

## Chapter 4

### **BIO-INDICATOR SPECIES AND CENTRAL AFRICAN RAIN FOREST REFUGES: A CASE STUDY FROM THE RAIN FOREST IN CAMEROON**

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#### 4.1. INTRODUCTION

Although there is much debate about the Pleistocene forest refuge theory in South America (van der Hammen & Hooghiemstra, 2000 ; Colinvaux *et al.*, 2001; Haffer & Prance, 2001), some authors dealing with the African situation generally agree that during the glacial periods limited and isolated patches of tropical rain forest (tropical rain forest refuges) persisted and survived the unfavourable climatic conditions. In Central Africa, a number of these so-called Pleistocene forest refuges are found in Gabon and Cameroon, amongst which the Campo-Ma'an area (Aubreville, 1962; White, 1979 & 1983, Hamilton, 1982; Maley, 1987; Sosef, 1994). However, there is some debate and disagreement about the exact location of these refuges within these areas (Robbrecht, 1996; Sosef, 1996; Leal, 2001). This is probably because tropical rain forest refuges are often studied on a large scale, and hence results, for example to the postulation of a single large refuge in the South-western Cameroon/Gabon area (Maley, 1987 & 1989). Understanding the present-day location of tropical rain forest refuges requires the use of direct evidences or "Paleo-evidence" such as palynological, paleobotany and related proxies records or indirect evidence such as the distribution patterns of endemic and slow dispersal species. More often, endemism and patterns in the distribution of slow dispersal taxa have been used by many authors to identify the location and extent of regional forest refuges (Rietkerk *et al.*, 1996; Robbrecht, 1996; Sosef, 1996; Achoundong, 2000). These studies interpreted localities with a high degree of endemism and plant diversity to coincide with former forest refuge areas. Although, paleo-evidence seems the best indicators for the study and location of tropical rain forest refuges, direct and indirect evidences complement each other.

Bio-indicator species are usually defined as species whose status and ecology provide information on the overall condition of the ecosystem and relative abundance reflect the quality and changes in environmental conditions, both biotic and abiotic (Heywood & Watson, 1995). Therefore, refuge indicators should be ecologically discriminating with limited dispersal and colonisation abilities. Sosef (1994) argued that it should be extremely difficult for such species to survive outside a rain forest refuge and that their present day distributions will likely coincide with the late Pleistocene refuges. The distribution patterns of strict and narrow endemic species, together with well known slow dispersal taxa, and species that reach their northern limit of distribution in the Campo-Ma'an area were used to study or confirm the position of a postulated Pleistocene rain forest refuge in south-western Cameroon. Special attention was given to taxa with slow dispersal abilities such as those within *Begonia* sect. *Loasibegonia* and sect. *Scutobegonia*, *Rinorea* spp., Caesalpinioideae and Rubiaceae. This study aims to examine the geographical position of late Pleistocene forest refuges by analysing the distribution of selected bio-indicator species. The distribution patterns of selected species are used to find out if they are concordant with the postulated rain forest refuge area or not, and then we interpret and discuss it both in terms of its historical causes and contemporary conditions. Furthermore, we will also study the ecology of *Aucoumea klaineana* (Okoumé) at its northern limit of distribution in order to find out if its distribution under the present climatic conditions in Cameroon is expanding or contracting.

### **Pleistocene vegetation changes in Central Africa**

Maley (1993) has identified four main climatic phases of the late Quaternary in Central Africa. The *Maluekian* (c. 70,000 to 40,000 BP) which corresponds to a relatively dry period marked by extensive forest retreat. The *Njilian*, lasting from 40,000 to 30,000 BP that was relatively wet and marked by a definite extension of forest. The *Leopoldian* (c. 30,000 to 12,000 BP) that culminated around 18,000 BP was relatively dry and marked by a new extension of open savanna environments. The *Kibangian* (c. 12,000 BP to the present) was relative wet until c. 3500 BP (Kibangian A) and marked by a new phase of forest extension. Later, came another drier period from 3500 BP to present (Kibangian B) corresponding to the beginning of another extension of savanna in some parts of Central Africa. According to the refugium theory, Central African rain forest underwent a series of climatic fluctuations in the late Pleistocene during which a considerable portion of the tropical lowland rain forest was repeatedly reduced to relatively small isolated patches, called forest refuges, due to unfavourable climatic conditions (Hamilton, 1982; White, 1993; Maley, 1989, 1990 & 1996). During the dry-out phases, some forest species were captured in these refuges, and some surviving species were not or hardly capable of migrating out of these again, due to their extreme low dispersal abilities (White, 1993).

Geological and palynological research conducted on lake sediments from several sites, has shown that c. 2500 BP the Central African forest experienced a “catastrophic destruction” that led to a major extension of the savanna (Maley & Brenac, 1998; Maley, 2002). Detailed pollen records from lake Barombi Mbo in western Cameroon, lake Ossa in south Cameroon, lake Kitinia in western Congo, lakes Mboandong and Njupi in south Congo reveal the presence of pseudo-periods of about 2000 to 2500 BP for several tree taxa typical of mature undisturbed forest (Maley & Elenga, 1993; Elenga *et al.*, 1994 & 1996; Reynaud-Ferrera *et al.*, 1996). During this phase, the rainfall suddenly became more seasonal, reducing the moisture available for the vegetation, and therefore leading to a mass disappearance of mature forest tree species in several parts of Central Africa (Reynaud & Maley, 1994; Maley & Brenac, 1998; Maley, 1987 & 2001). Reynaud & Maley (1994) argued that punctual climatic perturbations may have taken place in the 13<sup>th</sup> century followed by a phase with favourable climatic conditions from the 18<sup>th</sup> century onward that may have favoured the natural reforestation process that is being observed today. This is well illustrated in Cameroon and Gabon where the transgression of forest into the savanna at forest edges (coastal and inland savanna) is reported in some areas (Letouzey, 1968; White *et al.*, 2000).

Several climatological studies have shown that the southern part of Cameroon has suffered from a series of climatic crises marked by a severe decrease in rainfall that repeatedly occurs every 10 to 15 years, such as in 1973 and 1983 (Reynaud & Maley, 1994). In this region, the contrast of excess or deficit of rainfall is particularly pronounced in the Atlantic littoral zone, as described by Letouzey (1968 & 1985), where the coastal forest with *Lophira alata* and *Sacoglottis gabonensis* is found. More so than further inland where the lowland evergreen rain forests rich in Caesalpinioideae is located. These past climatic changes must have seriously influenced the vegetation pattern found in the area, since lowland Caesalpinioideae forests normally develop where the dry seasons do not exceed about 2 months, while

semi-deciduous forests prevail when the dry season varies between 2 to 3 months (Reynaud & Maley, 1994). Therefore, closed evergreen rain forests are mainly found in areas with high precipitation (above 2000 mm/year). Between 1500-2000 mm, the number of deciduous and semi-deciduous elements increase and below 1500 mm there is rather a dry deciduous forest. As a result, in the Campo-Ma'an area, the vegetation varies from the lowland evergreen rain forest rich in Caesalpinioideae in the wetter Campo area to a mixed evergreen and semi-deciduous forest in the drier Ma'an area (Chapter 2). The past climatic oscillations presumably have also resulted in the fluctuation of the sea level along the Campo-Ma'an coastline. Oslisly (2001) argued that between 35,000 to 40,000 BP the present coastline was at – 40 m below sea level and the sea was warmer than at present. From 30,000 BP onward, a new arid period began with a further regression of the coastline that reached its lowest level at – 120 m below the present sea level. During this period Bioko Island (Equatorial Guinea) was still attached to the continent. It is only between c. 10,000 to 11,000 BP that the sea level started to rise to reach its present level towards 5000 BP.

There is an ongoing debate on refuges and speciation. A small minority of authors more or less refute the idea that speciation is linked to fragmentation and isolation of forest biomes, while other authors suggest that these isolations are at the origin of a great number of taxa (Maley, 2001). Although many authors have discussed these issues, it is difficult to come to any conclusions given the problems of dating the appearance of different taxa. However, several authors pointed out that speciation in ecologically isolated environments (niches) and speciation in geographically isolated environments (vicariance), particularly under the effect of arid periods, are not incompatible, and seem to rather complement each other (Maley, 2001). For the reasons mentioned above and due to the lack of information related to the dating of endemic species, we did not classify the endemic species recorded during our study into neo- or paleoendemic categories.

## **4.2. METHODS**

### **Criteria for taxa selection**

The distribution patterns of species that are strictly endemic to the Campo-Ma'an area and those of narrow endemic species that also occur in south-western Cameroon (area that extends from Campo-Ma'an to Bipindi and Lolodorf) were used to verify the geographic position of late Pleistocene forest refuges. Other bio-indicator species comprise taxa with limited ecological and biological features. They are slow dispersing lowland rain forest species with restricted seed dispersal abilities, ecologically selective and intolerant to changing environmental conditions. Furthermore, species that occur in other proposed rain forest refuges and that reach their northern limit of distribution in the Campo-Ma'an area were also taken into consideration, as well as the availability of floras, monographs or taxonomic expertise giving sound identification and providing good distribution data. The various maps obtained were mainly based on the distribution of botanical specimens collected in the Campo-Ma'an area during the present study, and by previous scientists. In order to cover most of the area, we used a random stratified sampling method during which representative vegetation types were selected on the basis of human and physical factors such as rainfall, altitude, slopes, soils, the proximity to

the sea and land use. Furthermore, additional collections also came from specimens collected during the study in specific habitats such as river/stream banks and exposed rocks, and from specimens previously collected in the area by other scientists.

#### *Endemic species*

Strict and narrow endemic species are suitable to serve as bio-indicators because they generally have lower overall reproductive capacity and poorer dispersal abilities than widespread species. They are often susceptible to environmental changes and disturbance. Therefore, patterns of congruence of narrow endemism are important for the identification of forest refuges since areas with unusually high number of endemics are likely to coincide with areas where forests persisted during glacial periods (Williams, 1993).

#### *Begonia*

In the revision of the *Begonia* sect. *Loasibegonia* and sect. *Scutobegonia*, Sosef (1994) used these *Begonia* species to study the location of Pleistocene refuges in West and Central Africa. In our study we will only focus on those *Begonia* species that are endemic to the Lower-Guinea region as defined by White (1979). *Begonia*s from these groups are understory rhizomatous terrestrial herbs, which are often found on the soil or on wet rocks in mature and old secondary forests. They have indehiscent fruits that remain some months on the mother plant and bend towards the substrate before disintegration (Sosef, 1994). While rotting away, they release their seeds slowly at the base of the parent plant. Sosef (1994) argued that in addition to the fact that many of these species have a self-incompatibility system of reproduction, dispersal over a long distance will probably not occur since the seeds are so slowly dispersed. However, some seeds might also be transported by animals (with mud on the legs of passing animals) or by water because a number of species also occur near small streams (de Lange & Bouman, 1992; Sosef, 1994).

#### *Caesalpinioideae*

Several studies on the distribution patterns of Caesalpinioideae do suggest that they are suitable bio-indicators for locating late Pleistocene tropical rain forest refuges in Central Africa (Rietkerk *et al.*, 1996; Wieringa, 1999; Leal, 2001). *Caesalps* belong to the dominant canopy tree species in the Atlantic Biafran forest (Letouzey 1968 & 1985). They are often found in undisturbed mature and in old secondary rain forests and contained many species that occur gregariously. The explanation for the gregarious nature of these species might stem partly from the fact that they have ballistic seed dispersal abilities that limits dispersal distance, ectomycorrhizal relationships, and large cotyledons with copious nutrients that enable their seedlings to realise initial growth under dark conditions (van der Burgt, 1994; Newbery & Gartlan, 1996; Wieringa, 1999; Leal, 2001). Most *Caesalps* show seeds that disperse through the explosion of the pods. Their pods explode and the seeds are ejected to a maximum of 60 m from the mother tree (van der Burgt, 1994).

#### *Rinorea*

Achoundong (1996 & 2000) carried out studies on the distribution of *Rinorea* species in Cameroon. He found that *Rinorea* species are sensible bio-indicators for forest typification. *Rinorea* species are understory shrubs or small trees that are

usually found in the lowland rain forest and sometimes in high altitude forest. They are characterised by slow seed dispersal ability. The capsule of most species dehisces with 3 valves. Each valve contains 1-4 seeds that are released in the vicinity of the parent plant, a reason why they are often locally frequent. Hekking (1988) argued that ants might also disperse part of the seeds because there is a caruncle at the base of the seed that may attract ants. He went further to mention that nearly all species are restricted to their natural habitats, thus implying that their history of distribution and speciation is strictly connected with that of the tropical rain forest in which they occur.

#### *Rubiaceae*

All species used in our study are small trees, shrubs and herbs that are confined to the understorey of the lowland evergreen rain forest. Robbrecht (1996) argued that although most Rubiaceae species have fleshy fruits (drupes or berry-like) that allow for long distance dispersal by birds, they possess some advanced morphological syndromes by which cross-pollination becomes obligatory. As a consequence, their breeding system probably renders isolated cases of long distance dispersal of single diaspores ineffective because a self-incompatibility system is present in the majority of the species (Robbrecht, 1988 & 1996). Therefore, one may expect that relict populations of such forest Rubiaceae will need a long time to gradually recolonize the expanding spread of forest when favourable climatic conditions return after a period of forest reduction during a glacial period (Robbrecht, 1996).

#### **Data analysis**

After a taxonomic search in existing floras, monographs and herbaria, taxa were selected using the criteria discussed above. A list of selected taxa was given to specialists for further checking and the resulting distribution maps of species of each group mentioned above were analysed in a search for species showing discrete patterns. Then we compared the distribution patterns of each group in order to identify areas of frequent occurrence of these bio-indicator species. The overall distribution patterns found were used to identify the position of late Pleistocene rain forest refuges in south-western Cameroon.

### **4.3. RESULTS**

#### **Distribution patterns of bio-indicator species**

In total 178 bio-indicator species (Table 4.1) were selected on the basis of their biology (life strategy) and/or distribution (endemic). The list includes 58 strict and narrow endemics, 59 species of Rubiaceae, 32 species of Caesalpinioideae, 13 species of *Begonia*, 13 species of *Rinorea* and 24 species that reach their northern limit of distribution in the Campo-Ma'an area. As shown in Table 4.2, 77% of the total numbers of selected bio-indicator species were recorded in the National Park, 66% in the Kribi-Campo-Mvini area and 46% in the Nyabissan-Ma'an-Mekok area.

Table 4.2 Contribution of selected bio-indicator species in the Campo-Ma'an area

Area	Strict and narrow endemic	<i>Begonia</i>	Caesalps	<i>Rinorea</i>	Rubiaceae	Northern limit of distribution	Total No of bio-indicator species	%
Campo-Ma'an National Park	39	10	26	11	51	16	153	77
Kribi-Campo-Mvini area	33	7	25	10	46	11	132	66
Nyabissan-Ma'an-Mekok area	9	4	18	9	29	23	92	46
Campo-Ma'an area	58	13	32	13	59	24	199*	

\*Note that the total number of bio-indicator species in this table (199) is higher than the total number of species listed in Table 4.1 (178) because some species occur in more than one group. The Kribi-Campo-Mvini area is located in the western part of the Campo-Ma'an area while the Nyabissan-Ma'an-Mekok area is situated in the south-eastern part.

Several maps were produced to display the distribution patterns of bio-indicator species within their respective groups (Figures 4.2 to 4.8). Overall, there was a high concentration of bio-indicator species in the Park and the Kribi-Campo-Mvini area and a relatively low concentration of these species in the Nyabissan-Ma'an-Mekok area (Table 4.2 & Figure 4.7). A similar pattern was observed for the distribution of strict and narrow endemic species (Figure 4.2). The lowland evergreen forest rich in Caesalpinioideae and the submontane forest located in the National Park and in the western part of the Campo-Ma'an area were rich in bio-indicator species, while the mixed evergreen and semi-deciduous forest was characterised by a low concentration of these species (Figures 4.1 & 4.8). The distribution of *Begonia* showed that some species were often found in mountainous areas between Ebianemeyong and Akom II, or along slopes near hilltops in the lowland forest, and others were located along small streams in the lowland forest. Surprisingly, many of these *Begonias* were not recorded in the mixed evergreen and semi-deciduous forest in the Ma'an area. As for the Caesalps, their distribution showed a high concentration of species in the park and in the Kribi-Campo-Mvini area (Figure 4.4). There was also a decrease in the number of Caesalps in the coastal forest rich in *Sacoglottis gabonensis* (Campo area) and in the mixed evergreen and semi-deciduous forest with a predominance of semi-deciduous elements (Ma'an area). In *Rinorea*, many indicator species were mostly confined to the lowland forest, particularly in the evergreen forest rich in Caesalpinioideae (Figure 4.5). There was a decrease in the number of these species with increasing altitude and some of them were most frequent in the coastal forest. There was a relatively even distribution of bio-indicator species from the Rubiaceae family within the Campo-Ma'an area although the Ma'an area showed a relatively low concentration of these species (Figure 4.6). As for species that reach the northern limit of their distribution in the Campo-Ma'an area, there was a decrease in numbers from the border with Equatorial Guinea to the Kribi-Akom II area further north (Figure 4.7). Some species such as *Aucoumea klaineana*, *Dacryodes buettneri*, *Deinbollia pycnophylla* and *Testulea gabonensis* were limited to the southern part of Campo-Ma'an in the Ma'an area, to the Dipikar island and around Ebianemeyong and Mvini.



**Diameter class distribution of *Aucoumea klaineana* (Okoumé)**

As shown in Table 4.3 and Figure 4.9, there was a significant difference between the number of Okoumé stems/ha recorded in the Ma'an (270 stems/ha) and Ebianemeyong forests (1855 stems/ha). The diameter distribution pattern of Okoumé stems was similar in the two communities, with each community showing a reversed-J curve with a typical reduction of Okoumé stem frequency with increasing size classes (Figure 4.9). However, this curve was very sharp in the Okoumé community found on exposed hill slopes around Ebianemeyong because many stems were recorded below 10 cm DBH (more than 35%), few stems in the large and medium sized classes, and no stems above 80 cm DBH. In the Ma'an community, there was also a gradual reduction of stems within the various DBH classes, but about 30 large Okoumé trees were recorded with a diameter above 100 cm (in 0.2 ha).

Table 4.3 Summary of the number of species, number of stems/ha, mean basal area/ha, and the number of Okoumé stems/ha recorded in 2 plots of 0.1 ha each in the Ma'an forest close to the border with Equatorial Guinea and on exposed hill slopes around Ebianemeyong in the Campo-Ma'an National Park (Figure 4.10).

Location of the Okoumé forest	No of species	No of stems/ha	Mean basal area/ha	Okoumé DBH range (cm)	No of Okoumé stems/ha	Contribution of Okoumé from the total number of individuals recorded in 0.2 ha.
Ebianemeyong	62	3925	41.3	1-80	1855	43.7% (371 out of 785 recorded)
Ma'an	154	5615	73.6	1-175	270	4.8% (54 out of 1123 recorded)

Note that in the Ma'an area, the Okoumé community was found in the mixed evergreen and semi-deciduous forest at altitudes between 400 to 500 m, while in the Ebianemeyong area, they were mostly found in the Caesalpinioideae forest on exposed hill slopes between 600 to 700 m.

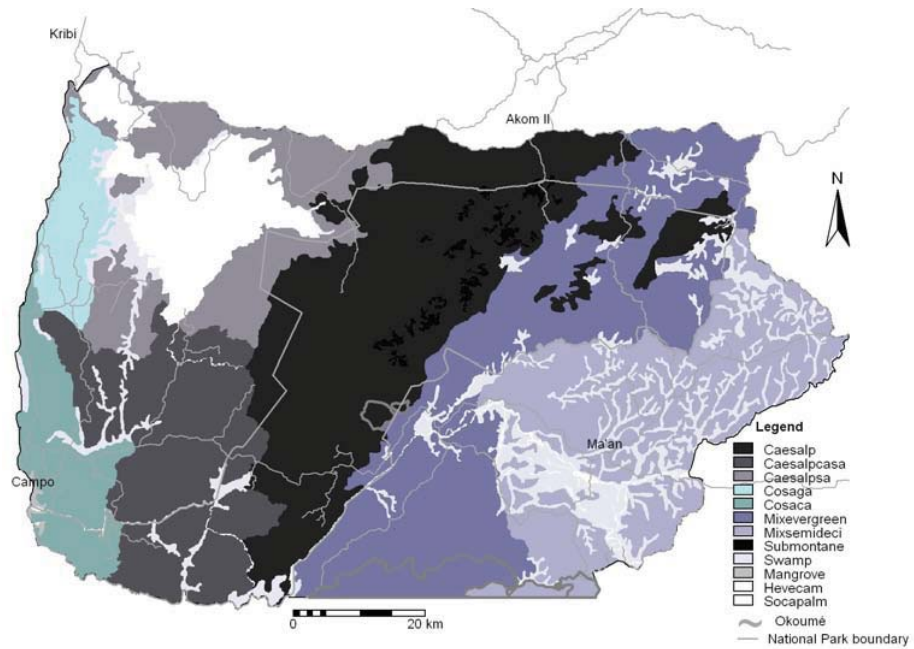


Figure 4.1 Vegetation map of the Campo-Ma'an area. Where Caesalp: Lowland evergreen forest rich in Caesalpinioideae; Caesalpcasa: Lowland evergreen forest rich in Caesalpinioideae with *Calpocalyx heitzii* and *Sacoglottis gabonensis*; Caesalpsa: Lowland evergreen forest rich in Caesalpinioideae and *Sacoglottis gabonensis*; Cosaga: Coastal forest with *Sacoglottis gabonensis*; Cosaca: Coastal forest with *Sacoglottis gabonensis* and *Calpocalyx heitzii*; Mixevergreen: Mixed evergreen and semi-deciduous forest with elements of evergreen forest predominant; Mixemideci: Mixed evergreen and semi-deciduous forest with semi-deciduous elements predominant; Submontane: Submontane forest on hill tops; Okoumé: small patches of Okoumé populations; Hevecam & Socapalm: agro-industrial plantations (Annex 5).

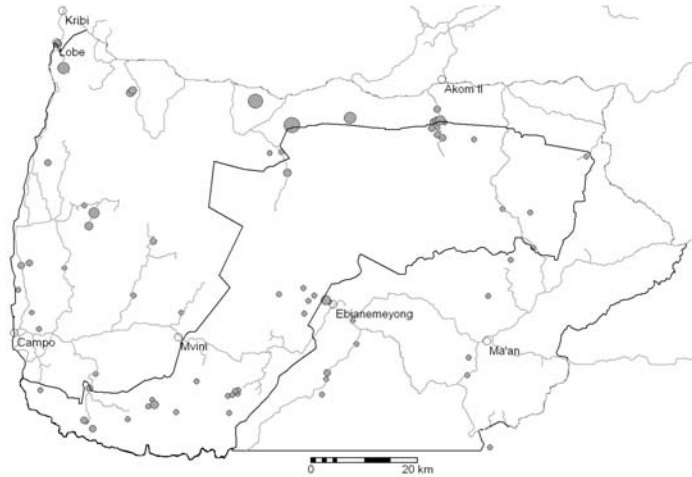


Figure 4.2 Distribution of 58 strict and narrow endemic plant species that only occur in the Campo-Ma'an area, and south-western Cameroon. Note that the size of the circle is proportional to the number of different species that occur in a given locality (a big circle means many different species in a given locality).

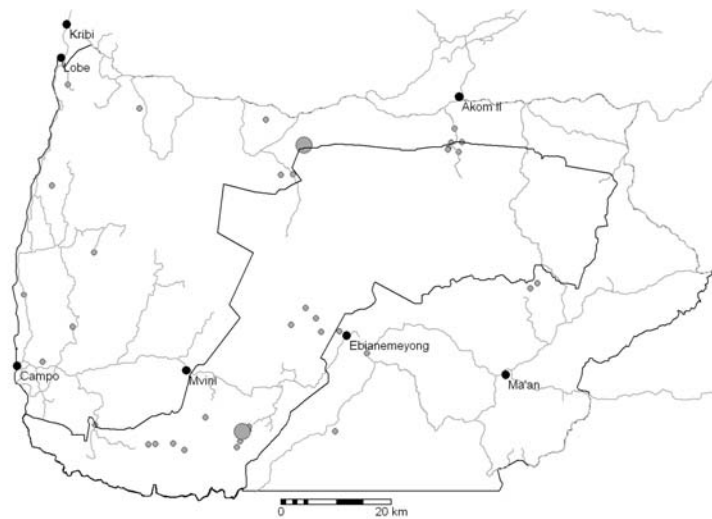


Figure 4.3 Distribution of 13 species of the *Begonia* sect. *Loasibegonia* and sect. *Scutobegonia* that are strictly endemic to the Campo-Ma'an and south-western Cameroon, or that reach their northern limit of distribution in Campo-Ma'an. The size of the circle is proportional to the number of different species that occur in a locality.

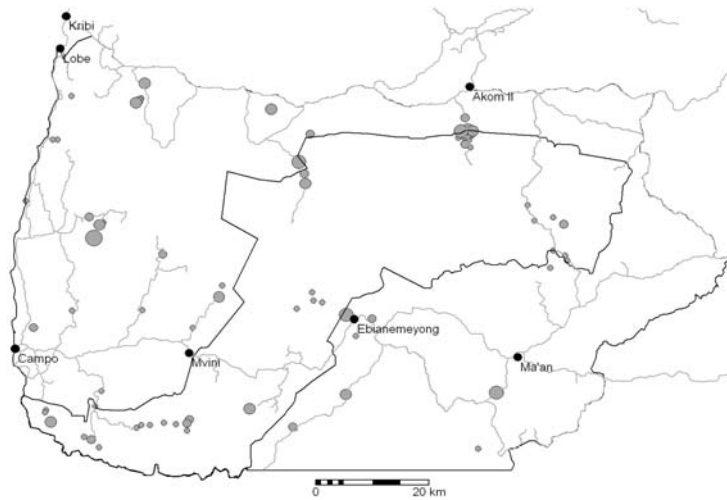


Figure 4.4 Distribution of 32 species of *Caesalpinoideae* that are either strictly endemic to the Campo-Ma'an and south-western Cameroon, endemic to Cameroon and Lower Guinea region, or that reach their northern limit of distribution in Campo-Ma'an. Note that the size of the circle is proportional to the number of different species that occur in a given locality.

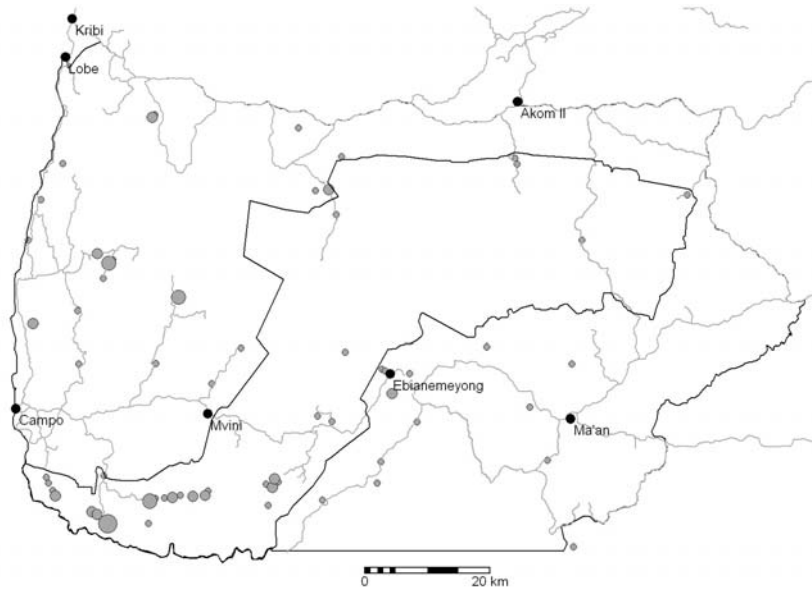


Figure 4.5 Distribution of 13 species of *Rinorea* that are either strictly endemic to the Campo-Ma'an and south-western Cameroon, endemic to Cameroon or the Lower Guinea region. The size of the circle is proportional to the number of different species that occur in a given locality.

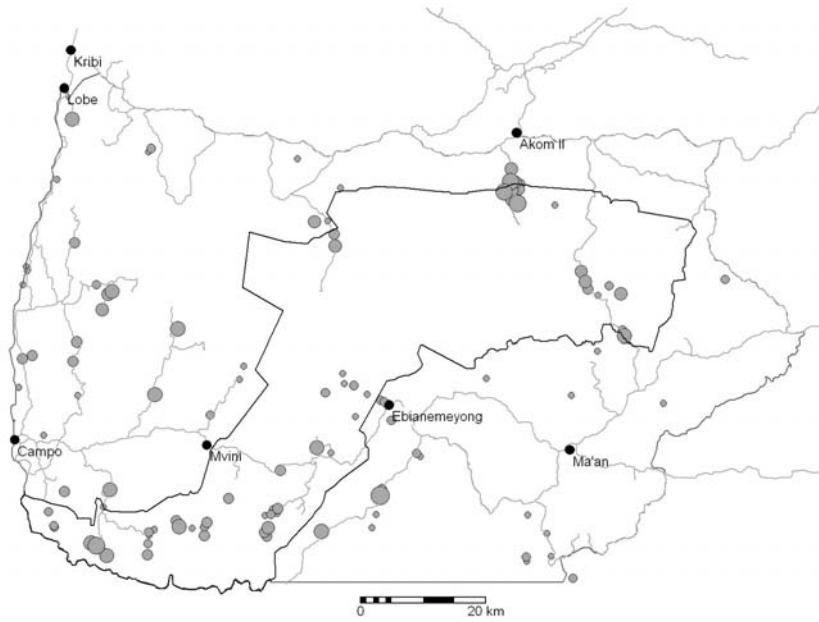


Figure 4.6 Distribution of 59 species of Rubiaceae which are either strictly endemic to the Campo-Ma'an and south-western Cameroon, endemic to Cameroon or the Lower Guinea region. Note that the size of the circle is proportional to the number of different species that occur in a given locality.

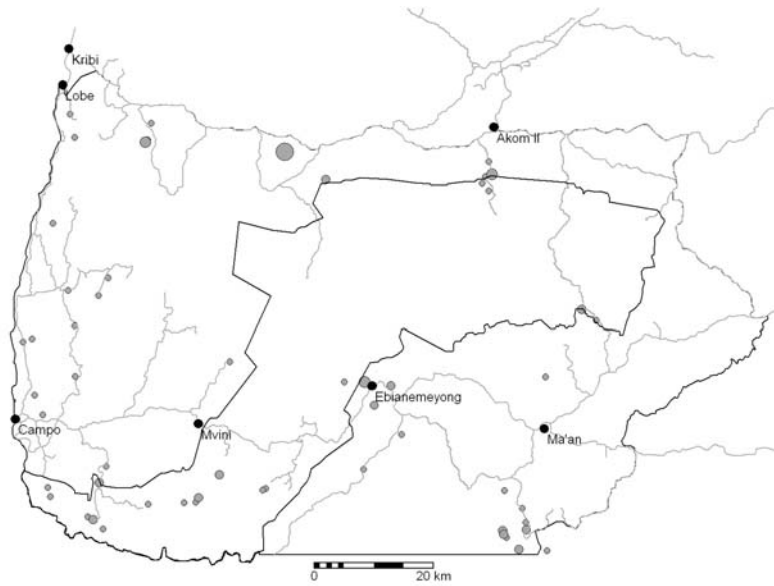


Figure 4.7 Distribution of 24 species that reach their northern limit of distribution in the Campo-Ma'an area. Note that the size of the circle is proportional to the number of different species that occur in a given locality.

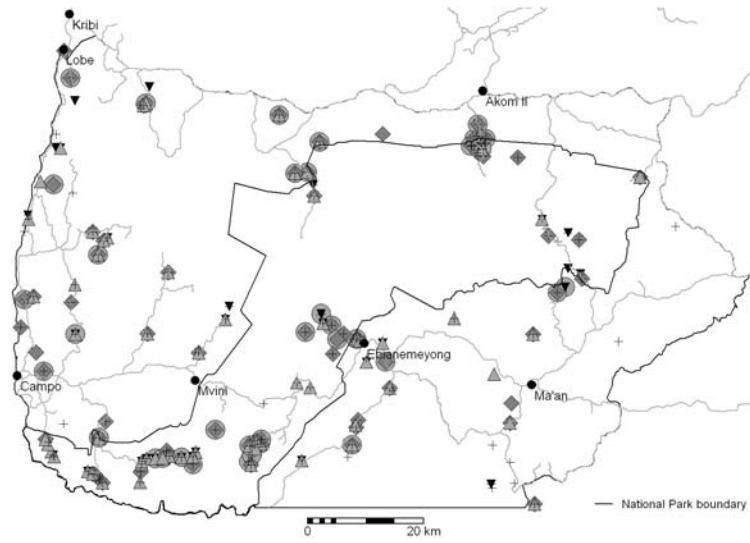


Figure 4.8 Distribution patterns of 178 selected bio-indicator taxa in the Campo-Ma'an area. Note that some species may overlap within localities. Where: □ (grey) = Strict and narrow endemics; ○ (grey) = *Begonia*; ▼ = Caesalpinioideae; △ (grey) = *Rinorea* and + = Rubiaceae species.

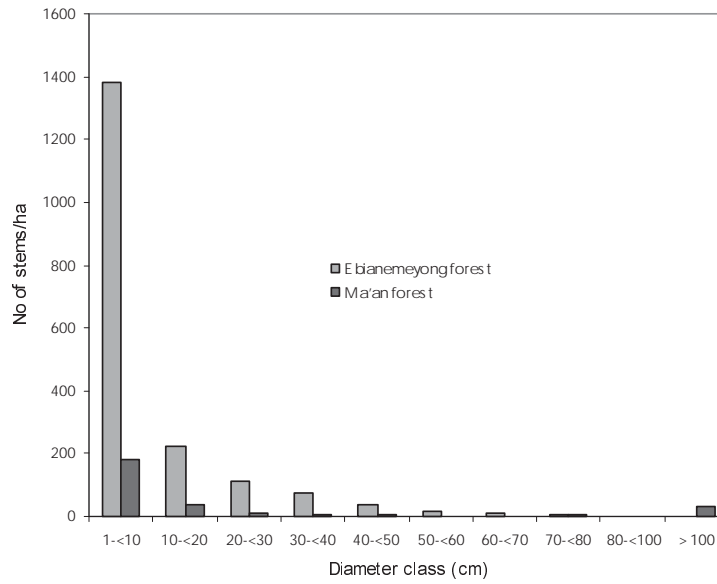


Figure 4.9 Diameter class distribution of the number of Okoumé stems/ha recorded in 2 plots of 0.1 ha each in the Ma'an forest and on exposed hill slopes around Ebianemeyong in the Campo-Ma'an National Park.

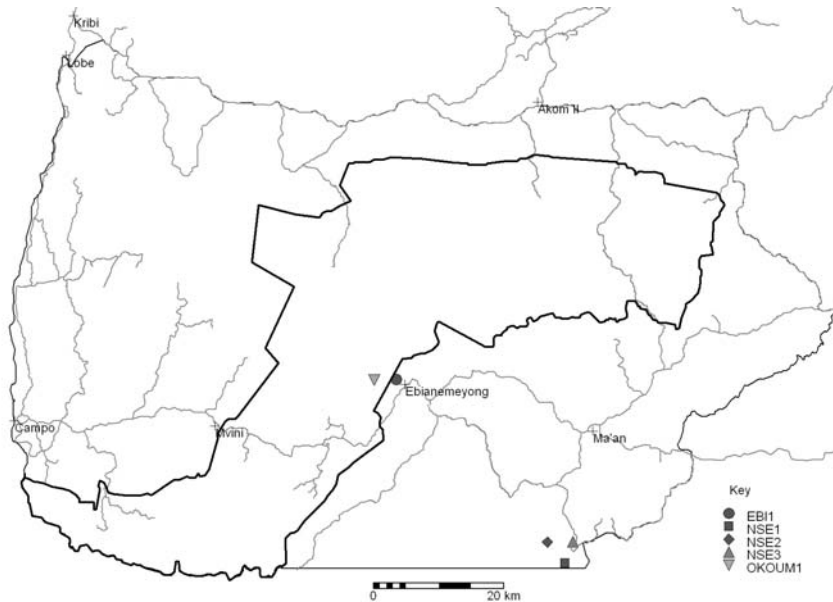


Figure 4.10 Distribution of *Aucoumea klaineana* (Okoumé) in the Campo-Ma'an area. Where EB11 and OKOUM1 represent their locations on exposed hill slopes around Ebinemeyong in the National Park and NSE1 to 3, in Nsengou near the border with Equatorial Guinea

#### 4.4. DISCUSSION

##### Evidence for a late Pleistocene refuge in the Campo-Ma'an rain forest

The Campo-Ma'an rain forest is characterized by a rich and diverse flora with more than 2297 species of vascular plants, ferns and fern allies belonging to 851 genera and 155 families. It has about 114 strict and narrow endemic species, 29 of which are only known from the area, 29 only occur in southwestern Cameroon, and 56 are near endemics that also occur in other parts of Cameroon (Chapter, 5). The distribution of 178 bio-indicator taxa selected on the basis of their biology, endemism and growth forms, more or less fitted the glacial forest refuges as proposed or discussed by several authors (Hamilton, 1982; Maley, 1987, 1989, 1991, 1993 & 1996; Rietkerk *et al.*, 1996; Robbrecht, 1996; Sosef, 1994 & 1996; and Achoundong, 2000). Overall, there was a high concentration of bio-indicator species in the lowland evergreen forest rich in Caesalpinioideae and the submontane forests in the National Park and Kribi-Campo-Mvini area, and a relatively low concentration of these species in the Ma'an area (Figure 4.8). Similar patterns were observed for the distribution of strict and narrow endemic species, *Begonia*, Caesalpinioideae and Rubiaceae (Figures 4.2 to 4.7). Achoundong (1996 & 2000) mentioned that in terms of distribution, two groups of *Rinorea* species could be distinguished in Cameroon. A group that is limited to the coastal plain and another

group which is mainly found inland. In the Campo-Ma'an area, the distribution of *Rinorea* species showed that *Rinorea microglossa* and *Rinorea sp. nov1.* were restricted to the coastal area between Kribi and Campo, while other species were mostly found in the lowland evergreen forest rich in Caesalpinoideae.

The Atlantic Biafran forest rich in Caesalpinoideae is often considered to represent the real climax forest vegetation while the Atlantic littoral forest type is regarded as the result of its degradation (Letouzey, 1983). In the Campo-Ma'an area, the distributions of Caesalps show a high concentration of bio-indicator species in the lowland evergreen forest rich in Caesalpinoideae, and in the submontane forest. There is a decrease in the number of species in the coastal forest rich in *Sacoglottis gabonensis*, and particularly in the mixed evergreen and semi-deciduous forest where semi-deciduous and secondary forest species became increasingly important. Furthermore, there was a high concentration of bio-indicator species in the park and in the Kribi-Campo-Mvini area on the higher slopes of the lowland forests and along riverbanks. This pattern supports the view of many authors who argued that during glacial times, patches of forests were restricted to higher altitude lowland forests, especially along the upper slopes of hills near the top (F.J. Breteler *pers. comm.*) or along riverbanks where there was enough humidity necessary for their survival. Therefore, we can hypothesize that past glacial forest expansion started in the Campo-Ma'an area from isolated patches of mid and higher elevation evergreen rain forest rich in Caesalpinoideae, located within the mountainous range that extends from Ebiamemeyong to the Akom II. Moreover, the Campo-Ma'an area has a dense hydrographical pattern with many rivers and streams that may have played an important role during the dry-out periods, as they supplied humid conditions that may have allowed the survival of some forest types. This is illustrated today with the occurrence of indicator species such as *Aphanocalyx ledermannii*, *Begonia anisosepala*, *B. zenkeriana* and *Gilbertiodendron demonstrans*, which are often found in marshy places and along stream and river banks in the coastal forest and on Dipikar Island. At the same time it may be hypothesized that the persistence of Caesalpinoideae forests in this so-called western part of the south Cameroon forest refuge prevented *Aucoumea klaineana* to extend its distribution further northwards.

As discussed in Chapters 2 & 6, the lowland evergreen forest rich in Caesalpinoideae with *Calpocalyx heitzii* and *Sacoglottis gabonensis* is only known from the Campo area. This forest type, as well as the coastal forest and the mixed evergreen and semi-deciduous forest are characterised by a high number of fully grown and developed secondary forest species. Letouzey (1983) mentioned that *Alstonia boonei*, *Calpocalyx heitzii*, *Lophira alata*, *Pycnanthus angolensis*, *Sacoglottis gabonensis* and *Terminalia superba* are light demanding species with an invasive habit that frequently colonise forest gaps. He further argued that forest types rich in such species, will have difficulties to expand into the Caesalpinoideae forest, because their regeneration will be hampered since their seedlings and saplings will not survive in the understorey of such forest communities. The present mosaic pattern of some forest types, characterised by a mixture of evergreen, semi-deciduous and secondary forest species, is probably the consequence of long-term disturbances, which may have affected these areas since the glacial times, particularly the major disturbance which culminated about 2500 BP (Maley, 2002). However, it should be noted that recent and past human activities have also



contributed to modify the balance of present-day ecological factors influencing the succession processes of these forests. We may therefore predict that if the current human perturbation is maintained the lowland rain forest rich in *Calpocalyx heitzii* and *Sacoglottis gabonensis* will further expand into the evergreen forest rich in Caesalpinioideae. But if the ongoing human pressure is controlled, we will rather expect a progressive expansion of the Caesalpinioideae forest towards the coast. In the drier Ma'an area, we will also expect to have more patches of evergreen Caesalpinioideae forest within the mixed evergreen and semi-deciduous forest. However, it should be mentioned that we expect a rather slow expansion of evergreen rain forest because it may not be able to cope with the relatively low precipitation recorded in the Ma'an area (below 1700 mm/year). Taking into consideration the fact that the Ma'an area is located within a transitional climatic zone with a relatively low annual rainfall, its vegetation represents a transition between the dry deciduous forest and the wet evergreen lowland forest rich in Caesalpinioideae.

The Campo-Ma'an rain forest, with its high concentration of endemic species and rich forest species diversity, is probably part of a late Pleistocene refuge as postulated in south-western Cameroon by several authors (Aubreville, 1962; White, 1979 & 1983, Maley, 1987, 1989 & 1990; Sosef, 1994). We assume that this refuge may probably extend further north-east along the mountainous range that goes up to the Bipindi area, because many narrow endemic species were also known to occur in the Akom II-Bipindi-Lolodorf areas. Overall, the distribution maps of the various bio-indicator species showed a low concentration of these species in the mixed evergreen and semi-deciduous forest located in the drier Nyabissan-Ma'an-Mekok area. A similar pattern was also observed from the distribution of strict and narrow endemic species. As shown in Table 4.2, only 15% of the total number of strict and narrow endemics and 46% of the selected bio-indicator species were recorded in this area. Furthermore, the drier Ma'an area is characterised by a semi-deciduous forest type with discontinuous canopy and the presence of many fully grown secondary forest species. This may suggest that the Ma'an area might have suffered from past human disturbance or that it may have been colonised by an open vegetation type during the dry-out periods. Therefore, it is probably undergoing a phase of forest recolonisation under the present climatic conditions. Taking into consideration the fact that the Ma'an vegetation shows a strong secondary character in terms of its species composition with many semi-deciduous elements, we can hypothesise that it was not part of the postulated forest refuge in south-western Cameroon under substantial drier atmospheric conditions than today.

It should be noted that these patterns in species richness are also the result of past and present biotic and abiotic structuring processes as has been clearly shown in Chapter 2. Taking into consideration the fact that paleo-evidence provides more information leading to the identification of the location and extent of Pleistocene rain forest refuges, the distribution patterns of bio-indicator species are often used to check the position of these forest refuges. Therefore, in the absence of paleo-evidence, it is almost impossible to unravel the role of the postulated rain forest refuges in the framework of other environmental processes that operated in the past without creating circular arguments. Furthermore, it is worth mentioning that past and present climatic changes, biological interaction, ecosystem dynamics, and

regional and evolutionary processes must in varying degree be taken into consideration to explain the high level of endemism and diversity recorded in the area. Moreover, it is suggested that further research to date the origin of endemic and slow dispersal species using recent modern molecular and phylogenetic (cladistic) techniques should be encouraged for a better understanding of the evolutionary processes of tropical rain forest taxa.

#### **Ecological aspects of *Aucoumea klaineana* (Okoumé) at its northern limit of distribution**

Okoumé is the most important timber species exploited in Gabon and accounts for over 90% of all timber export (White & Abernethy, 1997). In Gabon, it is a large canopy tree with winged seeds that by strong wind can be dispersed as far as several hundreds of metres from the parent tree. It tends to grow gregariously in stands with several individuals quite close together. Their roots are often joined, which allow the exchange of nutrients between individuals. In the Campo-Ma'an area, these roots sometimes form a visible striking network on exposed rocks on hill slopes. Although its centre of frequency is found in Gabon, it reaches the northern limit of its distribution in the Campo-Ma'an area and its southern limit in western Congo. Okoumé is a light demanding species with very little or no regeneration capacity within the ecological environment presented by the lowland evergreen forest. Its frequent occurrence in Gabon is probably the result of savanna colonisation and forest disturbance in the past (White *et al.*, 2000; Maley, 2002).

Our study has demonstrated that there are two different types of Okoumé communities in the Campo-Ma'an area. A more mature community is found at the border with Equatorial Guinea, and a younger community exists on exposed rocks on hill slopes around Ebianemeyong and the Kom River in the National Park (Figure 4.10). As shown in Table 4.3, there was a significant difference between the number of Okoumé stems/ha recorded in the Ma'an (54 individuals in 0.2 ha) and Ebianemeyong forests (371 individuals in 0.2 ha). The Ebianemeyong community was characterised by an almost pure mono-dominant stand with many small and medium sized stems, and no stems above 80 cm DBH. The forest floor was open, completely covered by grasses, creeping *Selaginella*, terrestrial ferns, orchids and *Begonia* species. In the Ma'an community, there was a gradual reduction of stems within the various DBH classes with more than 30 large Okoumé trees recorded with a diameter above 100 cm (in 0.2 ha). It is worth mentioning that there are some 30-40-year-old Okoumé plantations near Kribi between Bidou and Akok in the Kienke Forest Reserve.

Is the distribution of Okoumé under the present climatic conditions in Cameroon expanding or contracting? Pollen obtained from lake Ossa near Edea in south Cameroon showed that between 7500 and 3000 BP (mid Holocene) the distribution of Okoumé extended further north towards the Sanaga River, reaching lake Ossa at about 170 km north of the present limit of distribution (Reynaud-Farrera *et al.*, 1996; Maley, 2002). It is hypothesised that the current distribution range of Okoumé is the result of the contraction of a wider spread population that existed during mid Holocene. During the severe arid period that occurred around 2500 BP, there was a considerable reduction of the forest that may have resulted in the reduction of the geographical range of Okoumé or in its fragmentation into small remnant patches

(Reynaud-Farrera *et al.*, 1996; Muloko-Ntoutoume *et al.*, 1998; Maley, 2002). In the same period, the rainfall suddenly became more seasonal, thus resulting into an abrupt expansion of savanna and open vegetation types that may have favoured the development of pioneer species. Therefore, when wetter conditions favourable to a new expansion of the forest returned, logically we expect Okoumé, which is a light demanding species with an excellent dispersal ability, to gain ground in the expansion process in preference to the lowland evergreen rain forest species. However, Okoumé has not been successful to expand further north towards lake Ossa because the lowland evergreen rain forest species formed a "barrier" against its expansion.

The climatic fluctuations that occurred in the Central Africa region may have contributed to slow down the expansion of Okoumé, as well as that of many species that reach their northern limit of distribution in the Campo-Ma'an area, to progress further north beyond the Sanaga River. In Gabon, there is an equatorial climate with a pronounced dry season that occurs from June/July to August or September. During this period, the sky is often clouded causing a limited evaporation and a low temperature (Reitsma, 1988). There is a climatic transition around 3°N and the Campo-Ma'an area falls within a transitional zone where the typical equatorial climate shifts from a maritime type with 4 seasons, to a "pseudo-tropical type", with only two seasons in the northern coastal region around Douala (Gartlan, 1992; Maley & Elenga 1993). Therefore, in order to explain the suggested past occurrence of Okoumé around lake Ossa, some authors argue that an equatorial climate must have reigned over south Cameroon during mid Holocene (Maley, 2002). However, in the Campo-Ma'an area, we have noticed that Okoumé is struggling to expand further north of its present range of distribution under the present climatic conditions. But this expansion is called to a halt because the species is unable to establish under the closed canopy of the Caesalpinioideae forest as it needs open habitats to regenerate. In our opinion, the unfavourable natural regeneration conditions are probably the main reason for the limited occurrence of Okoumé in Cameroon. So far, in Campo-Ma'an area, Okoumé is only found either in mixed evergreen and semi-deciduous forest with discontinuous canopy or in atypical habitats as on exposed hill slopes.

#### **4.5. CONCLUSION**

This study added some evidence in support to the view that the Campo-Ma'an area forms part of a series of postulated tropical rain forest refuges in Central Africa. The distributions of 178 bio-indicator taxa selected on the basis of their life strategy, endemism and/or growth forms show a pattern that roughly coincides with a glacial forest refuge in south-western Cameroon as proposed by several authors. Overall, there was a high concentration of narrow endemic and bio-indicator species in the National Park and in the Kribi-Campo-Mvini areas, and a relatively low concentration of these species in the Ma'an area. These bio-indicator species were mostly found in the lowland evergreen forest rich in Caesalpinioideae, on high altitude lowland rain forests (especially along the upper slopes of hills near the top) or along riverbanks. However, it should be noted that these patterns in species richness are also the result of past and present climatic changes, abiotic factors, biological interaction, ecosystem dynamics, and regional and evolutionary

processes. Furthermore, human activities may also have contributed to modify the balance of present-day ecological conditions, resulting in shifts in the strength of contemporary ecological and evolutionary forces.

Table 4.1 List of 178 bio-indicator taxa consisting of 61 strict and narrow endemics, 59 species of Rubiaceae, 32 species of Caesalpinioideae, 13 species of *Begonia*, 13 species of *Rinorea* and 24 species that reach their northern limit of distribution in the Campo-Ma'an area. Note that some species may overlap within identified groups.

No	Family	Species	Guild	Habit	Chorology
1	Annonaceae	Monanthonaxis elegans (Engl. & Diels) Verdc.	sb	Sh	Sw-Cam
2	Annonaceae	Monodora zenkeri Engl. & Diels	sb	Sh	Sw-Cam
3	Apocynaceae	Petchia africana Leeuwenb.	sb	Sh	Sw-Cam
4	Apocynaceae	Tabernaemontana hallei (Boiteau) Leeuwenb.*	sb	Sh	Lg
5	Araceae	Culcasia bosii Ntepe-Nyame	sb	He	Sw-Cam
6	Balsaminaceae	Impatiens gongolana N.Hallé*	sb	Hb	Lg
7	Balsaminaceae	Impatiens hians Hook.f. var. bipindensis (Gilg) Grey-Wilson*	sb	Hb	Lg
8	Begoniaceae	Begonia anisosepala Hook.f.*	sb	Hb	Lg
9	Begoniaceae	Begonia cilio-bracteata Warb.	sb	Hb	Lg
10	Begoniaceae	Begonia clypeifolia Hook.f.*	sb	Hb	Lg
11	Begoniaceae	Begonia elaeagnifolia Hook.f.*	ep	Ep	Lg
12	Begoniaceae	Begonia heterochroma Sosef*	sb	Hb	Lg
13	Begoniaceae	Begonia letouzeyi Sosef	sb	Hb	Lg
14	Begoniaceae	Begonia mbangaensis Sosef	sb	Hb	Sw-Cam
15	Begoniaceae	Begonia microsperma Warb.	sb	Hb	Cam
16	Begoniaceae	Begonia montis-elephantis J.J.de Wilde	sb	Hb	Campo-Ma'an
17	Begoniaceae	Begonia potamophila Gilg	sb	Hb	Lg
18	Begoniaceae	Begonia sciaphila Gilg ex Engl.	sb	Hb	Lg
19	Begoniaceae	Begonia staudtii Gilg	sb	Hb	Lg
20	Begoniaceae	Begonia susaniae Sosef	sb	Hb	Lg
21	Begoniaceae	Begonia zenkeriana Smith & Wash.	sb	Hb	Sw-Cam
22	Burseraceae	Aucoumea klaineana Pierre*	pi	Tr	Lg
23	Burseraceae	Dacryodes buettneri (Engl.) Lam*	np	Tr	Lg
24	Celastraceae	Pristimera luteoviridis (Exell) N.Hallé var. kribiana N.Hallé	np	Swcl	Campo-Ma'an
25	Chrysobalanaceae	Dactyadenia cinera (Engl. ex de Wild) Prance & F.White	sb	Tr	Sw-Cam
26	Cyperaceae	Hypolytrum sp. nov. ined.	sb	Hb	Campo-Ma'an
27	Dichapetalaceae	Dichapetalum altescandens Engl.*	np	Lwcl	Lg
28	Dichapetalaceae	Dichapetalum librevillense Pellegr.*	np	Lwcl	Lg
29	Dichapetalaceae	Dichapetalum oliganthum Breteler	np	Lwcl	Sw-Cam
30	Dichapetalaceae	Tapura tchoutoi Breteler	sb	Sh	Campo-Ma'an
31	Dryopteridaceae	Lastreopsis davalliaeformis (Tardieu) Tardieu*	sb	He	Lg
32	Ebenaceae	Diospyros alboflavescens (Gürke) F.White	sb	Tr	Sw-Cam
33	Ebenaceae	Diospyros soyauxii Gürke & K. Schum.*	sb	Tr	Lg
34	Euphorbiaceae	Afrotrawia kamerunica Pax & Hoffm.	sb	Sh	Campo-Ma'an
35	Gramineae	Guadua mildbraedii Pilg.	sb	Hb	Campo-Ma'an
36	Gramineae	Hyparrhenia wombaliensis (Vanderyst ex Robyns) Clayton*	pi	Hb	Lg
37	Icacinaeae	Rhaphiostylis subsessilifolia Engl.	sb	Swcl	Campo-Ma'an
38	Ixonanthaceae	Ochthocosmus calothyrsus (Mildbr.) Hutch. & Dalziel*	np	Tr	Lg
39	Lauraceae	Beilschmiedia cuspidata (Krause) Robyns & Wilczek	sb	Tr	Campo-Ma'an
40	Lauraceae	Beilschmiedia dinklagei (Engl.) Robyns & Wilczek	sb	Tr	Campo-Ma'an
41	Lauraceae	Beilschmiedia klainei Robyns & Wilczek	sb	Tr	Sw-Cam
42	Lauraceae	Beilschmiedia papyracea (Stapf) Robyns & R.Wilczek	sb	Tr	Sw-Cam
43	Lauraceae	Beilschmiedia wilczekii Fougilloy	sb	Tr	Sw-Cam
44	Leguminosae-Caes.**	Amphimas ferrugineus Pierre ex Pellegr.*	np	Tr	Lg

*Plant diversity in a Central African rain forest: Implications for biodiversity conservation in Cameroon*

No	Family	Species	Guild	Habit	Chorology
45	Leguminosae-Caes.**	<i>Anthoantha isopetala</i> (Harms) J.Léonard	sb	Tr	Lg
46	Leguminosae-Caes.**	<i>Anthoantha leptorrhachis</i> (Harms) J.Léonard	sb	Tr	Cam
47	Leguminosae-Caes.**	<i>Aphanocalyx hedinii</i> (A. Chev.) Wieringa	np	Tr	Cam
48	Leguminosae-Caes.**	<i>Aphanocalyx ledermannii</i> (Harms) Wieringa*	sw	Tr	Lg
49	Leguminosae-Caes.**	<i>Berlinia auriculata</i> Benth.	ri	Tr	Lg
50	Leguminosae-Caes.**	<i>Berlinia craibiana</i> Baker f.	ri	Tr	Lg
51	Leguminosae-Caes.**	<i>Bikinia le-testui</i> (Pellegr.) Wieringa ssp. <i>le-testui</i>	np	Tr	Lg
52	Leguminosae-Caes.**	<i>Brachystegia cynometroides</i> Harms	np	Tr	Lg
53	Leguminosae-Caes.**	<i>Brachystegia mildbraedii</i> Harms	np	Tr	Lg
54	Leguminosae-Caes.**	<i>Copaifera religiosa</i> J.Léonard*	np	Tr	Lg
55	Leguminosae-Caes.**	<i>Daniellia klainei</i> A. Chev.*	ri	Tr	Lg
56	Leguminosae-Caes.**	<i>Detarium macrocarpum</i> Harms	sb	Tr	Lg
57	Leguminosae-Caes.**	<i>Dialium zenkeri</i> Harms	sb	Tr	Sw-Cam
58	Leguminosae-Caes.**	<i>Didelotia africana</i> Baill.	sb	Tr	Lg
59	Leguminosae-Caes.**	<i>Didelotia unifoliolata</i> J.Léonard	sb	Tr	Lg
60	Leguminosae-Caes.**	<i>Gilbertiodendron brachystegioides</i> (Harms) J.Léonard	np	Tr	Lg
61	Leguminosae-Caes.**	<i>Gilbertiodendron demonstrans</i> (Baill.) J.Léonard	np	Tr	Lg
62	Leguminosae-Caes.**	<i>Gilbertiodendron klainei</i> (Pierre ex Pellegr.) J.Léonard	np	Tr	Lg
63	Leguminosae-Caes.**	<i>Gilbertiodendron ogoouense</i> (Pellegr.) J.Léonard	np	Tr	Lg
64	Leguminosae-Caes.**	<i>Gilbertiodendron pachyanthum</i> (Harms) J.Léonard	np	Tr	Sw-Cam
65	Leguminosae-Caes.**	<i>Griffonia tessmannii</i> (De Wild.) Campère	np	Lwcl	Lg
66	Leguminosae-Caes.**	<i>Guibourtia tessmannii</i> (Harms) J.Léonard	np	Tr	Lg
67	Leguminosae-Caes.**	<i>Leonardoxa africana</i> (Baill.) Aubrév.	sb	Tr	Lg
68	Leguminosae-Caes.**	<i>Loesenera talbotii</i> Baker f.	sb	Tr	Lg
69	Leguminosae-Caes.**	<i>Oddoniodendron micranthum</i> (Harms) Baker f.	np	Tr	Lg
70	Leguminosae-Caes.**	<i>Paraberlinia bifoliolata</i> Pellegr.	np	Tr	Lg
71	Leguminosae-Caes.**	<i>Plagiosiphon longitubus</i> (Harms) J.Léonard	sb	Tr	Sw-Cam
72	Leguminosae-Caes.**	<i>Plagiosiphon multijugus</i> (Harms) J.Léonard	sb	Tr	Cam
73	Leguminosae-Caes.**	<i>Prioria joveri</i> (Normand ex Aubrév.) Breteler	np	Tr	Lg
74	Leguminosae-Caes.**	<i>Tetraberlinia moreliana</i> Aubrév.*	sb	Tr	Lg
75	Leguminosae-Caes.**	<i>Zenkerella citrina</i> Taub.	sb	Tr	Lg
76	Loganiaceae	<i>Mostuea neurocarpa</i> Gilg*	sb	Sh	Lg
77	Loganiaceae	<i>Strychnos canthioides</i> Leeuwenb.	np	Lwcl	Campo-Ma'an
78	Melastomataceae	<i>Amphiblemma letouzeyi</i> Jacq.-Fél.	sb	Hb	Sw-Cam
79	Melastomataceae	<i>Calvoa calliantha</i> Jacq.-Fél.	sb	Hb	Sw-Cam
80	Melastomataceae	<i>Calvoa stenophylla</i> Jacques-Félix	sb	Hb	Campo-Ma'an
81	Melastomataceae	<i>Guyonia tenella</i> Naud.*	sb	Hb	Lg
82	Menispermaceae	<i>Albertisia glabra</i> (Diels & Troupin) Forman	sb	Swcl	Sw-Cam
83	Moraceae	<i>Dorstenia dorstenioides</i> (Engl.) Hijman & C.C.Berg	sb	Hb	Campo-Ma'an
84	Moraceae	<i>Dorstenia involuta</i> M.Hijman	sb	Hb	Campo-Ma'an
85	Ochnaceae	<i>Testulea gabonensis</i> Pellegr.*	np	Tr	Lg
86	Orchidaceae	<i>Bulbophyllum alinae</i> Szlachetko	ep	Ep	Campo-Ma'an
87	Orchidaceae	<i>Podantriella batesii</i> (la Croix) Szlachetko & Olszewski	sb	Hb	Campo-Ma'an
88	Orchidaceae	<i>Polystachya letouzeyana</i> Szlachetko & Olszewski	ep	Ep	Campo-Ma'an
89	Orchidaceae	<i>Vanilla africana</i> Lindley subsp. <i>cucullata</i> (Kraenzlin & K. Shum.) Szlachetko & Olszewski	np	Hcl	Sw-Cam
90	Podostemaceae	<i>Ledermanniella anithomae</i> C. Cusset	rh	Hb	Campo-Ma'an
91	Podostemaceae	<i>Ledermanniella batangensis</i> (Engl.) C. Cusset	rh	Hb	Campo-Ma'an
92	Podostemaceae	<i>Ledermanniella bosii</i> C. Cusset	rh	Hb	Campo-Ma'an

*Bio-indicator species and Central African rain forest refuges*

No	Family	Species	Guild	Habit	Chorology
93	Podostemaceae	Ledermanniella kamerunensis (Engl.) C. Cusset	rh	Hb	Campo-Ma'an
94	Rubiaceae	Bertiera bicarpellata (K. Schum.) N.Hallé	sb	Sh	Lg
95	Rubiaceae	Bertiera laxa Benth.	sb	Sh	Lg
96	Rubiaceae	Bertiera laxissima K. Schum.	sb	Sh	Lg
97	Rubiaceae	Bertiera retrofracta K. Schum.	sb	Sh	Lg
98	Rubiaceae	Bertiera subsessilis Hiern	sb	Sh	Lg
99	Rubiaceae	Chassalia ischnophylla (K. Schum.) Hepper	sb	Sh	Lg
100	Rubiaceae	Chassalia zenkeri K. Schum. & K. Krause	sb	Sh	Lg
101	Rubiaceae	Chazaliella insidens (Hiern) Petit & Verdc. subsp. insidens	sb	Sh	Lg
102	Rubiaceae	Chazaliella sciadephora (Hiern) Petit & Verdc. var. condensata Verdc.	sb	Sh	Cam
103	Rubiaceae	Ecpoma apocynaceum K. Schum.	pi	Sh	Sw-Cam
104	Rubiaceae	Ecpoma gigantostipulum (K. Schum.) N.Hallé	pi	Sh	Lg
105	Rubiaceae	Hymenocoleus glaber Robbrecht	sb	Hb	Cam
106	Rubiaceae	Hymenocoleus nervopilosus Robbrecht orientalis Robbrecht	sb	Hb	Lg
107	Rubiaceae	Ixora aneimenodesma K. Schum. aneimenodesma	sb	Sh	Cam
108	Rubiaceae	Ixora euosmia K. Schum.	ri	Sh	Lg
109	Rubiaceae	Ixora hippoperifera Bremek.	sb	Sh	Lg
110	Rubiaceae	Ixora macilenta De Block	pi	Sh	Lg
111	Rubiaceae	Ixora nematopoda K. Schum.	sb	Sh	Lg
112	Rubiaceae	Ixora synactica De Block	sb	Sh	Sw-Cam
113	Rubiaceae	Oxyanthus laxiflorus K. Schum. ex Hutch. & Dalziel	sb	Sh	Lg
114	Rubiaceae	Oxyanthus oliganthus K. Schum.	sb	Sh	Cam
115	Rubiaceae	Pavetta camerounensis S.Manning subsp. camerounensis	sb	Sh	Cam
116	Rubiaceae	Pavetta gabonica Bremek.	sb	Sh	Lg
117	Rubiaceae	Pavetta gracilipes Hiern	sb	Sh	Lg
118	Rubiaceae	Pavetta kribiensis S.Manning	sb	Sh	Sw-Cam
119	Rubiaceae	Pavetta mpomii S.Manning	sb	Sh	Sw-Cam
120	Rubiaceae	Pavetta staudtii Hutch. & Dalziel	sb	Sh	Cam
121	Rubiaceae	Pseudosabicea medusula (K. Schum.) N.Hallé	np	Hb	Cam
122	Rubiaceae	Pseudosabicea proseglyta N.Hallé	pi	Hb	Lg
123	Rubiaceae	Pseudosabicea segregata (Hiern) N.Hallé	pi	Hb	Lg
124	Rubiaceae	Psychotria aemulans K. Schum.	sb	Sh	Campo-Ma'an
125	Rubiaceae	Psychotria avakubienensis De Wild.	sb	Sh	Lg
126	Rubiaceae	Psychotria batangana K. Schum.	sb	Sh	Campo-Ma'an
127	Rubiaceae	Psychotria bifaria Hiern var. bifaria	sb	Sh	Lg
128	Rubiaceae	Psychotria calceata Petit	sb	Sh	Lg
129	Rubiaceae	Psychotria camerunensis Petit	sb	Sh	Cam
130	Rubiaceae	Psychotria camptopus Verdc.	sb	Sh	Lg
131	Rubiaceae	Psychotria dimorphophylla K. Schum.	ri	Sh	Campo-Ma'an
132	Rubiaceae	Psychotria ebensis K. Schum.	sb	Sh	Lg
133	Rubiaceae	Psychotria globosa Hiern var. ciliata (Hiern) Petit	sb	Hb	Lg
134	Rubiaceae	Psychotria humilis Hiern var. humilis	pi	Hb	Lg
135	Rubiaceae	Psychotria integrifolia Petit	sb	Sh	Lg
136	Rubiaceae	Psychotria lanceifolia K. Schum.	sb	Sh	Sw-Cam
137	Rubiaceae	Psychotria latistipula Benth.	sb	Sh	Lg
138	Rubiaceae	Psychotria letouzeyi Petit	sb	Sh	Lg
139	Rubiaceae	Psychotria oligocarpa K. Schum.	sb	Sh	Sw-Cam
140	Rubiaceae	Psychotria sadebeckiana K. Schum. var. elongata Petit	sb	Sh	Cam

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No	Family	Species	Guild	Habit	Chorology
141	Rubiaceae	Psychotria sadebeckiana K.Schum. var. sadebeckiana	sb	Sh	Cam
142	Rubiaceae	Sericanthe auriculata (Keay) Robbrecht	sb	Sh	Lg
143	Rubiaceae	Sericanthe jaefelicis (N.Hallé) Robbrecht	sb	Sh	Lg
144	Rubiaceae	Tricalysia amplexicaulis Robbrecht	sb	Sh	Cam
145	Rubiaceae	Tricalysia lasiodelphys (K. Schum. & K. Krause) A. Chev. subsp. lasiodelphys	sb	Sh	Lg
146	Rubiaceae	Tricalysia obstetrix N.Hallé	sb	Sh	Lg
147	Rubiaceae	Tricalysia pedunculosa (N.Hallé) Robbrecht var. pedunculosa	sb	Sh	Lg
148	Rubiaceae	Tricalysia soyauxii K. Schum.	sb	Sh	Lg
149	Rubiaceae	Tricalysia sylvae Robbrecht	sb	Sh	Lg
150	Rubiaceae	Tricalysia talbotii (Wernham) Keay	sb	Sh	Cam
151	Rubiaceae	Tricalysia vadensis Robbrecht	sb	Sh	Lg
152	Rubiaceae	Vangueriella laxiflora (K. Schum.) Verdc.	sb	Swcl	Cam
153	Sapindaceae	Deinbolia macroura Gilg ex Radlkofe	sb	Sh	Campo-Ma'an
154	Sapindaceae	Deinbolia mezilii D.W. Thomas & D.J. Harris	sb	Sh	Campo-Ma'an
155	Sapindaceae	Deinbolia pycnophylla Gilg ex Radlk.*	sb	Sh	Lg
156	Scytopetalaceae	Rhaptopetalum sessilifolium Engl	sb	Sh	Sw-Cam
157	Sterculiaceae	Cola fibrillosa Engl. & Krause	sb	Tr	Sw-Cam
158	Sterculiaceae	Cola subglaucescens Engl.	sb	Tr	Sw-Cam
159	Sterculiaceae	Cola sulcata Engl.	sb	Tr	Sw-Cam
160	Sterculiaceae	Scaphopetalum acuminatum Engl. & K. Krause	sb	Sh	Campo-Ma'an
161	Sterculiaceae	Scaphopetalum brunneo-purpureum Engl. & K. Krause	sb	Sh	Campo-Ma'an
162	Sterculiaceae	Scaphopetalum paxii H. Winkler	sb	Sh	Sw-Cam
163	Sterculiaceae	Scaphopetalum zenkeri K. Schum.	sb	Sh	Sw-Cam
164	Violaceae	Rinorea albidiflora Engl.	sb	Sh	Lg
165	Violaceae	Rinorea campoensis M. Brandt ex Engl.	sb	Sh	Campo-Ma'an
166	Violaceae	Rinorea dentata P. Beauv.	sb	Sh	Lg
167	Violaceae	Rinorea exappendiculata Engl. ex Brandt	sb	Sh	Lg
168	Violaceae	Rinorea gabunensis Engl.	sb	Sh	Lg
169	Violaceae	Rinorea kamerunensis Engl.	sb	Sh	Lg
170	Violaceae	Rinorea ledermannii Engl.	sb	Sh	Lg
171	Violaceae	Rinorea longisepala Engl.	sb	Sh	Lg
172	Violaceae	Rinorea microglossa Engl.	sb	Sh	Sw-Cam
173	Violaceae	Rinorea sp. nov1. ined.	sb	Sh	Cam
174	Violaceae	Rinorea sp. nov2. ined.	sb	Sh	Cam
175	Violaceae	Rinorea verrucosa Chipp	sb	Sh	Lg
176	Violaceae	Rinorea woermaniana (Buttn.) Engl.	sb	Sh	Lg
177	Zingiberaceae	Aulotandra kamerunensis Loes.	sb	Hb	Sw-Cam
178	Zingiberaceae	Renealmia densispica Koechlin	sb	Hb	Sw-Cam

\* for species that reach their northern of distribution in the Campo-Ma'an area

\*\* Leguminosae-Caes. = Leguminosae-Caesalpinioideae

**Guild:** ep = epiphyte, np = non pioneer light demanding, pi = pioneer, rh = rheophyte, ri = riverine, sb = shade-bearer and sw = swamp.

**Habit:** Ep = epiphyte, Hb = herb, Hcl = herbaceous climber, He = hemi-epiphyte, Lwcl = large woody climber, Swcl = small woody climber, Sh = shrub, and Tr = tree.

**Chorology:** Campo-Ma'an = species that are strictly endemic to Campo-Ma'an, Sw-Cam = endemic to southwestern part of Cameroon (Kribi-Akom Il-Bipindi-Lolodorf areas), Cam = endemic to Cameroon, Lg = Lower Guinea endemic plant species.