes-Côte d'Azur 71.30% species of Least Concern and 10.80% of threatened species, Delage and Hugot (2015) for the flora of Corsica reported 69.56% species of Least Concern and 9.70% of threatened species, Quéré et al. (2015) recorded 68.56% species of Least Concern and 15.10% of threatened species. This observation on the conservation status of plant species would reveal a non-worrying threat situation for the flora of forest areas used by the local populations. Rural forests are subjected to slash-and-burn agriculture, hunting, and exploiting non-timber forest products by local populations. However, these anthropogenic exploitation activities are regulated by conservation and sustainable management practices such as agroforestry, seasonal clearing, use of traditional preservation knowledge and the prohibition of artisanal and/or commercial timber exploitation. It is the farmers' respect for these principles of preservation and sustainable use of plant resources that had reduced the threats to the vascular flora of rural forests. De Watcher (2001) noted that the low population density and the cyclic nature of shifting agriculture do not threaten the forests. Bohoussou (2014) pointed out that the success of the conservation of a site depends on the local population's involvement because they constitute the first threat.

The distribution of species growth temperaments according to IUCN Red List categories in rural forests showed that shade-bearer species dominated in the Least Concern (LC) category. This category also had high densities of individuals in pioneer and shade-bearer species. This could be due to the effects of human activities over the last decades, which have created gaps in the canopies and induced slight disturbances in the forests. Plant species classified as threatened should benefit from prioritized follow-up actions and regulated protection, even though efforts still have to be made to eradicate the threats on plant biodiversity in all the Cameroon's rainforest.

Conclusions

This study has shown that the rural forests are rich in species and have very diversified floras in the understories and canopies. The important floristic composition observed resulted from slight or moderate induced disturbances, which are responsible for the species diversity within the land-use types of these forests. However, rural forests have shown a reduction in species richness and a decrease in tree density in the canopies due to slash-and-burn agriculture, illegal logging and tree mortality through senescence. Analysing the growth temperament of the species with respect to light has revealed that the understories were richer in shade-bearer species and abundant in pioneer species individuals. Furthermore, non-pioneer light-demanding species and shade-bearer species dominated the canopies. Rural forests in the face of past anthropogenic disturbances and the current subsistence activities of local populations show an important successional dynamic marked by the strong presence of non-pioneer light-demanding species and shade-bearer species, whose roles are to maintain and restore the forest's maturity. The assessment of the conservation status and threats of species in rural forests unveiled a large dominance of woody plant species with Least Concern status and a low presence of threatened species. Indeed, no major threats were identified on plant species in rural forests. Despite their slight degradation, the ban on commercial logging, the practice of agroforestry and the seasonal agricultural activities carried out by local populations, they allowed the good conservation of plant biodiversity. It would be desirable that forestry law considers the role of rural forests in the well-being of local communities and the preservation of plant species. For a more efficient sustainable management of those rural forests, effective development and management plans should be put in place to reduce the pressures of anthropogenic activities, the multiplicity of land-use types and eliminate species threats in these forest areas. The planning of forest areas reserved for exploitation by rural populations would improve local conservation techniques and perpetuate the sustainable management of forest biodiversity. In addition, legal management of the rural forests could help to limit the anthropogenic activities and pressures on community forests.

Abbreviations

APG: Angiosperm Phylogeny Group; CIRAD: French Agricultural Research Centre for International Development; dbh: Diameter at breast height; DRC: Democratic Republic of the Congo; DFR: Dja Fauna Reserve; FAO: Food and Agriculture Organization of the United Nations; IUCN: International Union for Conservation of Nature; MINFOF: Ministry of Forestry and Wildlife; SPSS: Statistical Package for the Social Sciences.

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Author contributions

The first author (OCK) collected the data, analysed it and wrote the manuscript. The fourth author (RGDM) revised the manuscript. The fifth (LZ) supervised the work. All authors read and approved the final manuscript.

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Availability of data and materials
The data generated and analysed during the present study are available from the corresponding author.

Declarations

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Not applicable.

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The authors declare that they have no conflicts of interest.

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